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Science of Gymnastics Journal (ScGYM®)

Science of Gymnastics Journal (ScGYM®) (abrevated for citation is SCI GYMNASTICS J) is an international journal that provide a wide range of scientific information specific to gymnastics. The journal is publishing both empirical and theoretical contributions related to gymnastics from the natural, social and human sciences. It is aimed at enhancing gymnastics knowledge (theoretical and practical) based on research and scientific methodology. We welcome articles concerned with performance analysis, judges' analysis, biomechanical analysis of gymnastics elements, medical analysis in gymnastics, pedagogical analysis related to gymnastics, biographies of important gymnastics personalities and other historical analysis, social aspects of gymnastics, motor learning and motor control in gymnastics, methodology of learning gymnastics elements, etc. Manuscripts based on quality research and comprehensive research reviews will also be considered for publication. The journal welcomes papers from all types of research paradigms.

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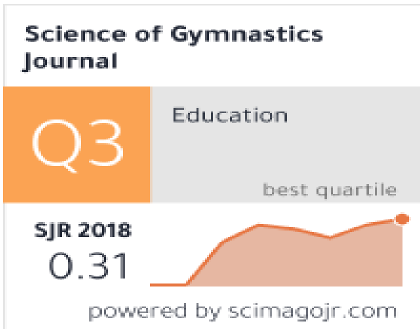

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CONTENTS

EDITORIAL

Dear friends,

These days our lives are run by COVID-19. Our gymnastic family mourns Dieter Hoffman, an excellent German coach and expert, a FIG Academy lecturer, who recently died of Covid-19. We do not know what comes next but I am certain we all want to go back to our normal life.

Despite many negative effects of Covid–19, it had a positive effect on our journal. Our authors wrote as many as16 articles for this issue which is a record for the journal.

We are all adjusting to new circumstances. As you probably already know, conferences will be held online. Bulgaria will host a symposium on rhythmic gymnastics and Portugal on gymnastics. For more detailed information please see the following pages. Please join the symposia and take an active part with your ideas and views!

For this issue our authors researched many different topics, including biomechanics, motor control, motor learning, theory of training, physiology, psychology, physical education, sociology and history, in relation to rhythmic and artistic gymnastics and trampolining.

Countries participating with articles include: USA, Slovakia, Tunisia, Germany, Brazil, Australia, Portugal, Slovenia, Spain, Turkey, Greece, Iran and Ukraine,

Anton Gajdoš provides a short historical note on Nina Bocharova, the Olympic Champion from Russia in WAG at the Olympics 1952 in Helsinki.

Our editorial board decided to make an exception and publish a letter – manifesto of International Socio-Cultural research group on WAG lead by Natalie Barker-Ruchti (USA) to the Editor and a comment on the letter by William Sands (USA). While we believe the letter and the comment present issues that may be important to our audiences, I'd like to stress that our journal remains focused on the publication of scientific articles presenting evidence-based solutions only. Nevertheless, there should be no doubt that our journal supports the United Nations Declaration of Human and Children Rights and believes its provisions should be respected.

Just to remind you, if you quote the Journal, its abbreviation on the Web of Knowledge is SCI GYMN J.

I wish you pleasant reading and a lot of inspiration for new research projects and articles,

Ivan Čuk
Editor-in-Chief

DIETER HOFMANN (1941-2020)

Probably the most successful German coach of all times, Dieter Hofmann, passed away of COVID-19

The former head coach of the GDR national team, Dieter Hofmann, died in Freiburg on 18 April 2020 due to a lung disease caused by the Covid-19 virus.

Dieter Hofmann left his mark on several generations of gymnasts. Before German reunification, his gymnasts won 52 gold, silver and bronze medals at international competitions. The highlight of his coaching career was doubtless the Olympic Games in Seoul, where the team of the GDR won the silver medal behind the USSR in the team final. Besides this great success, his gymnasts won one gold, one silver and 3 bronze medals at the finals.

In the transition period after the fall of the Wall in Berlin, he end the head coach of the Federal Republic of Germany, Franz Heiland, looked after the reunited German national gymnastics team at the historic cross-country friendly competition GER-USA-USSR in the no less historic Munich Olympic Hall.

After German reunification, he found a new purpose in life in the northern Swiss town of Liestal, where he expanded the local performance centre with his typical dynamism. His strategical, analytical and didactical thinking was well appreciated all over the world. Due to this endless enthusiasm, he taught in several courses of the FIG Coach Academy. His contribution to the development of gymnastics is well documented in the Age group development and competition program for Men's Artistic Gymnastics, which was created and compiled mainly by him and Hardy Fink as the Director of the Coach Academy.

After his retirement, he settled in the Black Forest near Freiburg. Not only because of its geographical proximity to the Institute for Sport and Sports Science at the University of Freiburg he was a very welcome guest at the annual Freiburg International Gymnastics Congress, an event that brings together important scientists and trainers.

Flavio Bessi

AN ANALYSIS OF HEAD KINEMATICS IN WOMEN'S ARTISTIC GYMNASTICS

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Original article

Abstract

Concussions in gymnastics have scarcely been researched; however, current evidence suggests that concussion rates may be higher than previously reported due to underreporting among coaches, athletes, and parents. The purpose of this study was to outline a method for collecting head impact data in gymnastics, and to provide the first measurements of head impact exposure within gymnastics. Three optional level women's artistic gymnasts (ages 11-16) were instrumented with a mouthpiece sensor that measured linear acceleration, rotational velocity, and rotational acceleration of the head during contact and aerial phases of skills performed during practice. Peak linear acceleration, peak rotational velocity, peak rotational acceleration, duration, and time to peak linear acceleration were calculated from sensor data. Kinematic data was time-synchronized to video and then sensor data was segmented into contact scenarios and skills characterized by the event rotation, apparatus, landing mat type, skill type, skill phase, landing stability, and body region contacted. The instrumented gymnasts were exposed to 1,394 contact scenarios (41 per gymnast per session), of which 114 (3.9 per gymnast per session) contained head contact. Peak kinematics varied across skill type, apparatuses, and landing mats. The median duration of impacts with head contact (177 ms) was longer than measured impacts in youth and collegiate level soccer. Results from this study help provide a foundation for future research that may seek to examine head impact exposure within gymnastics to better inform concussion prevention and post-concussion return to play protocols within the sport.

Keywords: *head impact exposure, gymnastics, concussion, head injury.*

INTRODUCTION

Between 1.1 and 1.9 million sports- and recreational- related concussions occur each year among youth athletes in the United States (Bryan, Rowhani-Rahbar, Comstock, Rivara, & Bryan, 2016). While concussions are commonly associated with player-to-player collisions in contact sports such as American football (Buzas, Jacobson, & Morawa, 2014; Lincoln et al., 2011), concussions can also occur from falls or collisions with objects in sports such as gymnastics. Repeated epidemiological studies have shown a low incidence of concussions in both youth and collegiate level gymnastics activities (Caine et al., 2003; Marshall, Covassin, Dick, Nassar, & Agel, 2007); however, current research suggests that the incidence of concussion in gymnastics may be higher due to underreporting among athletes (Meehan, Mannix, O'Brien, & Collins, 2013), and a lack of knowledge of concussion signs and symptoms among coaches (Mannings, Kalynych, Joseph, Smotherman, & Kraemer, 2014). A recent survey by O'Kane reported that over 30% of retired gymnasts had sustained a blow to the head followed by at least one concussion symptom during their gymnastics careers (Kane, Levy, Pietila, Caine, & Schiff, 2011). Since gymnastics is not normally associated with concussions, it is possible that athletes, coaches, and parents may not be adequately educated on the symptoms, guidelines, and risks associated with the injury. A recent case report published by Knight et al. highlights this issue as the parents of a young gymnast diagnosed with a mild traumatic brain injury ignored the medical professional's recommendations and allowed their daughter to compete in a regional competition where she later sustained a second mild traumatic brain injury (Knight, Dewitt, & Moser, 2016).

Gymnastics is a broad term used to describe six unique disciplines: women's and men's artistic gymnastics, rhythmic gymnastics, acrobatic gymnastics, trampoline and tumbling, and aerobic gymnastics, where athletes utilize various apparatuses to perform complex somersaulting and twisting maneuvers. Within each discipline, athletes perform a variety of distinct skills on various apparatuses (e.g. balance beam) and landing surfaces (e.g. crash mats). These combinations of skills, apparatuses, and landing surfaces result in unique movement profiles and head injury mechanisms. For instance, previous research has shown that landing forces can vary across surfaces (McNitt-Gray, Yokoi, & Millward, 2016), apparatuses (Burt, Naughton, & Landeo, 2007), and heights (Mcnitt-Gray et al., 1993). Therefore, as the environment and movement characteristics of the gymnastics skill change, the risk for head injury may also change.

Understanding the specifics of head motion during play is essential to better define concussion mechanisms, risk, and return to sport safety. While the kinematics of the head in sports such as American football and soccer have been extensively studied (Cobb et al., 2013; Miller, Pinkerton, et al., 2019), only one study to date has attempted to measure the kinematics of the head during gymnastics related activities (Beck, Rabinovitch, & Brown, 1979). This study, by Beck et al., set out to understand the acceleration of the head during full body swings around the high bar (Beck et al., 1979). To do this, Beck et al. utilized a plastic helmet equipped with accelerometers that provided approximate motion of the head during the gymnastics skill. Current advancements in sensor development now allow researchers to measure head accelerations without the use of helmets, and may provide a more accurate estimate of head motion. Of these devices, a mouthpiece-based sensor has been suggested to be ideal as it provides tight coupling with the upper dentition and skull (Wu et al., 2016) and is easy to wear in a variety of sports. These devices have been utilized in previous studies with soccer athletes (Miller, Pinkerton, et al., 2019; Rich et al., 2019) and may be useful for studying head kinematics within gymnastics.

Despite the growing concern over concussions in sport, there is a paucity of data examining head injury mechanisms and head impact frequency within gymnastics, a sport in which concussions can occur and head impacts may be common. Therefore, the purpose of the current study was to outline a method for measuring and analyzing head kinematics in gymnastics. A secondary goal of the current study was to provide the first measurements of head kinematics and head impact exposure within gymnastics.

METHODS

Three optional level club women's artistic gymnasts (11-16 yrs) capable of performing a wide range of gymnastics skills were recruited to participate in this study. Gymnasts were excluded from this study if they were below the optional level and/or did not participate on a competitive USA gymnastics sanctioned team. The sample size was limited to three gymnasts due to the pilot nature of this study and primary objective of developing a method to measure and analyze head kinematics in gymnastics. The study protocol was approved by the Wake Forest University School of Medicine Institutional Review Board (IRB), and parental consent and participant assent were properly acquired for participation in the study. The gymnasts were instrumented for a combined total of 34 practices over a six month period with a validated custom fit mouthpiece (Rich et al., 2019) outfit with a triaxial accelerometer and gyroscope. To prevent changes in the conformation of the mouth from resulting in sensor coupling errors, gymnasts were excluded if they had been continually wearing orthodontic braces for less than six months. The mouthpiece was custom fitted to a 3D printed dental model created from a high resolution scan (3shape, Copenhagen, DK) of the upper dentition obtained by a trained staff member and reviewed by a dental technician to ensure proper fit and tight coupling to the upper dentition. Two time-synchronized cameras, arranged such that all apparatuses were in full view of at least one camera, filmed the gymnasts during each practice. Data acquisition of the sensor is controlled by a user-defined linear acceleration trigger threshold. When this value is exceeded for a prescribed period of time, the device records linear acceleration and rotational velocity at sample rates up to 4,681 Hz and 800 Hz, respectively.

Other research using the same mouthpiece-based sensor has used a sampling frequency of 4,684 Hz and an acceleration threshold of 5 g's sustained for greater than or equal to 14 samples to collect 60 ms of data per recording (Rich et al., 2019). Although there have been many previous studies that examine head impact exposure using similar instrumentation, the gymnastics environment is different from most team sports. Therefore, a frequency analysis was performed by calculating the fast Fourier transform (FFT) of all events collected during a single session at 350 Hz to identify the ideal sampling frequency for this environment. A sampling frequency of 350 Hz was chosen as it was the maximum sampling frequency that the researchers could successfully time synchronize the data with video and capture the full duration of contact events due to sensor limitations. The dominant frequencies of the head during gymnastics skill motion were at or less than 35 Hz. Therefore, a sampling frequency of 100 Hz, was deemed sufficient to capture head kinematic data. The number of pre-impact samples and post-impact samples were extended so that both contact (i.e. when a gymnast comes in contact with a surface) and aerial (i.e. when an athlete performs a skill) data could be recorded by the mouthpiece sensor. The extended time of recording not only improved video pairing, but ensured that all contact scenarios within a skill series could be recorded. The final configuration utilized a sampling frequency of 100 Hz and a trigger threshold of 4 g sustained over 3 samples.

Data collected by the sensor was processed according to the methods of Miller et al. (Miller et al., 2018) and Rich et al. (Rich et al., 2019); excluding the filter since the sampling frequencies in the current study were much lower. Briefly, linear acceleration and rotational velocity data were rotated to align with an anatomic coordinate system (X points from posterior to anterior, Y points from right to left, Z points from inferior to superior), rotational acceleration was computed by numerically differentiating the gyroscope data using a five-point difference formula, and finally linear acceleration was transformed to the head center of gravity (CG) using rigid body dynamics.

Recorded mouthpiece events were paired with observed events on film using the mouthpiece timestamp and the video time to the nearest second. A frame-by-frame analysis was conducted for each event by identifying when the initiation of the peak linear acceleration occurs. Then the mouthpiece data was synchronized to the frame of the video where the athlete initially contacted the surface. In cases where an event was triggered without surface contact (e.g., from the linear acceleration produced by the athlete's rotation during a skill) the initiation of the peak signal was synchronized to the initiation of movement by the athlete. All kinematically-significant movements by the athlete (e.g., initial contact of foot, initiation of hip circle, etc.) were then identified in the video and matched to the event recording. Contact scenarios were segmented from the time of initial surface contact to the time the athlete's body part left contact with the surface or when the athlete's motion stopped (Figure 1). Skills, defined as gymnastics-related actions performed by the gymnast (e.g., back handspring), were segmented from the time of initial contact or initiation of movement, to the time the athlete's body part left contact with the apparatus or when the athlete's motion stopped (Figure 1). Segmented contact scenarios and skills were then zeroed to the mean of the previous five samples of the recording. If the start of the scenario occurred at the beginning of the recording, the first five samples of the contact scenario or skill were used to zero the segmented data.

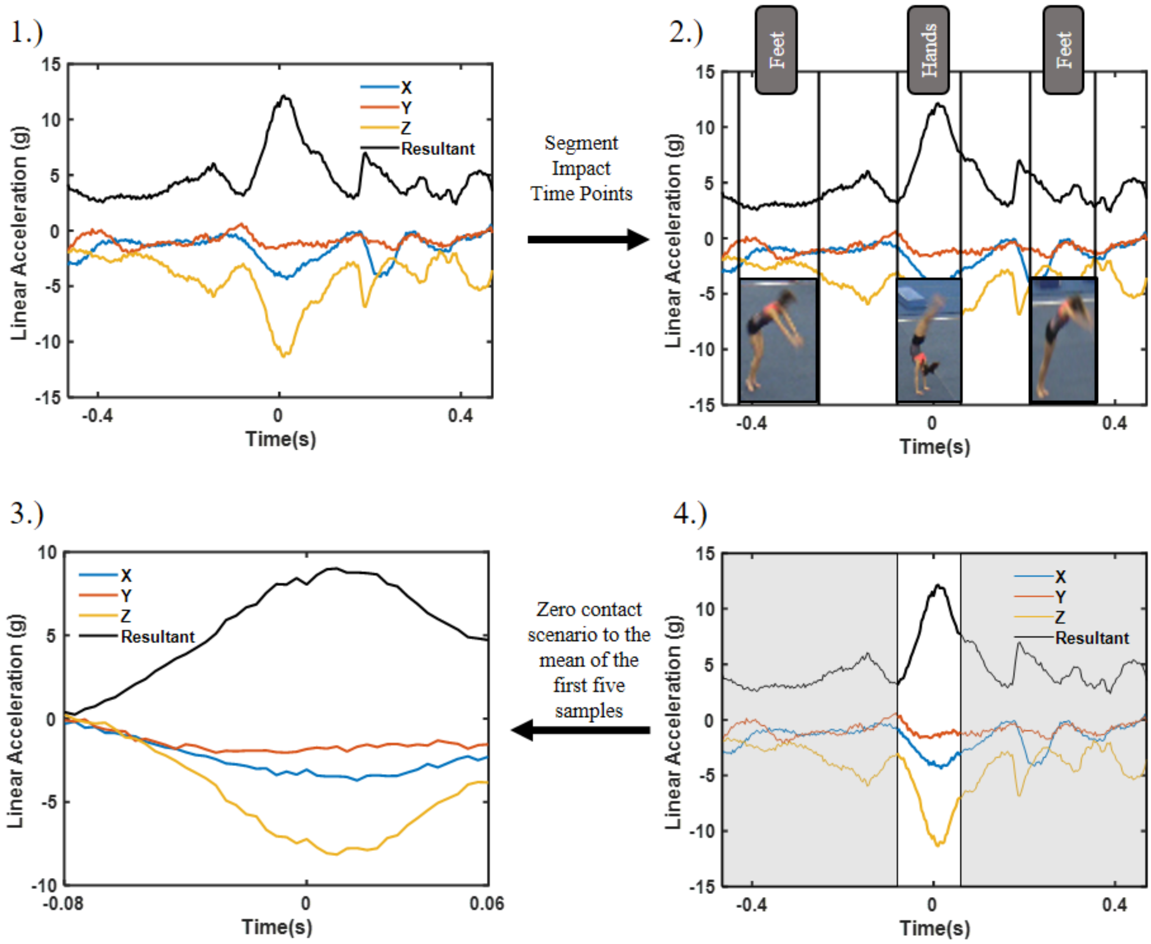

Figure 1. From plot 1-4, transformed data (1) is segmented (2) and then individual contact scenarios (3) are zeroed to the mean of the previous five samples of the recording (4).

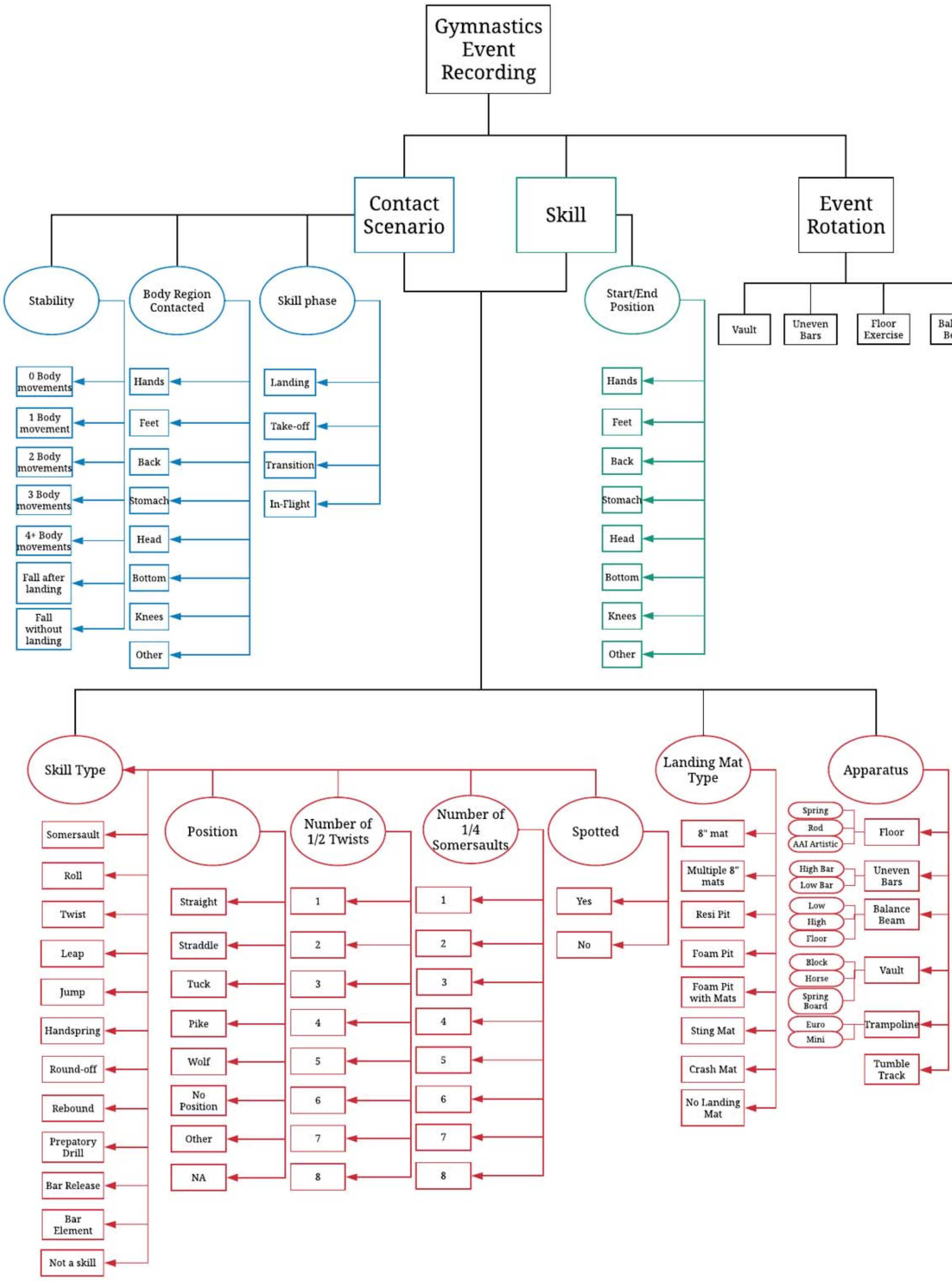

Figure 2. Flow chart outlining all possible categorizations of event recordings, contact scenarios, and skills.

Each recording was categorized by the series of skill types the gymnast performed before and after the event trigger (Figure 2). Then, each *contact scenario* during the recording was categorized by characteristics of the skills preceding and following contact (type, number of somersaults, number of twists, body position, presence of a spotter), initial body region contacted, apparatus, landing mat type, skill phase, and landing stability (for feet landings only). Landing stability was quantified by the number of body movements (i.e. arm circle, step) performed after landing. Each *skill* during the recording was categorized by characteristics of the skill (type, number of somersaults, number of twists, body position, presence of a spotter), preceding skill type, following skill, apparatus, and type of landing mat used. Contact scenarios and skills were only defined if the recording included both the initiation and completion of the contact scenario or skill.

Peak resultant linear acceleration (PRLA), peak resultant rotational velocity (PRRV), and peak resultant rotational acceleration (PRRA) were calculated for each contact scenario and skill. Additionally, the duration was calculated as the time between the first minimums before and after the PRLA magnitude was below 10% of the maximum magnitude. The time to PRLA, was calculated as the time between the PRLA and the first minimum before the PRLA magnitude was below 10% of the maximum magnitude. In cases where segmented contact scenarios or skills did not contain a minimum below 10% of the maximum magnitude either before or after the PRLA (e.g. flat trace), the first or last sample of the segmented recording was used to calculate time to PRLA and duration.

Summary statistics of peak kinematic data were evaluated by skill type, skill phase, apparatus, landing mat type, body region contacted, landing stability, and presence of a spotter. 5th, 50th, and 95th percentile values for PRLA, PRRV, PRRA, duration, and time to PRLA were reported for all categories.

RESULTS

Of 34 data collection sessions, 29 contained event recordings that were paired with video for analysis. Athlete A participated for 10 sessions before sustaining a concussion and retiring from gymnastics. Athlete B participated for 9 sessions before sustaining a foot injury and was not able to participate further. Athlete C participated for 24 sessions, 9 of which were concurrent with Athlete B. Throughout the 29 analyzed practices a total of 1,394 contact scenarios (41 per day per athlete) and 516 skills (19 per day per athlete) were segmented from 1,270 event recordings. Events were triggered by 55 different skill series with the most common skill series being round-off back handspring somersault. The kinematics of skills were not analyzed in this paper. The majority of contact scenarios occurred during the floor rotation (55.6%) followed by the vault (18.3%), balance beam (15.1%), and bars (11.0%). Whereas, contact scenarios most frequently occurred on the floor apparatuses (52.6%), the trampoline apparatuses (16.6%), and the balance beam apparatuses (12.6%). The most frequently contacted body regions were the feet (64.4%), hands (23.1%), and back (7.1%). While, only 12 contact scenarios contained direct contact to the head, 114 contact scenarios contained direct head contact or secondary head contact (e.g. the gymnast landed on their back first and then their head hit a surface) (3.8 per gymnast per session). Additionally, the majority of contact scenarios did not utilize any landing mat (82.1%), but 17.9% of contact scenarios utilized one of seven landing mat setups: an 8” mat (5.2%), crash mat (0.5%), foam pit (1.9%), mats stacked in the foam pit (1.2%), multiple 8” mats (0.5%), Resi pit (7.0%), and a sting mat (1.6%). Only 1.4% of contact scenarios recorded during the practices occurred after or while a coach spotted a gymnast. Lastly, of the contact scenarios with which landing stability could be determined (15.4%), 12.1% had zero body movements (e.g. perfect stability), 25.6% had one body movement, 24.2% had 2 body movements, 8.8% had 3 body movements, 8.4% had 4 or more body movements, 20.5% were from a fall after landing, and 0.5% were from a fall without a foot landing.

Overall, the 5th, 50th, and 95th percentile PRLA magnitudes were 3.5 g, 6.7 g, and 12.4 g, respectively. The 5th, 50th, and 95th percentile PRRV magnitudes were 2.5 rad/s, 8.0 rad/s, and 19.3 rad/s, respectively. The 5th, 50th, and 95th percentile PRRA magnitudes were 71.6 rad/s^2, 190.0 rad/s^2, and 425.9 rad/s^2. Peak kinematic magnitudes did not always occur at the same time. For instance, PRRA and PRRV always occurred after PRLA. The median time differences for PRRA and PRRV were 0.040s and 0.060s after the PRLA.

Skill Types. Rolls had the highest median PRLA (11.3 g, n=2), followed by leaps (9.4 g, n=171), and falls (8.6 g, n=27) (See Appendix Table 1). Similarly, rolls had the highest median PRRV (17.5 rad/s, n=2) followed by handsprings (7.9 rad/s, n=497), then contact scenarios with no skill type (7.6 rad/s, n=67). Once more, rolls had the highest median PRRA (856.4 rad/s^2, n=2), followed by falls (290.5 rad/s^2, n=27), then somersaults (247.6 rad/s^2, n=171). The duration of contact was much shorter for rolls (0.099s) then all other skill types (0.154s-0.214s). Similarly, the time to PRLA was much shorter for rolls (0.026s) then all other skill types (0.060s-0.103s).

Apparatus. Contact scenarios occurring from skills performed on the vaulting horse had the highest 95th percentile PRLA (19.8 g, n=56) followed by the high bar (15.4 g, n=44), then the high beam (13.1 g, n=31) with contact scenarios occurring from skills performed on the low beam having the lowest 95th percentile PRLA (7.0 g) (See Appendix Table 2). However, contact scenarios occurring from skills performed on the spring floor had the highest 95th percentile PRRV (19.7 rad/s, n=51) followed by the low beam (19.6 rad/s, n=62), then the floor beam (18.8 rad/s, n=82) with contact scenarios occurring from skills performed on the low bar having the lowest 95th percentile PRRV (11.3 rad/s, n=33). Contact scenarios occurring from skills performed on the vaulting horse had the highest 95th percentile PRRA (862.4 rad/s^2, n=56) followed by contact scenarios where there was no apparatus (524.8 rad/s^2, n=83), and the AAI artistic floor (485.9 rad/s^2, n=544) with contact scenarios occurring from skills performed on the mini trampoline (192.4 rad/s^2, n=19) having the lowest 95th percentile PRRA. Duration of contact scenarios varied from 0.0160 s on the AAI Artistic floor and vault spring board to 0.331 seconds on the Euro trampoline. Time to PRLA varied from 0.049 seconds for contact scenarios occurring from skills performed on the low bar to 0.173 seconds for contact scenarios occurring from skills performed on the Euro trampoline.

Landing Mat Types. Contact scenarios occurring on mats stacked in the foam pit had the highest 95th percentile PRLA (22.6 g, n=16) followed by the crash mat (16.5 g, n=7), then the 8” mat (14.1 g, n=73) with contact scenarios occurring on multiple 8” mats having the lowest 95th percentile PRLA (6.7 g, n =7) (See Appendix Table 3). Similarly, contact scenarios occurring on mats stacked in the foam pit had the highest 95th percentile PRRV (21.2 rad/s, n=16), followed by contact scenarios occurring on the Resi pit (17.5 rad/s, n=97) and contact scenarios occurring on competition standard equipment (16.1 rad/s, n=1145). Once more, contact scenarios occurring on mats stacked in the foam pit had the highest 95th percentile PRRA (1,406.3 rad/s^2, n=16) followed by contact scenarios occurring on sting mats (691.7 rad/s^2, n=22) and Resi pits (577.6 rad/s^2, n=97). The duration of contact scenarios varied from 0.100 s on mats stacked in the foam pit to 0.488 s when athletes landed in the foam pit. Additionally, the time to PRLA varied from 0.044 s when athletes landed on mats stacked in the foam pit to 0.200 s when athletes landed in the foam pit. Within this study, all contact scenarios occurring on mats stacked in the foam pit occurred while the athlete was rotating more than one full somersault to their back

Body Regions. Direct impacts to the head had the highest 95th percentile PRLA (20.8 g, n=12) followed by impacts to the back (18.3 g, n=99) and bottom (14.3 g, n=30) (See Appendix Table 4). Similarly, direct impacts to the head had the highest 95th percentile PRRV (26.2 rad/s, n=12) followed by impacts to the hands (19.0 rad/s, n=322) and back (18.2 rad/s, n=99) with impacts to the bottom having the lowest 95th percentile PRRV (10.0 rad/s, n=30). Additionally, impacts to the head had the highest 95th percentile PRRA (1,472.2 rad/s^2, n=12) followed by impacts to the back (825.9 rad/s^2, n=99) and feet (429.6 rad/s^2, n=897). Duration of contact scenarios ranged from 0.168s when athletes landed on their back to 0.498 s when athletes landed directly on their head. Time to PRLA ranged from 0.070 seconds when athletes landed on their back to 0.222 seconds when athletes landed directly on their head. When impacts were differentiated by head contact (See Appendix Table 5), impacts with head contact (n=114) had greater 95th percentile PRLA (Y-18.3 g, N- 10.8 g), PRRV (Y-19.1 rad/s, N-15.8 rad/s) and PRRA (Y-866.2 rad/s^2, N-420.6 rad/s^2) and shorter durations (Y-0.177s, N- 0.185s) and time to PRLA (Y-0.071s, N-0.090s) than impacts without head contact.

Skill Phase. Landings had the highest 95th percentile PRLA (14.3 g, n=375) followed by transitions (10.5 g, n=895) and then take-offs (10.1 g, n=121) (See Appendix Table 6). However, transitions had the highest 95th percentile PRRV (n=895, 17.1 rad/s), followed by landings (14.2 rad/s, n=375) and take-offs (12.2 rad/s, n=121). Landings had the highest 95th percentile PRRA (600.5 rad/s^2, n=375), followed by take-offs (508.8 rad/s^2, n=121) and transitions (411.9 rad/s^2, n=895). Duration of contact scenarios was shortest during take-offs (0.140s) and longest during landings (0.210s). However, time to PRLA was shortest during take-offs (0.060 s) and longest during transitions (0.097s).

Landing Stability and Spotting. The 95th percentile PRLA and PRRA did not vary much by landing condition (9.4 g-14.0g, 241.5 rad/s^2-481.3 rad/s^2), but there were large differences in PRRV (6.6 rad/s-17.8 rad/s) with 4+ body movements resulting in the highest 95th percentile PRRV (See Appendix Table 7). Additionally, duration of contact scenarios and time to PRLA generally increased with increasing number of body movements. When contact scenarios were differentiated by spotting (See Appendix Table 8), contact scenarios with spotting had lower 95th percentile PRLA (Y-8.2g, N-11.6g), higher 95th percentile PRRV (Y-16.4 rad/s, N-16.0 rad/s), and lower 95th percentile PRRA (Y-267.3 rad/s^2,N-456.0 rad/s^2) with longer durations (Y-0.260s,N-0.183s) and time to PRLA (Y-0.110s,N-0.090s) than impacts without spotting.

Concussion. During the study period, one gymnast sustained a concussion after a fall to their back from the high beam. The PRLA, PRRV, and PRRA for this contact scenario were 21.2 g, 26.8 rad/s, 1512.4 rad/s2, respectively. Figure 3 shows the corresponding linear acceleration, rotational velocity, and rotational acceleration over time and compares the PRLA and PRRA of the concussive impact event to all other recorded events. The concussive event had the second highest PRLA and the second highest PRRA, but the highest combined probability of concussion risk (Rowson & Duma, 2013), compared to all other impact events.

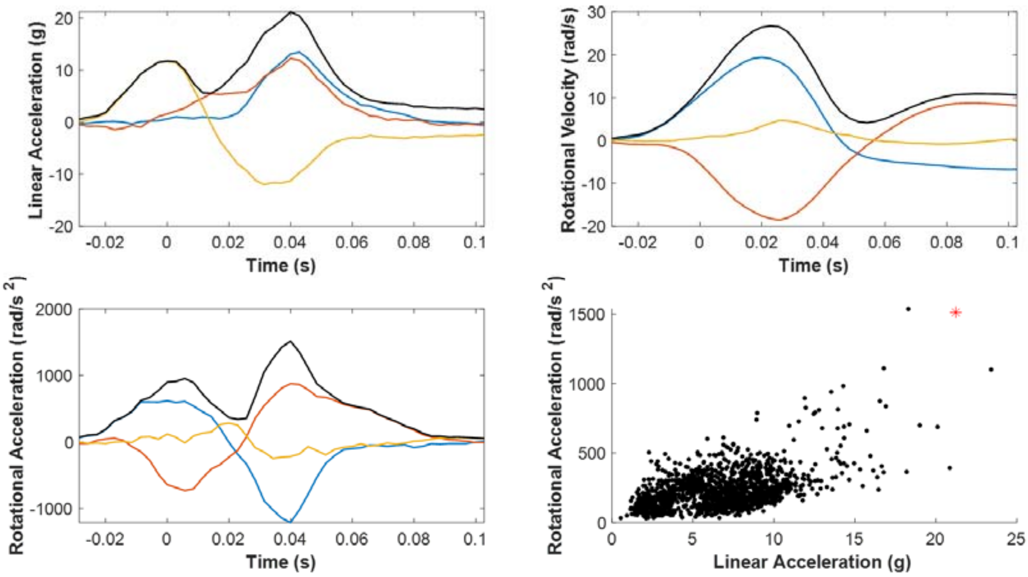

Figure 3. The linear acceleration (top left), rotational velocity (top right), and rotational acceleration (bottom left) during an injurious fall from high beam. Plot (bottom right) compares the peak resultant linear and rotational acceleration magnitudes from this contact scenario (represented by *) to all other recorded contact scenarios.

DISCUSSION AND CONCLUSIONS

This study developed a methodology to measure and evaluate head kinematics in gymnastics. Additionally, head kinematics of one to three optional level gymnast's ages (11-16) were analyzed during 29 practices. To the best of the researcher's knowledge, this is the first study to measure head kinematics across a variety of contact scenarios commonly experienced in women's artistic gymnastics. From these data, it is possible to characterize the frequency and magnitude with which the head accelerates during gymnastics skills. Collectively, the gymnasts sustained over 1,000 contact scenarios (41 per gymnast per practice), 10% of which contained head contact. Head contact was associated with greater peak kinematic magnitudes and shorter impact durations compared to contact scenarios without head contact. These data provide a framework to help inform and guide evidence-based decisions regarding return to gymnastics and concussion safety within gymnastics. The frequency of head contact events per gymnast per session (3.8) was slightly higher than the frequencies reported in collegiate and youth soccer practices (1.86 (Press & Rowson, 2017)-3.52 (McCuen et al., 2015),1.69 (McCuen et al., 2015)). However, median PRLA (6.7 g) and PRRA (190.0 rad/s^2) magnitudes were below those reported in soccer (9.4 g, 689.1 rad/s^2) (Miller, Pinkerton, et al., 2019) and youth football (21.7 g, 973 rad/s^2) (Urban et al., 2013). Interestingly, the duration of impacts was on average much longer (177 ms) than impacts reported in soccer (Miller, Pinkerton, et al., 2019) (17.2 ms), potentially due to the compliant surfaces gymnasts contacted. So, while gymnasts may be exposed to more frequent low magnitude head contact scenarios, they experience these acceleration events for longer durations which may have an effect on concussion risk.

An interesting finding from this study was that in addition to experiencing a high frequency of head contact scenarios, gymnasts experienced an even higher frequency of body-contact acceleration events that were the result of surface contact with a body part other than the head during gymnastics skills such as: leaps, jumps, somersaults, and handsprings. Head contact is typically associated with concussions (Buzas et al., 2014); however, it is not a requirement, and concussions following surface contact to a body region other than the head have been documented within gymnastics (Knight et al., 2016). Within this study, impacts without head contact were below magnitudes thought to increase risk of head injury and generally consistent with values reported in everyday activities (Miller, Urban, et al., 2019). PRLA magnitudes were greatest when the athlete contacted the surface on their bottom, which occurred during unintentional falls after landing or intentional skills performed on the floor or trampoline apparatuses. However, PRRV and PRRA magnitudes were higher when the athlete's feet were the point of contact such as when the athlete was performing a somersault, round-off, handspring, etc. It is likely that during these scenarios the head is accelerating as the athlete rotates, looks for the ground, or falls resulting in higher rotational magnitudes. Additionally, a smaller number of contact scenarios where the athlete contacted their bottom were measured compared to foot landings, and it is possible that apparatus, skill type, and skill performance variations during these contact scenarios could have skewed impacts with bottom contact towards smaller kinematic magnitudes.

It is well documented in the gymnastics literature that ground reaction forces during landing can be reduced by decreasing skill height, and using landing mats (McNitt-Gray et al., 2016; Mcnitt-Gray et al., 1993; Mills, Yeadon, & Pain, 2010). In contrast to these data, this study found that peak acceleration magnitudes were higher in contact scenarios that contained landing mats compared with scenarios performed on competition standard surfaces where no safety mat was used. While this study contained a limited number of contact scenarios across mat types, this contrary result may also be due in part to the preference of using landing mats only when performing higher difficulty skills with greater height and rotational speed. Thus, while comparisons of landing mat performance cannot be derived from these data, these data do provide evidence for understanding scenarios where more appropriate landing mats should be used. For instance, mats were stacked in the foam pit when gymnasts performed yurchenko timers on the vault, a skill in which the gymnast performs a back handspring over the vaulting table and rotates to their back. This skill series reported a maximum peak linear acceleration of 23.4 g, a maximum peak rotational velocity of 22.1 rad/s, and a maximum peak rotational acceleration of 1,537.3 rad/s^2, which were similar to that of the concussive impact observed in this study. It is possible that a more compliant landing mat placed in the foam pit would help to reduce peak impact magnitudes when performing this skill series.

This study also found that acceleration magnitudes were highest on the vaulting horse, followed by the high beam, and the AAI artistic floor. In contrast, ground reaction forces have been reported highest on the floor exercise compared to the beam (Burt et al., 2007). However, the height of the apparatus in addition to the apparatus stiffness has an effect on accelerations experienced on the event (McNitt-Gray et al., 2016; Mcnitt-Gray et al., 1993). While, almost all contact scenarios that arose from skills on the AAI artistic floor finished on the same equipment, beam and vault apparatuses contain a dismount component that requires the gymnast to jump from the elevated apparatus to a landing mat placed on the ground. So, although contact scenarios from skills performed onto the high beam and vault may expose athletes to lower accelerations than floor impacts, dismounts and/or falls off these apparatuses expose athletes to high head acceleration magnitudes that may result in injury.

The results of our study demonstrate that head acceleration magnitudes are affected by apparatus, body region, and landing mat usage. For instance, while the maximum linear acceleration for rolls was 16.8 g, a result of an athlete performing a backward extension roll on the floor apparatus with head contact and no landing mat, the minimum peak linear acceleration for rolls was 5.9 g, the result of an athlete performing a forward dive roll with head contact onto a sting mat on the floor apparatus. In one case, the athlete's head was unprotected by the equipment and poor rolling technique led to forceful head contact with the apparatus; whereas, in the other case, the athletes rolling technique prevented forceful head contact and the presence of a landing mat potentially contributed to a reduction in acceleration magnitudes. Therefore, when examining concussion risk and head impact exposure during gymnastics, all components of gymnastics skills: the apparatus, landing mat, skill type, and skill technique, should be considered.

In addition to frequent body-contact impacts, gymnasts are exposed to a number of non-contact head acceleration events during gymnastic skills with high rotational components such as: twists, somersaults, and bar elements. The peak linear accelerations during these skills may reach magnitudes similar to that of foot impacts; however, the duration of these events is much longer, reaching upwards of 2.7 seconds. During this time, rotational velocities may reach magnitudes of up to 25.9 rad/s. Rotational velocities during these skills may vary by athlete growth (Ackland, Elliott, & Richards, 2003), anthropometrics (Ackland et al., 2003), skill level, and skill technique (King & Yeadon, 2004), and while it is unlikely that an athlete will sustain a concussion from the proper performance of these skills, it is possible that high rotational velocities experienced during recovery from concussion may result in symptomatic episodes. This study provides an initial glimpse of the rotational velocity experienced during common gymnastics movements and provides insight and consideration towards the development of return to sport guidelines following concussion in gymnastics.

This study was limited by inherent constraints of the wearable mouthpiece sensor used in the study. The data storage on the device and download rate limited the sampling rate to 100 Hz. Previous research examining head impacts in sport utilize much higher sampling rates to identify high rate, short duration head impact events. It is possible that these types of contact scenarios may occur when an athlete contacts an unprotected apparatus or floor, resulting in higher frequency events where aliasing may occur at a lower sampling rate. The sensor was also limited in its ability to precisely time synchronize events to the video within 1 second. Because of this, variations due to time-matching error may have resulted in small errors in calculated durations and time to peaks. This was accounted for by calculating the duration of the contact scenario separately from the video; however, future research should aim to improve the device time synchronization precision to obtain more precise duration and time to peak data. Lastly, head impact frequencies reported in this paper may be lower than what is truly experienced by gymnasts due to sensitivity limitations resulting from pre-set sensor configurations that filter out low magnitude contact scenarios and device limitations that result in missed contact scenarios when multiple events (true and false) occur in quick succession of one another. Future efforts of calculating head impact frequency in gymnastics should combine video and sensor data to improve accuracy.

An additional limitation of this study was the low sample size, small number of practice days, and sole use of optional level gymnasts. The pilot nature of this study provides a limited representation of youth gymnastics as a whole, as all study participants were from the same region and practice within the same gym, but still provides important insights into possible head kinematics experienced in the sport. This sample was selected to achieve the primary goal of developing a method to measure and analyze head kinematics in gymnastics; however, the small sample limits the generalizability of the kinematic measurements reported. During the study, all three gymnasts sustained an injury that required at least a week of recovery before full return to sport, resulting in a limited number of data collection events. Moreover, while optional level athletes can perform more skill types than compulsory (lower level) gymnasts, compulsory gymnasts may obtain more frequent head contact scenarios with lower peak kinematic magnitudes as a result of common preparatory drills performed during the lower levels. Future research should aim to increase sample size and include a variety of different levels of gymnastics to examine the wide range of potential combinations of skills, landing mats, apparatuses, and body regions that may occur in day-to-day practice of gymnastics.

Gymnastics is a sport not commonly considered when discussing concussive injuries; however, concussions in gymnastics do occur, and it is important for parents, coaches, athletes, and medical professionals to better understand the mechanisms for which these injuries can happen in the sport. The data in this study demonstrate that head kinematics and consequently head injury risk in gymnastics are affected by skill type, skill performance, landing mat usage, apparatus, and body region contacted. Medical professionals guiding gymnasts back to sport from concussion should consider these variables and their relationship to non-contact and body-contact head acceleration scenarios to reduce the risk of a second concussive impact and symptomatic episodes during recovery. Future research on head injuries in gymnastics is needed to better understand high risk skills and mechanisms for which risk can be mitigated in the sport.

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BIOMECHANICAL CHARACTERISTICS OF STAG LEAP WITH BACK BEND OF THE TRUNK: A CASE STUDY

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Case study

Abstract

Biomechanical considerations as reflected in correct or incorrect technique, particularly in all gymnastic disciplines are more than undoubted. The stag leap as a variation of split leaps is one of the fundamental gymnastics skill and a key movement in the development of elite female gymnasts. The aim of the study was to analyse the kinematic characteristics of the stag leap with back bend of the trunk performed in rhythmic gymnastics and simultaneously find out the explosive power regarding this particular element. A member of Slovakian national team was involved in the study. Kinematic characteristics of the element were analysed. A capture system consisting of 8 infrared cameras were employed to collect the data. The explosive power of the lower limbs were diagnosed by a jump ergometer with 2 standardized tests: vertical counter-movement jump with the fixation of the arms and 10-second repetitive vertical jumps with arms movements. In addition, the explosive power of the lower limbs was also observed in the flight phase of the element. The results in 10-second repetitive jumps show the highest value of gymnast centre of mass 46.4 cm, contact time 0.195 s and the best active output in the flight phase 58.3 W.kg^{-1}. While performing the difficulty element, slightly different data were observed due to the complexity and more demanding motor coordination of both upper and lower body segments: the highest value of gymnast centre of mass was 40.8 cm, contact time 0.209 s and the output in the active flight phase 52.8 W.kg^{-1}.

Keywords: *rhythmics, kinematic characteristics, explosive power, 10-second repetitive jumps, vertical counter-movement jump.*

INTRODUCTION

Rhythmic gymnastics (RG) is define as an aesthetic, purely feminine Olympic sport that combines the sporting art of physical capacities with the art of dance. To achieve a top performance level it is important to master the difficulty of the applicable rules, the technique of demanding elements or equipment and the ability to connect all components of rhythmic gymnastics with music, style of music, rhythm, pace, etc. The sports performance is the result of all these factors of high intensity and in the evaluation, in addition to the technical demonstration, puts great emphasis on the aesthetic demonstration (Miletić, Katić & Males, 2004). As it has been already scientifically approved, the most limiting abilities in RG are the explosive power and flexibility, mostly of lower limbs, which affects performance of a gymnast to the great extent. According to Hutchinson et al. (1998) RG belongs to the “high jump-challenging sports”. In addition, as stated by Ashby & Heegaard (2002), jumps are fundamental movements, requiring complex motor coordination of both upper and lower body segment.

One of the most important factors in RG is technique. The correct “model” technique and difficulty element forms is specified in the RG Code of Points, updated for each Olympic cycle. The overall motor coordination of both the upper and lower body limbs (Ashby & Heegaard, 2002) is an important for the correct execution. In addition to the technical demonstration and flexibility, the explosive power of the lower limbs is an essential part of the performance in RG, which is required to perform take-off of difficulty and choreography elements. It is also considered one of the most important indicators for talent identification (Di Cagno et al., 2008). Flexibility, explosive power, reaction time and anthropometric characteristics account for 41% success in performing the basic elements of difficulty in RG, while the frequency of movement and the volume of performing specific manipulation with the requisite (ball, hoop, ribbon, clubs, rope) is 26% (Miletić, Katić & Males, 2004). In addition to the technical skills, performance in rhythmic gymnastics also affects several fitness and coordination abilities. The lack of strength, mobility and movement accuracy can lead to catastrophic performance (Brooks, 2003). During the intense training sessions gymnasts are asked to perform routines while fatigued, and to find the best compromise among technical effectiveness, safety, and high intensity effort (Sands et al., 2011). Thus, the high level of the basic requirements of fitness is necessary for the success in learning of skills.

The functional diagnosis and analysis of the top-level athlete’s movements using various training aids must be an essential part of their training. To improve sports performance in RG it is necessary to analyse constantly the exercise patterns and to diagnose the limiting factors. Despite growing popularity of RG, still there is a lack of biomechanical analyses in literature, regarding the techniques of the specific difficulty elements (Cicchella, 2009). Nevertheless, the most part of RG coaches have a great difficulty to analyse the most common errors while performing jumps and leaps (Sousa & Lébre, 2010). Doubtlessly, the use of technological equipment and methods leads to an improvement in the training process and thus the competition performance. Thanks to the three-dimensional (3D) analysis we can study the movement in more details and find execution errors that are often invisible at the speed by a naked eye, and then affect and correct the technique of the elements. It is the biomechanics that is the science that discovers the cause of erroneous execution before it we can identify it (Sands, 2011).

The aim of the study was to analyse the kinematic characteristics of the stag leap with back bend of the trunk performed in rhythmic gymnastics and simultaneously find out the explosive power regarding this particular element. The study was approved by the Ethics Committee of FPES CU in Bratislava.

METHODS

The study was conducted by a senior Slovakian team member in RG, a multiple national champion and a participant of the European and World Championships (age 23 years; body weight 62 kg; body height 176 cm). The basic difficulty element - *the stag leap with back bend of the trunk* (Fig. 1) has been investigated. According to the actual FIG RG Code of Point (FIG, 2017) this particular element is a typical jump with a trunk bend backwards with a difficulty value of 0.3 points. An angle between the legs (thighs) of at least 180° is required, the maximum bend of the front lower limb and the head in the back bend must be in proximity to some part of the lower limb; contact under current rules is not required.

Figure 1. Stag leap with back bend of the trunk (FIG, 2017)

To execute the element properly 4 phases must be performed fluently, with no hesitation between:

1st - preparatory phase,
2nd - take-off phase,
3rd - flight phase,
4th - landing phase.

The gymnast began to perform the element with the preparatory phase: from the standing position, legs are together and the arms are streched out of the side. The gymnast then performs two steps forward and jumps from one food into the demi-squat with arms close to the body. Preparatory phase is followed by 2-feet take-off "as fast and as high as possible", so the elastic energy is used. Once the gymnast is airborne in the flight phase she must show the correct form of the element - stag position with back bend of the trunk. To land properly with no errors she must slow down the speed to zero.

Testing and data were conducted in a laboratory environment. We obtained the data by analysing the kinematic variables of the element, particularly the spatial and temporal characteristics. To record the movement and to get precise and correct data, we used eight high-speed Blaster company cameras scA640-120gc, which were arranged to capture the entire movement of the element. The recordings were focused from three different angles. The entire process of recording and storing has been done in Simi Motion 3D program (the German company Simi Reality motion Systems GmbH based in Unter-schleissheim). The difficulty element was executed on a dynamometric plate. Before the recording the element, 12 important anthropometric points has been identified on the bodies of the gymnasts where markers were placed to serve for better visibility when recording and depicting the angles between the body segments in CorelDraw 12 program (Fig. 2).

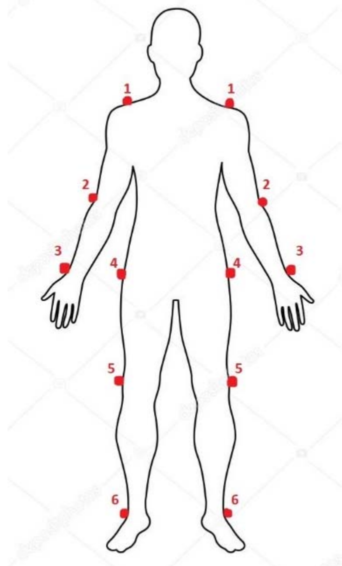


Figure 2. Anthropometric points - marker placement of the gymnast (R = right, L = left) 1. L and R arms - the highest lateral point on the acromial extension; 2. L and P elbows - a point at the edge of the head of the spoke bone; 3. L and P wrists - a point at the edge of the head of the spoke bone; 4. L and R hips - the highest point of the head of the thighbone; 5. L and R knees - a point on the outer epicondylitis of the fistula; 6. L and R ankles - a point on the outer ankle.

The Fitro Jumper (Zemkova & Hamar, 2004), Fig.3 has been used for data acquisition, measurement and diagnosis of the take-off explosive power. The explosive power of the lower limbs were diagnosed by use of a jump ergometer with 2 standardized tests: vertical counter-movement jump with the fixation of the arms and 10-second repeated vertical jumps with arms movements (Bosco et al., 1983). In addition, the explosive power of the lower limbs was also observed during the difficulty element. The gymnast performed 3 separate attempts of the stag leap with back bend of the trunk. The kinematic characteristics in the flight phase of the element was detected and analysed. A Simi Motion capture system were employed to collect the following data: the height of the centre of mass (CoM) in the flight phase (cm), the contact time of the feet (s) and the output in the active phase of take-off ($W.kg^{-1}$).

Figure 3. Fitro Jump ergometer (Zemkova & Hamar, 2004).

All measurements were done at the end of preparatory period of the season. In this phase gymnast has been trained 6 times per week, 6 hours per day. Weekly training load contained specific physical preparation, including dance and gymnastic skills. The distribution of individual training components in the weekly microcycle was as follows: endurance – 25 %, speed – 12,5 %, strength – 12,5 %, coordination – 12,5 %, gymnastic skills training + dance preparation – 37,5 %.

RESULTS

Analyse of the stag leap with back bend of the trunk. As stated, kinematic characteristics of the stag leap with back bend of the trunk has been obtained by analysing 4 phases of the element: 1st - preparatory phase, 2nd - take-off phase, 3rd - flight phase, 4th - landing phase. The gymnast's attention during each phase of the jump is not equal. In general, the attention is higher during the approach and the flight, and lower during the take-off and the landing. Better preparatory phase helps the gymnast in better control of the movements during the flight. Longer flight phase allows the gymnast to reach a correct body shape and form of the element.

The analyse of temporal characteristics shown that from the moment of the first step in preparatory phase up to the landing, elapsed time was 3.090 s. In the table 1 duration of each phase is demonstrated. As expected, the shortest phase with duration of 0.120 s was the take-off.

Table 1
Duration (s) of the stag leap from the preparatory phase to the moment of the landing (the 1st foot contact).

Phases of the element	Duration
Preparatory phase	1.710
Take-off phase	0.120
Flight phase	0.500
Landing phase	0.760

Regarding the *spatial characteristics*, we analysed the angles between the individual body segments as follows:

- Head - middle of the arms – middle of the hips
- Shoulder joint - elbow joint - wrist
- Hip joint - shoulder joint – elbow joint
- Hip joint - knee joint - ankle joint
- Knee joint - hips - knee joint
- Ankle joint - hip joint - ankle joint
- Middle of the arms - middle of the hips - mat
- Hip joints - shoulder joints

At each phase, we have chosen those angular changes that are important and crucial for execution of the element.

In the *preparatory phase* the detected flexions were: hip joint - knee joint - ankle joint; hip joint - shoulder joint - elbow joint; hip joint – shoulder joint. Results show a slight difference between the right and left body segments, table 2.

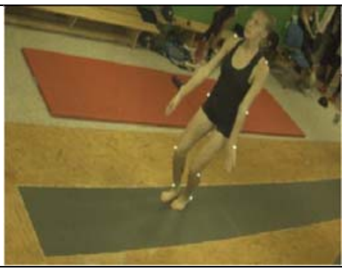
In the *take-off phase* (the last contact before the flight) we analysed hip joint – shoulder joint; hip joint - knee joint - ankle joint; hip joint - shoulder joint - elbow joint; middle of the arms - middle of the hips – mat; head flexion backwards. Results are shown in table 3.

Flight phase is the most important regarding the minimum requirements for the difficulty value. Spatial changes have been analysed between joints: hip – right knee – right ankle; hip – shoulder – elbow; right knee – hip – left knee; hip – shoulder; head flexion backwards (table 4). According to the actual FIG RG rules (FIG, 2017) the required angle between the legs (thighs) must be at least 180° during the flight phase. This is what the angle of the knee joint of the anterior lower limb - hips - knee joint of the posterior lower limb represents. The gymnast didn´t meet the minimum requirement, and she reached the value of angle 160°. Another requirement according to the FIG rules is the maximum back bend with the head closest as possible to any part of the lower limb. As it is shown in table 4, gymnast achieved an insufficient back bend angle 133°, but a maximum flexion in the right knee joint (anterior lower limb).

Many errors in execution can occur in *landing phase*. As demonstrated in table 5, these angular changes were observed regarding the correct performance of the element: hip – right knee – right ankle; right ankle – hips – left ankle; shoulder – hip; hips – shoulder – both elbows; head flexion backwards.

In the landing phase, table 5, at the first contact with the floor, the shoulders with the hips remain almost the same as in the previous flight phase, 136° versus 133° respectively. This is due to the fact that the shoulders remain slightly tilted. Forward flexion of the trunk in this position could cause a large step after completing the element, and thus an error in execution.

Table 2
Angles (°) between individual body segments in the preparatory phase; R = right, L = left.



Body segment	Range between the segments
Hip - knee - ankle	R = 127; L = 126
Hip - shoulder - elbow	R = 11; L = 13
Hip – shoulder	170

Table 3
Angles (°) between individual body segments in the take-off phase; R = right, L = left.

Body segment	Range between the segments
Hip - knee - ankle	R = 172; L = 175
Hip - shoulder - elbow	R = 76; L = 66
Hip – shoulder	172
Middle arms – middle hips – mat	85
Head flexion backwards	170

Table 4
Angles (°) between individual body segments in the flight phase; R = right, L = left.

Body segment	Range between the segments
Hip – R knee – R ankle	56
Hip - shoulder - elbow	R = 133; L = 113
R knee – hip – L knee	160
Hip - shoulder	133
Head flexion backwards	102

Table 5
Angles (°) between individual body segments in the landing phase; R = right, L = left.

Body segment	Range between the segments
Hip – R knee – R ankle	168
R ankle – hips – L ankle	98
Hip - shoulder	136
Hip – shoulder – R & L elbow	R = 166; L = 85
Head flexion backwards	151

Table 6
CoM height (cm) in vertical counter-movement jump with fixation of the arms.

	CoM height
Attempt no.1	38.5
Attempt no.2	39.0
Attempt no.3	41.8

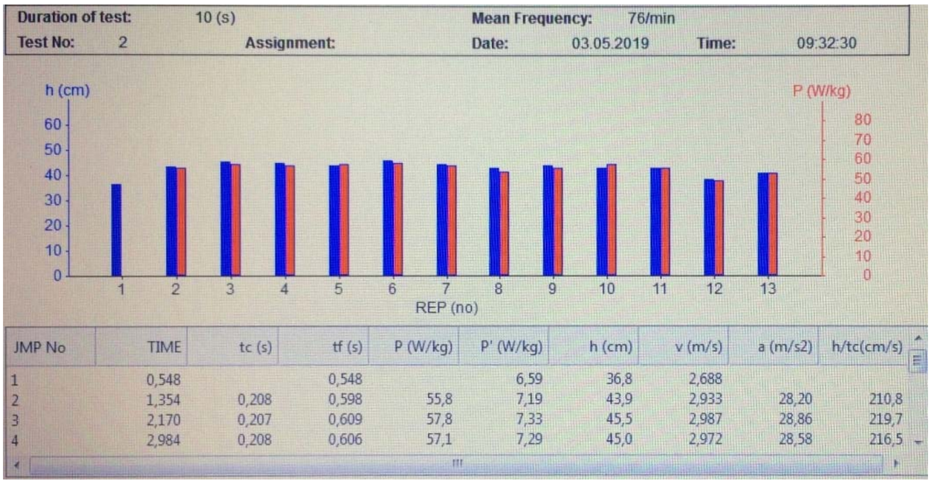


Figure 4. Record of series of 10-second repetitive vertical jumps with arms movement
■ = the height reached by the gymnast (cm); ■ = the achieved performance in the active take-off phase ($W.kg^{-1}$).

Table 7
Contact time (s), *CoM height (cm) and output* (W.kg^{-1}) *in the active phase in 10-second repetitive vertical jumps with arms movement, 3 best values.*

Contact time	CoM height	Output in the active phase
0.195	46.4	58.3
0.200	45.5	57.8
0.205	45.0	57.7

Table 8
Contact time (s), *CoM height (cm) and output* (W.kg^{-1}) *in the active phase in the stag leap with back bend of the trunk on the platform of jump ergometer (3 attempts).*

Contact time	CoM height	Output in the active phase
0.213	34.1	46.0
0.209	40.8	52.8
0.198	36.2	46.4

Explosive power measurements. Explosive power, as a combination of force and velocity, depends on how quickly the gymnast can develop maximal force within the neuromuscular system. As stated at beginning, RG belongs to the “high jump-challenging sports”. Speed in development of force is crucial to success in jumps not only in RG. High and graceful jumps are required in each gymnastic routine, independently from the use of requisite or apparatus.

The explosive power of the lower limbs were diagnosed by use of a jump ergometer with 2 standardized tests. To detect a maximal effort of the gymnast during the single jump *the vertical counter-movement jump with the fixation of the arms has been used*. Gymnast performed three attempts, with enough time for rest. The height of the CoM was measured (table 6).

The 10-second repetitive vertical jumps with arms movements provide much more information about lower limb power than a simple vertical jump test for height. As the gymnast might perform different jumps, leaps and hops during the routine, the force and rate of acceleration become major priorities.

From the series of 10-second repetitive vertical jumps with arms (Fig 4), the 3 best values of the contact time; the CoM height of the flight phase; and the output in the active take-off phase (from the first foot contact with the mat to the last foot contact with the mat) were recorded (table 7).

In addition, the explosive power of the gymnast’s lower limbs was also observed during the difficulty element. The gymnast performed three attempts of *the stag leap with back bend of the trunk on the platform of jump ergometer*. We studied the same variables as in the previous test: the contact time; height of the flight phase, e.g. CoM height; and the output in the active take-off phase (table 8).

The gymnast began to perform the element with preparatory phase, followed by 2 feet take-off “as fast and as high as possible”, so the elastic energy is used. The output in the active take-off phase together with complex coordination of the body segment play an important role in reaching the dynamic jump. As it shown in table 8, the gymnast achieved the best output value in the second attempt (52.8 W.kg^{-1}). Probably, the best output value had also impact on the highest CoM height of the jump in the same attempt (40.8 cm).

DISCUSSION

The stag position in the air, together with split and ring, is the most frequently performed in RG. Although, the difficulty value of the element observed in this study is only 0.3 point (maximum = 1.0 point), we considered this jump as one of the most demanding, due to several reasons, e.g. numbers of articulations, flexions of the body segments involved while performing the element, as well as requirements on explosiveness and flexibility regarding the perfect execution. Gymnast during take-off phase must coordinate all body segments (leg, trunk, arms and head) in order to achieve the maximum take-off. In the flight phase, at one moment, gymnast must make a maximum range in the hip joint, at least 180 ° between the lower limbs, a maximum flexion in the knee joint of the anterior lower limb and a maximum extension in the knee joint of the posterior lower limb. A maximum back bend of the trunk and head in proximity to some part of the lower limb are required. As far as the upper limbs are concerned, the most technically optimum is that the upper limb that is opposed to the anterior lower limb is raising forward and the second one is pointing towards the ankle of the posterior lower leg. This allows the gymnast to fix her shoulders symmetrically, with no technical collision (Selecká, 2019). Given all these requirements, both take-off and landing are very demanding, which requires proper coordination of all movements and strength of the abdominal muscles and back. While landing, it is important that the gymnast does not flex trunk forward or backward, but stays straight, which is not easy after the maximum back bend. Additionally, the gymnast must slow down the landing with external forces, jumps down over the toes to the semi-squat, transfer the weight of the body to the lower limb and while extending the knee, take a step forward by posterior lower limb. This will help straighten the entire body and prevent heavy landing and possible injuries. For a technically correct element, proper coordination of all movements and body parts, explosive power of lower limbs and sufficient flexibility are required.

Despite the “popularity” of the stag leap in gymnastics only few studies deal with the biomechanical characteristics of this particular difficulty element or the similar variations in rhythmic gymnastics (Cicchella, 2009; Sousa & Lebre 2010, Purenović et al., 2010; Rodríguez & Rodríguez, 2018) or other related gymnastic disciplines (Mkaouer et al., 2012; Olej et al., 2018; Kyselovičová et al., 2019). In general, studies mainly focused on the analysis of individual phases of the element, underlining the flight phase due to difficulty requirements. However, the decisive part is the take-off, in which the short, maximum muscular and voluntary effort of the gymnast is concentrated. In addition, most errors occur at take-off and are usually due to incorrect force application.

Indeed, the height of the jump or the leap depends on the depth of the semi-squat in preparatory phase just before the take-off. As it has been found in the study of Purenović et al. (2010) the semi-squat also depends on the strength of the leg flexor muscles. By increasing the depth of the semi-squat, up to the optimal value, gymnast increases the height of the jump or the leap, although excess semi-squat decreases the resulting height. Our results show the average of the knee articulations (angle between hips – knees – ankles) 126.5°. As suggested by Jastrjembskaia & Titov (1998) the optimal semi-squat depth is 112º. Variations ±20º reduce the resulting height.

The take-off sub-phase gives to the gymnast's CoM a vertical speed. As the speed is greater, it causes a greater flight’s height. According to Zemkova & Hamar (2004), the take-off in high-jump challenging athletes does not last more than 0.2 s. Therefore, the power an athlete is able to develop in a relatively short time is decisive. Our gymnast also fluctuated around this value, reaching the best contact time 0.195 s in *take-off phase of stag leap with back bend of the trunk* and 0.198 s in 10-second repetitive vertical jumps with arms movement.

Similar results are also found in the study by Cagno et al. (2008). The authors analysed the length of contact time of the feet with the mat at the Optojump and the length of the flight phase of the Italian gymnasts during the *split leap with the trunk bended backwards.* The results of contact time show an average of 0.200 ± 0.01 s, which is comparable to our findings, when the gymnast in all three attempts of particular difficulty element shows contact times 0.213 s, 0.209 s and 0.198 s, respectively. The Italian gymnast's average length of the flight phase (0.500 ± 0.01 s) is exactly the identical as of the Slovakian gymnast (0.500 s).

The most comparable results are found in the study of Purenović et. al. (2010) who followed a similar element (*split leap with the trunk bended backward, and one leg implied in the take-off, after the running*). Due to fact that in our research we only investigated the temporal variables of the CoM, we can only compare the duration of the flight phase. The obtained research results showed the longer duration of the flight phase (0.57 s) to the values achieved in this study (0.50 s).

Logically, greater flight time gives a greater opportunity for the gymnast to establish required form of the body during the flight phase. During this phase, a gymnast reaches a necessary shape at first, and then prepares for landing. Duration of the shape depends on the duration of the flight and the time taken to reach the shape evaluated by judges. The time to reach the form can only be reduced by increasing the velocity of the center of mass at the take-off (Jastrjembskaia & Titov, 1998).

Vertical potential of rhythmic gymnasts has been measured also by Gateva (2014). The findings showed the average jump height of Bulgarian gymnasts 37.4 ± 4.2 cm, with maximum 53.0 cm and minimum 32.0 cm. Our gymnast´s values show similarity, with the average jump height 39.7 cm, calculated from 3 attempts in vertical counter-movement jump with the fixation of the arms.

CONCLUSIONS

Biomechanical considerations as reflected in correct or incorrect technique, particularly in RG as well as others gymnastic disciplines are more than undoubted. This case study focused on kinematic analysis of the Stag leap with back bend of the trunk, and simultaneously on the explosive power of lower limbs regarding this particular RG difficulty element. In the study biomechanical analyse was presented on basis of the results of one subject. Although the gymnast was a top level she didn´t meet the minimum FIG requirement for the recognition of the element value (the range between legs of at least 180°), and reached only160°. On the other hand, CoM height in the flight phase has been considered as "above average" (40.8 cm), and had an impact on the correct overall execution (e.g. symmetrical shoulder position, maximum knee flexion of the anterior leg and maximum knee extension of the posterior leg). We assume that the CoM height in the flight phase of gymnast was positively influenced by her output in the active take-off phase (52.8 $W.kg^{-1}$) mostly. Based on the results of kinematic 3D analysis and diagnostics of the explosive force of the lower limbs, we especially recommend to include plyometric exercises to the training 3 times per week and combine them with the coordination exercises that correspond to physical activity in specific jumps of RG, as they focus on active reflection and the use of elastic energy.

Despite the limitation of this study (e.g. one gymnast only, which caused not enough measurements for the statistical analyse) we can conclude that the evaluation of the kinematic characteristics by 3D analysis is a very exceptional way to identify the errors in the execution of the specific difficulty element, as well as the key phases. Additionally, our finding demonstrates the significance of the explosive power of the lower limbs in rhythmic gymnastics. This information could help in practice to design and organise specific training, to evaluate the training stimuli with the aim to minimize errors and maximize effectiveness. However, to understand this issue better, it is necessary to conduct the studies with a wider sample of top-level rhythmic gymnasts preferably within the competition conditions.

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KINETIC AND KINEMATIC ANALYSIS OF THREE DIFFERENT EXECUTION MODES OF STAG LEAP WITH AND WITHOUT THROW- CATCH BALL IN RHYTHMIC GYMNASTICS

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Original article

Abstract

Visual analysis of rhythmic gymnastics shows that the greatest difficulty lies in jumps. Performing jump with optimal speed, great amplitude, and better coordination and without any mistakes, does not depend only on the gymnast's capacity but also on the apparatus used, the jump made and the applied momentum. The objective was to study the qualities of strength, speed and flexibility developed during the three execution modes of stag leap with ring with and without throw-catch ball. Seven gymnasts from the national rhythmic gymnastics team aged between 15 to 21 years participated in this study. The protocol in making three stag leaps with rings consist of the following: the first without apparatus, the second with throwing ball during the chasse step, and the third with throwing ball at the time of pulse during stag leap with ring. The basic descriptive parameters and statistical significance of differences were determined by using the SPSS 20.0, statistical program for data processing. The results show a significant variation at p <0.05 in the execution factors when introducing apparatus such as, horizontal and vertical velocity, right knee angle, force, horizontal displacement of toe, the angular momentum of the centre of mass and angular velocity of right leg. This decrease differs according to the moment of throwing the ball. In conclusion, we can argue that introducing ball during the chasse step causes a change in the basic performance factors.

Keywords: *kinetic, kinematic, stag leap, chasse step, throw-catch ball.*

INTRODUCTION

Rhythmic gymnastics (GR) is an exclusively female Olympic sport that involves performing exercises with musical accompaniment. When a gymnast performs her competition routine, she coordinates her body movement with handling an apparatus, such as ball, hoops, ropes, ribbons and clubs (Sierra-Palmeiro, Bobo-Arce, Pérez-Ferreirós, & Fernández-Villarino, 2019), according to the code of points FIG (2017-2020) the gymnast must include only elements that can be performed safely and with high degree of aesthetic and technical proficiency. There are four difficulties components: Body Difficulty (BD), dance steps combination (S), dynamic elements with rotation (R), and apparatus difficulty (AD). BD elements are elements from the difficulty tables in the code of points FIG (2017-2020), and it is divided into three groups: leaps/jumps; balances and rotations.

According to Gantcheva, Mineva, Locquet, and Léziart (2008), gymnasts choose 34.61% BD of jump prescribed by the code of points, and it's the most globally exploited group. Polat (2018) defined RG as a high leap demanding, Hutchinson, Tremain, Christiansen, and Beitzel (1998) defined jumps as a fundamental movement that requires complex motor coordination of the upper and lower limbs, on the other hands, they have seen them an essential component in RG performance. All the difficulties of jumps/leaps must have a defined and fixed shape during the flight and height (elevation) of the jumps that is sufficient to show the corresponding shape since if the jump shape is not fixed and defined, it will not be valid, and this depends on the diverse elements; such as muscular strength, explosive power body build, muscular speed, elasticity and motor coordination (Çimen, 2012). Ttherefore, to be able to execute the jumps with this amplitude, it requires a fairly high speed of execution which needs some strength potential in order to accelerate or flourish the gymnast's own body. Also, it is necessary to achieve a level of automation and a very high gestural coordination to be able to coordinate between the jump and the work of the selected apparatus.

BD are valid when performed with a minimum of 1 fundamental apparatus technical element specific to each apparatus and/or without fundamental apparatus technical element, for the jumps they are mostly in connection with throwing apparatus, throwing is valid, if the apparatus is thrown at the beginning, during or towards the end of the difficulty, and with catch, if the apparatus is caught at the beginning during or towards the end of difficulty (FIG, 2017-2020).

Regarding the technical aspects, according to Bobo-Arce and Méndez-Rial (2013) jumps are the skills mostly studied, from where many studies analyzed several aspects of the jump. The study conducted by Purenović, Bubanj, Popović, Stanković, and Bubanj (2010) determined the difference in the certain kinematics parameters, between two types of the leap, the front split leap with the trunk bended backward and both legs implied in the takeoff after the running. Another study that evaluated the variation of execution factors, is when performing gymnastics jumps split leap with and without throw catch of the ball (Mkaouer, Amara, & Tabka, 2012). The study conducted by Miletić, Katić, and Maleš (2004) established the probable influence of the characteristic motor's ability and skill factors on the jumping/leaping performance. Another two studies conducted by (Sousa & Lebre, 1996, 1998): the first analyzed the different techniques used by the gymnast to perform two jumps: the leap jump, and the leap jump with trunk extension, and the second, analyzed the fundamental kinematic parameters and the technique used in RG to perform four different jumps. The published study of Polat (2018) examined and compared the parameters of leaps executed with two different take offs on split leap and stag leap with ring, the first take off from 1 foot and the second take off from 2 feet.

Up to date in biomechanical literature, they have compared several jumps with stretch and/or bent legs with and without apparatus, but there is no existence of any study that compared the differences between throwing during the take-off and throwing during jump.

As a result, strength, speed, flexibility and coordination have an important role on rhythmic gymnastics performance's capability. In this regard, we propose to study, in this research, the qualities of strength, speed and flexibility developed during the three modes of execution of the stag leap with ring, the first without apparatus, the second with throw-catch of ball on take-off, and the third with throw-catch of ball on jumps. We will focus primarily on the degree of deployment of the execution factors with a special attention on the quality of execution, and in order to provide athletes and coaches feedback for better choices to the technique used since they have the same values.

METHODS

Seven volunteer rhythmic gymnasts from the Tunisian senior national team (age 18.71 ± 2.69 years; height 1.67 ± 0.04 m; weight 58.43 ± 4.03 kg) (table1); (average training 20h/week) agreed to participate in this study. The subjects were in good health, without muscular, neurological or tendon injury. After being informed in advance with the procedures, methods, benefits, and possible risks of the study, each participant had to review and sign a consent form to participate in the study. The experimental protocol was performed in accordance with the Declaration of Helsinki for human experimentation (Carlson, Boyd, & Webb, 2004) and was approved by the local Ethical Committee.

The kinetic and kinematic study was performed at the Higher Institute of Sport and Physical Education of Ksar-Saïd (ISSEP Ksar Said), on an evolution mat wherein is integrated a force plate (Kistler Quattro Jump, type: 9290AD, ref. 2822A1-1, sampling frequency 500 Hz). It is a two-dimension "2D" study based on a reference (ox; oy). The stag leap with ring sequences were recorded using two cameras (50 Hz; Sony DCR-PC108E Mini DV, 1 million pixels CCD and Shutter speed, 1/4000th of a second) with wide conversion lens (0.6x; 45.5 by 29 mm). Body markers using the Hanavan model (Hanavan, 1964) modified by De Leva (1996) were digitized using the video-based data analysis system SkillSpector® 1.3.2 (Brønd, 2009) (Odense SØ – Denmark) with quantic-spline data filtering. The body segments' centres of mass (COM) were computed using the de Leva (1996) model. The video acquisition is accomplished through the FireWire bus (iLink / IEEE 1394), in full frame without compression. The construction of key positions and 3D kinogramme is developed by Curious Labs, Inc. Poser® Software 4.0.3 (Figure 1).

The gymnast is placed on the mat in front of the two cameras, one facing 5 m from the mat and the other in profile 3 m from the axis of movement. The gymnast wears 20 reflective markers glued to her body; she performs a momentum in the form of chasse step (Figure 2) while trying to be placed on force plate during the impulse to perform the stag leap with ring.

Before the event, each gymnast performs the jump 3 times trying to calibrate its evolution to make the jump on force plate. It is a dual kinematic and dynamic approach, carried out over 3 days from 14 to 16 o'clock. The video acquisition is synchronized with the force platform through a mechanical system. Each gymnast, after a free warm-up of 15 min, is called to make three different jumps: arm straight (a) Chasse Step + Stag Leap with ring Without Ball (CS SL WB): The gymnast standing up, the body straight, feet tight on the half-point. She makes a chasse step followed by an elevation of the free leg flexed forward with attachment of the thigh to the horizontal, this action is followed by an elevation of the back leg support in ring and also with a good fixing of the shape in order to achieve a stag leap with ring (Figure 2); (b) Throw the Ball during the Chasse Step + Stag Leap with ring (TB CS SL): the gymnast standing up with a ball in her hand, the body straight, feet tight on the half-point, she swings her hand backwards to take the momentum of throw, she throws the ball during the chasse step with arm straight and catches it during the stag leap with ring without making technical mistakes (Figure 3); (c) Chasse Step + Throwing Ball during the Stag Leap with ring (CS TB SL): the gymnast standing up with a ball in her hand, the body straight, feet tight on the half-point, She takes a chasse step with swinging her arms backwards to throw the ball during the stag leap with ring with arm straight and catches it during reception without making technical mistakes (Figure 4).

Table 1
Descriptive statistics of anthropometric measurements.

	Min	Max	Mean	SD
Weight (kg)	54	65	58.43	4.03
Height (m)	1.62	1.74	1.67	0.04
Age	16	21	18.86	2.03
Years of practice	11	15	12.14	1.95

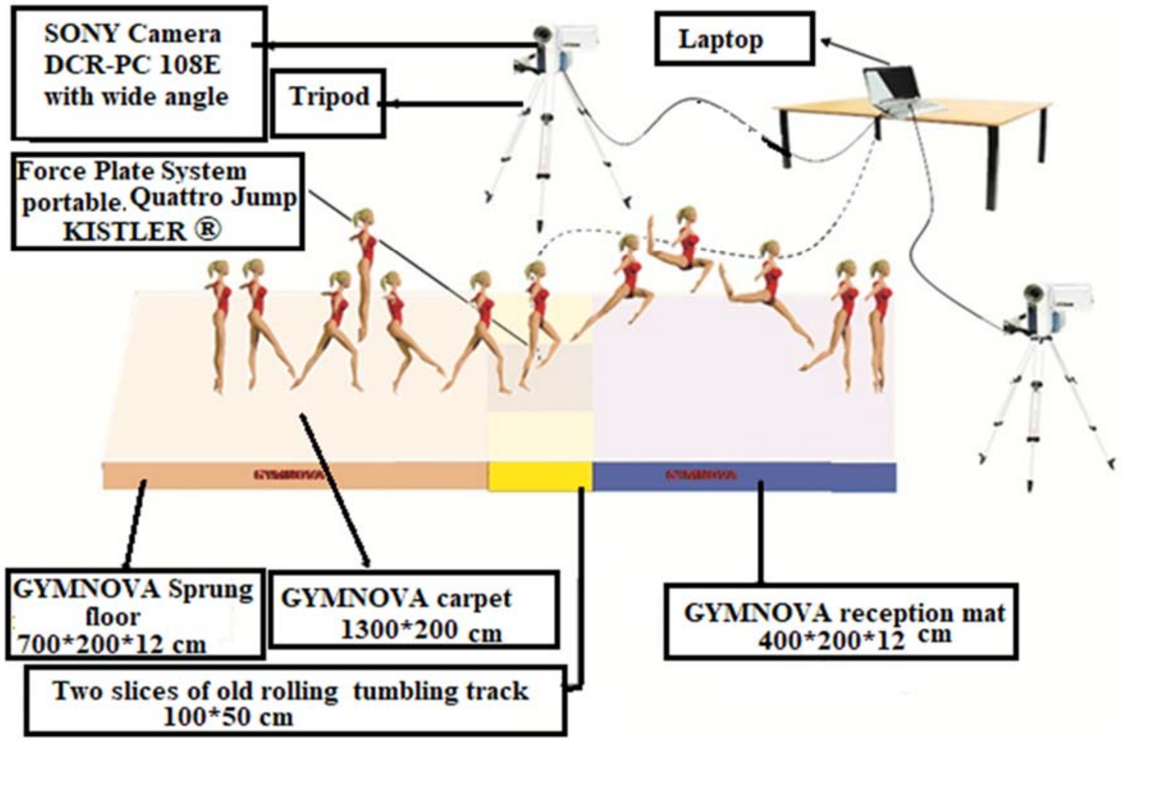

Figure 1. Experimental device.

Figure 2. Chasse step stag leap with ring without throw-catch of the ball.

Figure 3. Throwing ball during the chasse step.

Figure 4. Throwing ball during the stag leap with ring.

A	B	C
B	C	A
C	A	B

Figure 5. Randomized protocol, Latin Square (Zar, 1984).

Each jump is performed three times [randomized protocol, Latin Square Zar (1984), (Figure 3)], with a recovery of 2 minutes between repetitions. Two international judges evaluate the exercises, based on the code of point FIG (2017-2020). The best evolution of each gymnast was chosen for the comparative study.

Data are reported as mean ± standard deviation (SD). Effect size (*dz*) was calculated using GPower^{TM} software [Bonn FRG, Bonn University, Department of Psychology (Erdfelder, Buchner, Faul, & Brandt, 2004)]. The following scale was used for the interpretation of dz: < 0.2, [trivial]; 0.2<0.6, [small]; 0.6<1.2, [moderate]; 1.2<2.0, [large]; and >2.0, [very large] (Scanlan, Dascombe, & Reaburn, 2012). The normality of distribution estimated by the Kolmogorov-Smirnov test was acceptable for all variables. Therefore, ANOVA with repeated measures was applied to compare different stag leap with ring, Bonferroni test was applied to pair wise comparisons. The results were considered significantly different when the probability was less than or equal to 0.05 ($p \leq 0.05$). Statistical analyses were performed using the software package SPSS version 20.0 [SPSS, Chicago, IL, USA].

RESULTS

The results are considered significantly different when the probability is less or equal to $p \leq 0.05$, performance factors when the stag leap with ring is executed without apparatus (CS SL WB) ware significantly different from those when stag leap with ring is executed with throw-catch of the ball on the chasse step (TB CS SL) or on the stag leap with ring (CS TB SL) (table 2).

Table 2 shows the univariate analysis of CS SL WB, TB CS SL and CS TB SL. These were compared between the three modes and presented in table 3.

Bonferroni post hoc test demonstrated that the three modes had different effect on the execution factors of the stag leap. The horizontal velocity of the COM (Vx_{COM}) decreased when throwing ball on the chasse step (CS SL WB Δ TB CS SL = 17.25 % with $p \leq 0.05$). On the other hand, the vertical velocity of the COM (Vy_{COM}) decreased when throwing ball on the stag leap (CS SL WB Δ CS TB SL = 13.27 % with $p \leq 0.05$).

Indeed, we noticed a drop of the angular momentum of the COM (Ma_{COM}) when throwing ball on the chasse step (CS SL WB Δ TB CS SL = -82.56% with $p \leq 0.05$).

Alternatively, the horizontal displacement of the COM (dx_{COM}) decreased when throwing ball on the chasse step and also on the stag leap with ring (CS SL WB Δ TB CS SL = 25.19 % with $p \leq 0.05$ and CS SL WB Δ CS TB SL = 19.66 % with $p \leq 0.05$).

Similarly, the horizontal displacement of the toe (dx_{toe}) decreased during the two techniques with throw−catch of ball (CS SL WB Δ TB CS SL = 18.83 % with $p \leq 0.05$ and CS SL WB Δ CS TB SL = 1.42 % with $p \leq 0.05$).

Table 2
ANOVA repeated measure. Univariate analysis of three modes execution of the stag leap with ring.

	df	Mean Square	D	Sig.	Effect Size (*dz*)	Power
COM Horizontal Velocity Vx_{COM} (m/s)	2	0.177	4.980	0.027	1.823	0.700
COM Vertical Velocity Vy_{COM} (m/s)	1.061	0.422	7.351	0.032	2.215	0.642

COM Horizontal Displacement dx_{COM} (m)	2	0.074	10.011	0.003	2.582	0.948
Horizontal Displacement of toe dx_{toe} (m)	2	0.085	8.966	0.004	2.444	0.923
COM Angular Momentum Ma_{COM} (kgm²/s)	2	93905.086	4.763	0.030	1.783	0.679

Table 3
Post Hoc comparative study between the three modes of stag leap with ring execution.

		Mean ± SD	Mean Difference	Standard Error	Sig.	Effect Size (*dz*)
Vx_{COM} (m/s)	CS SL WB vs TB CS SL	1.837 ± 0.126 1.520 ± 0.224	0.317	0.088	0.034	3.602
Vy_{COM} (m/s)	CS SL WB vs CS TB SL	2.449 ± 0.209 2.124 ± 0.237	0.326	0.034	0.000	9.588
Ma_{COM} (kgm²/s)	CS SL WB vs TB CS SL	-41.767 ± 84.171 -239.509 ± 194.205	197.742	58.743	0.045	3.366
dx_{COM} (m)	CS SL WB vs TB CS SL	0.778 ± 0.142 0.582 ± 0.184	0.195	0.042	0.011	0.464
	CS SL WB vs CS TB SL	0.778 ± 0.142 0.625 ± 0.117	0.152	0.043	0.035	0.353
dx_{toe} (m)	CS SL WB vs TB CS SL	1.051± 0.187 0.853 ± 0.166	0.199	0.051	0.025	3.901
	CS SL WB vs CS TB SL	1.051± 0.187 1.036 ± 0.114	-0.183	0.054	0.045	0.294

(COM) Centre of mass; (Vx) Horizontal Velocity; (Vy) Vertical Velocity;(Ma) Angular Momentum; (dx) Horizontal Displacement; (dx toe) Horizontal Displacement of the toe; (CS SL WB) chasse step and stag leap without ball;(TB CS SL) Throw the ball during the chasse step and stag leap with ring; (CS TB SL) chasse step and throwing ball during the stag leap with ring.

DISCUSSION

The purpose of the present study was not only to examine the effect of introducing ball on the execution factors of stag leap with ring, but also to study which of the two techniques with apparatus allows a perfect execution of the jump, form where, kinetic and kinematic analysis show a difference in the degree of deployment of qualities speed and of displacement of the COM.

Vertical velocity achieved by our gymnasts shows a significant difference between the technique without ball and with throwing ball during the stag leap with ring with a favour to the technique without apparatus. This drop can be explained by blocking the arms actions during the jump with throwing (CS TB SL). According to Rutkowska-Kucharska (1998) the arm swing caused a statistically increase in height in all kinds of jumps and since the amplitudes of displacement of the COM are on average more important at fast speed than at slow speed (Grandjean, Paparemborde, & Baron, 1985). Therefore, there is a positive correlation between the height (i.e., vertical displacement) and the vertical speed. This means that to have a higher vertical speed it is necessary to add the arms swinging from where the fall of the speed during the blocking of the arms on the techniques of throwing the ball during the jump. Since, this jump is realized with two legs flexes which requires better attention, while without apparatus, gymnast performs an asymmetrical movement of the arms to adjust her posture which increase the vertical velocity. This is different to the work of Mkaouer et al. (2012) who determined a significant difference but with a favour to the jump with throw-catch of ball, who explained this raise by the arm action when throwing while the speed of slit of the legs, since this jump is realized with two legs stretched, which explains the difference between two jumps. Also, stag leap with ring and split leap differs greatly in their biomechanical model, the first is mainly vertical jump while the second is a horizontal leap. According to these results, the vertical speed of LB CS SL is better than CS TB SL, which can be explained by the fact that in the first technique the gymnast has the free hand so she can swing her arms, in accordance to Feltner, Bishop, and Perez (2004) and Harman, Rosenstein, Frykman, and Rosenstein (1990) which showed that vertical jump was significantly larger in the arm swing jumps compared to the no arm swing jumps and was due to a larger vertical velocity of the COM.

In addition, horizontal velocity shows also a significant difference between CS SL WB, with a drop when throwing ball, which conformed by the work of Mkaouer et al. (2012). This decrease can be explained by the fact that the gymnast throws the apparatus during the chasse step where it is necessary to adjust its position to be able to catch ball without execution errors. The tested gymnasts developed a horizontal velocity fairly low compared to the stag leap, this difference can be explained by the type of jump made since the split leap according to Sousa and Lebre (1998), is classified among the jump that have a high horizontal speed, while the stag leap with ring is classified among the jumps that have a low horizontal velocity.

This decrease can be explained by the blocking of the arms action during the jump with apparatus. Without apparatus, the gymnast performs an asymmetrical movement of the arms to accelerate, while with a throw of the ball and especially when the apparatus is thrown during the jump. The gymnast cannot perform this movement to ensure the gesture with a good height and correct direction.

The horizontal displacement of the toe (dx_{toe}) and COM (dx_{COM}) from the beginning to the end of the jump shows a significant difference between CS SL WB versus TB CS SL and between TB CS SL versus CS TB SL, almost similar to that found by Sousa and Lebre (1998) during a single stag leap with ring. In this respect, the analysis of the obtained results allows us to notice that the technique without apparatus (i.e., CS SL WB) make a greater horizontal displacement than those with ball (i.e., TB CS SL and CS TB SL), which can be explained by the introduction of a second task “throw / catch” of the ball, since the gymnast in these two techniques will adjust her body position to catch the apparatus, knowing that she does not have the right to realize an additional steps for catching ball. That's why we find a decrease in the distance travelled during the two techniques with apparatus.

Angular momentum of the COM (Ma_{COM}) shows also a significant difference between CS SL WB versus TB CS SL (Ma_{COM} = -41,767 Vs -239,509 kgm²/s respectively). This decline according to Pascal (2003), can be explained by the fact that the kinetic moment can only be changed if a new external force is applied on the body; in other words, only the phases where we are in contact with the ground or tackle allow us to maintain or change the kinetic moment of the body. This notion is fundamental since the drop was introduced when the ball is thrown during the chasse step so the gymnast must bring her arm forward to catch the ball instead of placing it next to her ear.

CONCLUSIONS

The results of this study have shown that the technique without apparatus (CS SL WB) is the best compared to the two other techniques in economy of effort, particularly in terms of vertical and horizontal velocity, horizontal displacement of the toe and of the COM and of the angular momentum of the COM in regards to the technique with apparatus, the values undergo a decrease which differs according to the moment of throwing of the ball, "to throw during the chasse step (TB CS SL) or to throw during the jump (CS TB SL)". The results showed that the technique with throw during the jump (CS TB SL) proves the best technique compared to the first one (TB CS SL) allowing a better vertical velocity (Vy_{COM}) and an optimal horizontal displacement of toe and COM. In addition, the TB CS SL has only the best horizontal velocity (Vx_{COM}) and angular moment of COM (Ma_{COM}).

In conclusion, we can argue that the technique with throwing ball during the jump (CS TB SL) is the best technique to have a stag leap with ring jump with optimal performance factors.

In light of the results of this study, it is recommended for coaches and gymnasts to work on this technique at the beginning without ball, in order to improve it, and on the exercise they should choose the technique with throwing during the jumps since they have the same value according to the code of points (FIG, 2017-2020).

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A MULTI-BODY MODEL OF A SPRINGBOARD IN GYMNASTICS

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Case study

Abstract
In order to develop and optimize movements in gymnastics vault, knowledge of take-off velocity and angular momentum is important. Due to the short times of contact on the springboard, high-frequency kinemetric methods are very time-consuming for the determination of the take-off parameters. A multi-body model of a springboard was developed to determine the take-off forces to calculate specific take-off parameters. The Gymnova springboard was modeled using the simulation environment software alaska. The evaluation under dynamic conditions was carried out with a falling mass test, drop-jumps and forward handspring. The evaluation was done on the parameters of the ground reaction forces (GRF): force impact (p) and maximum vertical force (F_{max}). For the drop-jump and forward handspring simulation the real measured acceleration of the upper board was given as input parameter in the model. When comparing the vertical displacement of the real and the modelled upper board, a discrepancy of 6.1 % can be observed. For the falling mass test differences for p=0.4 % and F_{max}=28.2 % were achieved between the real board and the model. For typical loads for the gymnastics sport, drop-jumps have been used. There were realized differences of up to 8.4 % for F_{max} and 6.8 % for p. For the final stage of the review, forward handstand vaults were examined. Horizontal and vertical forces were investigated. Through thorough evaluation on several stages, it was possible to develop a springboard model that is suitable to calculate the GRF under dynamic conditions successfully in 2-d. Therefore, the forces acting on the take-off position can be calculated. Take-off parameters can be determined from these forces. This evaluation also shows that the horizontal forces in especial have to be observed.

Keywords: *artistic gymnastic, springboard, modeling, vault.*

INTRODUCTION

Kinematic methods have been used to determine the specific parameters in gymnastics vault in the past. There the main focus was on the phase of table contact and the phase of flight after table take-off (Chen, Yu, & Cheng, 2009; Dainis, 1979; Yeadon, Jackson, & Hiley, 2014). Due to the short duration of the springboard phase, analyses were highly demanding and therefore difficult to get, so that there were a few individual studies published so far (Sano, Ikegami, Nunome, Apriantono, & Sakurai, 2007). Investigations with 50 Hz video by Farana and colleagues, show that forward vaults of the Kasamatsu (Handspring with 1/4 or 1/2 turn in the flight phase after board take-off) category result in contact times of 0.11 s (±0.02 s) . Due to the short contact time with the athlete on the springboard, a high frequency video was primarily used to calculate take off parameters (Chen et al., 2009; Coventry, Sands, & Smith, 2006). The application of three-dimensional kinematics in conjunction with marker placement or manual digitizing can be very time consuming and therefore inefficient for both, the coaches and the athletes. Furthermore, immediate feedback is missing.

There was a study by Čuk, I., Penic, S., Supej, M., & Križaj, D., (2011) in which the authors have developed a miniature accelerometer to analyse the take-off phase from the board. With this application it was possible to determine the board contact time and the take-off velocity.

In order to determine the acting board forces, a model describing the dynamic characteristics of the springboard will be used. With these forces and properly reduced kinematics, the angular momentum and the take-off velocity can be calculated.

There were already studies that have employed calculation of forces on the springboard. In most cases, the forces under the board were measured and resulting upper board forces were calculated by means of a mathematical model (Čuk, I., Penic, S., Supej, M., & Križaj, D., 2011; Greenwood & Newton, 1996; Sands, Smith, & Piacentini, 2006; Sano et al., 2007). As a result, the authors did not measure the forces that directly affect the athletes on the upper springboard.

For the evaluation of a mathematical model of the springboard, Hao and colleagues chose a static and a dynamic stage (Hao, Wu, Wang, Xiao, & Wan, 2013). In the static stage, the springboard was loaded with known weights and the vertical displacement of the upper board was measured. The displacement of the upper board was used as a comparison for the calculated displacement of the model (Hao et al., 2013). For evaluation of the dynamic properties of the model, they performed drop-jumps and compared the ground reaction forces with a simulated drop-jump in the virtual human modeling and simulation software MSC Adams/LifeMod (Company: LifeModeler, Inc., California, USA).

In all the studies, it was not possible to calculate forces on the upper board which are necessary for the determination of specific take-off parameters (velocity or angular momentum).

The aim of this article was to introduce a model of a springboard and the evaluation of this model under dynamic conditions. First, the development of the model in an iterative process will be shown. Then the dynamic evaluation will be performed by three methods, comparing experimental and simulated data, respectively. In a first step, defined force impacts (equivalent to impulse) were evoked by means of a falling mass test. This falling mass test was based on the standard test procedure for gymnastics equipment of the International Gymnastics Federation. This procedure determines the weight of the falling mass and the drop of height. Furthermore, impact surface, rebound and deflection of the falling mass were defined (Fédération Internationale de Gymnastique, 2006, p. 38). In the second method, test persons performed drop-jumps to realize typical vertical force impacts on the board. Furthermore Motoshima, Kitagawa, and Maeda (2015) had shown in a study that there was a correlation between the Kasamatsu vault and the performance at the drop-jump. Finally, in the last step, a forwards handspring created skill-specific loads.

METHODS

The modeling of the springboard was based on the approach (equation 1) derived by Sano (Sano et al., 2007). This model was built on the following approach: The board

reaction force (BRF) was composed of three main forces, these were:
1) Differences between the effective force below the springboard and ground reaction force (GRF)
2) Less the weight force of the board (m·g) (net weight of the board) and
3) The sum of the forces accelerating the upper boards segments ($m_{Segm} \cdot a_{Segm}$).
$BRF = GRF - m \cdot g - \sum m_{Segm} \cdot a_{Segm}$

The Olympic Gymnova springboard, used in 2012, was modelled using the interactive simulation environment software alaska developed by Institute of Mechatronics, Germany (Institute of Mechatronics, 2014). The model was created based on geometric bodies, technical fixed and revolute joints as well as force elements. The springboard model (Fig 1) consists of an upper board divided into twelve segments. Each segment was linked to its neighbour via revolute joints and torque springs. The typical board curvature was realized by approximated angles at initial conditions. The springs between the lower and upper board were modelled by one-dimensional single force elements. While, the lower frame of the springboard was made of steel and consists of five rigid parts. The board model was coupled to the environment via contact elements with corresponding stiffness parameters (Lehmann et al., 2015; Lehmann, Schleichardt, Naundorf, & Knoll, 2017). The physical input parameters (spring stiffness, modulus of elasticity and rotational stiffness of the torque springs between the segments) were determined experimentally from static experiments.

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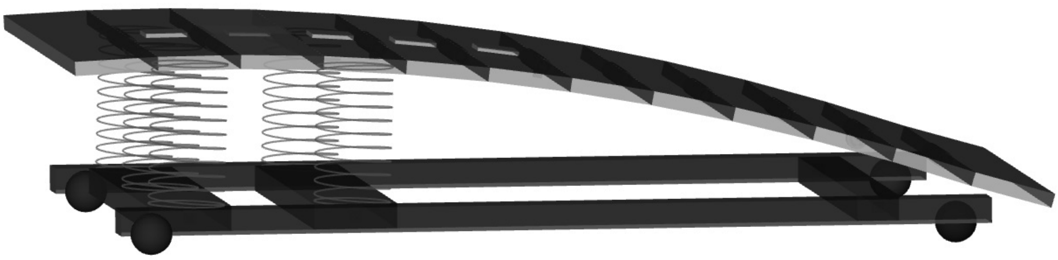

Figure 1. Model of the Gymnova springboard (Lehmann, 2018).

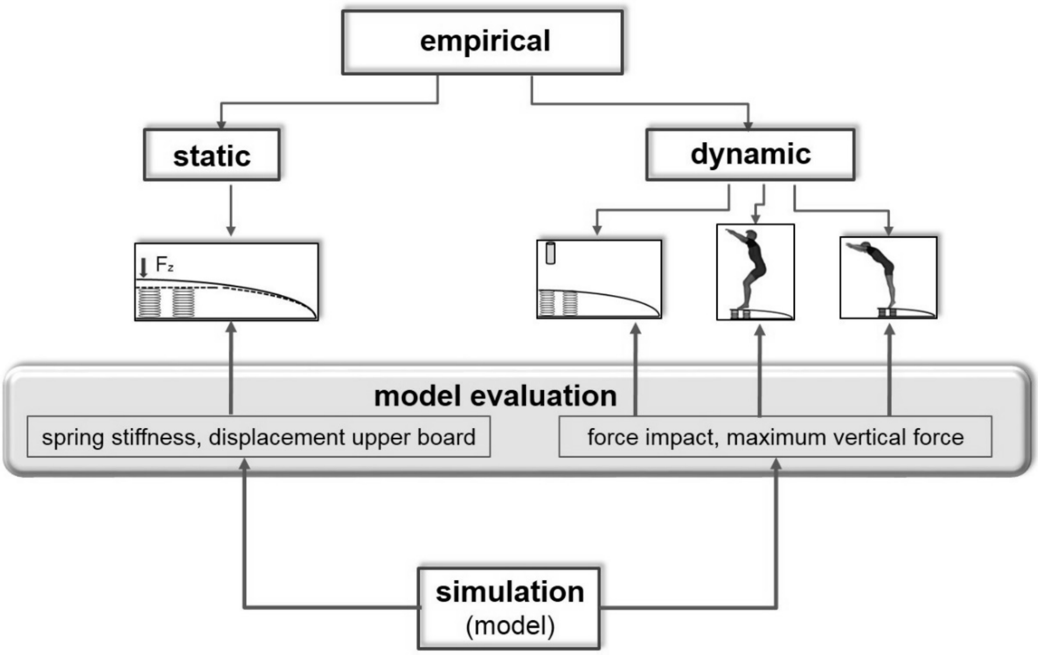

Figure 2. Stages of the model evaluation.

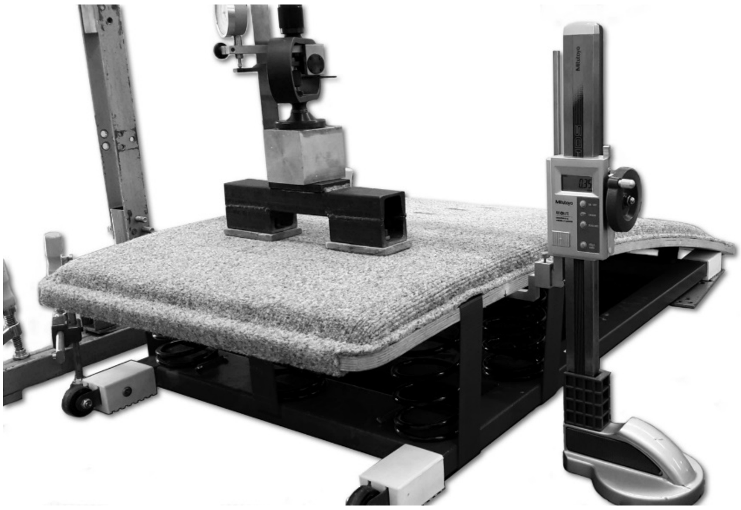

Figure 3. Testsetup for the determination of the vertical displacement (Lehmann et al., 2017).

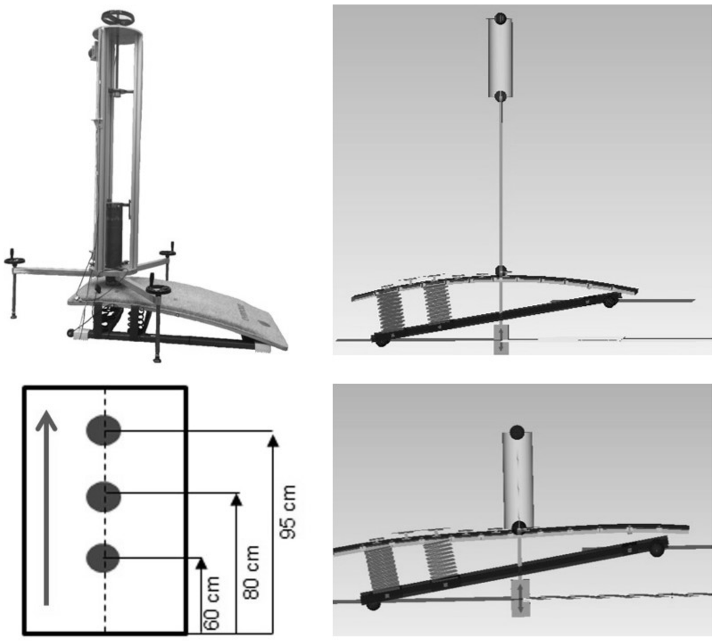

Figure 4. Measuring equipment; Measuring positions with jump direction [arrow] used for standard dynamic test (left), Simulation of the falling mass for MP60 (up: simulation in initial position, down: contact between falling mass and springboard and resulting board deformation, inclined board for vertical impulse generation [MP60: 7.6 °, MP80: 3.1 °]) (Lehmann et al., 2016).

Using the four methods of evaluation (Fig 2), the springboard model parameters were adjusted by method of a standardized static load and typical sport-dynamic loads.

First stage – Static experiments. The static evaluation of the modelled springboard was conducted using the main take-off positions as point of load attack (Coventry et al., 2006). For this purpose, a test apparatus was used which detected the vertical displacement of the upper board of statically transmitted forces. The forces were determined with a calibrated force-measuring device on the upper board. This device consisted of a calibrated mechanical force measuring yoke with dial gauge and a digital height gauge to detect the vertical displacement of the upper board (Fig 3).

With this setup, forces were gradually transferred from 0.4 to 3.6 kN (stepping up, step 0.4 kN) at measuring points (0.6 m, 0.8 m, 0.95 m) measured from the fore edge (Lehmann et al., 2017).

Second stage – Falling mass. For the dynamic comparison between the model and the springboard, it was necessary that defined force impacts were applied to the springboard while the ground reaction forces (GRF) were measured. As it was desired to drop a certain mass vertically from a predefined height, equipment was used according to the guidelines of the International Federation of Gymnastics (Fédération Internationale de Gymnastique, 2006).

For the experimental investigations, three tests were performed (Fig 4) on certain measuring points (MP). The MP were oriented at the main take-off positions (0.6 m [MP60]; 0.8 m [MP80], forward and 0.95 m [MP95], backward vaults). A mass (20.3 kg) was dropped from the height of 0.8 m onto the board. In order to determine the GRF, the springboard was placed on two force plates (0.4 x 0.6 m, 1000 Hz; AMTI Watertown, USA). The springboard was then inclined, depending on the impact point (MP60: 7.6 °, MP80: 3.1 °), in order to make the force impact act perpendicularly to the upper board. Three-dimensional GRF were recorded (1000 Hz). The detected force-time curves were then smoothed for further evaluation with cubic splines. The maximum vertical force (F_{max}) and the force impact (p) were calculated.

For the falling mass simulations, a cylindrical body was added to the springboard model. The falling mass (20.3 kg) dropped from 0.8 m under the affect of gravity onto the model (Fig 4). This ensures that a defined impulse was generated perpendicularly on the springboard. Ground contact elements were used to calculate the vertical GRF.

Third stage – Drop-Jump. For the dynamic evaluation of the model under standardized sport-specific conditions, an athlete (age: 23, mass: 75.4 kg, height: 1.8 m) performed three drop-jumps (DJ) from a gymnastics stool (height: 0.4 m). Ground reaction forces were recorded by means of two force plates (1000 Hz, AMTI Watertown, USA). Three acceleration sensors (he 333 AD 50 g, Hermann Elektronik, Germany) detected the acceleration of the upper board. These were placed in the middle of the upper board (bottom) at the positions MP95, MP80 and MP60.

For the rheonomic condition simulation, the information of the vertical movement of the upper board was calculated from the measured accelerations by two-fold integration over the duration of the contact time. The vertical movement was then applied to the model at locations of MP. The comparison between the model and the real board was carried out for the parameters F_{max} and p.

Fourth stage – Forward Handspring. A forward handspring was chosen for model evaluation under sport-specific loads. In addition to the vertical GRF, it was of fundamental importance to also calculate the horizontal GRF. A gymnast (age: 23, mass: 75.4 kg, height: 1.8 m) performed at one's own discretion three vaults over a vaulting table (height: 1.35 m). The movement of the upper board on MP80 was measured by acceleration sensors (he 333

AD 50 g, Hermann Elektronik, Germany), the GRF was recorded by two force plates (1000 Hz, AMTI Watertown, USA), as described above. The simulation of the board´s dynamic behavior in forward handsprings was carried out by means of a rheonomic condition. For this purpose, the acceleration signal of the MP80 was converted to a time series of the upper board´s displacement by two-fold integration and made available for the alaska simulation. The simulation started from the first board contact of the athlete to the take-off from the springboard. The horizontal forces were simulated by means of an extra horizontal viscoelastic-damping element between the environment and the springboard frame. Thus, the calculated horizontal forces can be thought of as quasi frictional forces. The mechanical properties of this element were determined by fitting with the experimental data. The comparison between experimental data and simulation data was likewise based on the GRF, i.e., F_{max} and p.

RESULTS

Static experiments. When comparing the vertical displacement of the real and the modelled upper board for the main take-off position for forward vaults, a discrepancy of 6.1 % can be observed (Lehmann et al., 2017). Keep in mind that the model was not set up to reflect static forces. In a practical application, is intended to calculate the forces of the highly dynamic board movement caused by jumps.

Falling mass. With the standardized falling mass test, GRFs were measured. Vertical force maxima F_{max} ranged between 4372 N and 7237 N for each measurement point. Impacts p were determined from 169 Ns up to 171 Ns. The simulated impulse was calculated from 161 Ns to 162 Ns and simulated F_{max} from 4355 N to 5195 N. The resulting relative differences were between 0.4 % and 28.2 %.

Drop-Jump. The evaluations of the vertical GRF of the three experimental drop-jumps (DJ) determined the maximal vertical forces up to 6369 N. The force impulses result from 571 Ns - 574 Ns. The simulated GRF F_{max} were maximal 5677 N. For the simulated vertical impulses p 612 Ns, 612 Ns and 610 Ns were calculated (Table 1). There was high correspondence between the simulated and experimentally determined force-time characteristics of the GRF. This result was also reflected in the percentage calculation of the differences of F_{max} and p. Therefore, for the three DJ the mean differences of 8.4 % for F_{max} and 6.8 % for p between the model and the real springboard have been determined (Table 1). Furthermore, in the simulated deformations, a wave-like deflection was attributed to the highly elastic upper board.

Forward Handspring. For the forward handspring (hs) it appeared that the horizontal forces accounted for to about 40 % of the vertical maximum forces. The vertical and horizontal force-time curves of the three experimental forward handsprings are shown in Fig 5 and Fig 6. The comparison between the simulated and measured vertical GRF yields differences that ranged from 0.7 % to 24.0 %, while for the horizontal forces amounts up to 66.7 % (Table 2).

DISCUSSION

Based on the concept of the mathematical model of Sano (Sano et al., 2007), a multi-body model of the Gymnova springboard was developed in the simulation software alaska. This reflects the dynamic characteristics of the springboard in the 2-d (sagittal plane). Standardized conditions were used to determine the model's parameters by means of experimental static methods. For this purpose, a comparison of the vertical displacement of the upper board was carried out (Lehmann et al., 2017). For the main take-off position, the smallest deviation (6.1 %) between model and real board could be achieved. Since the model is not intended to only reflect the static conditions, it was evaluated under dynamic conditions at three stages with falling mass tests, drop-jumps and handsprings.

By means of falling mass simulations, the model has been analyzed under standardized conditions for differences in the dynamic behavior compared to the real springboard. In this study, the vertical dynamic feedback (i.e., maximum vertical force together with the impact force) were used for analyzing the differences. A reason for the difference up to 28.6 % in the peak of force in the falling mass tests can be explained by the insufficient interaction between the springs and the dampers of the whole model, including the soft surface layer. Hence, the values of the experiment were achieved almost without deviation, especially at the most compliant measuring point (MP95).

Table 1
Experimental and simulated vertical maximal force (F_{max}) and force impulse (p) and differences for three drop-jumps (dj).

		dj 1	dj 2	dj 3	mean (SD)
experimental	F_{max} [N]	5962	6369	5680	
	p [Ns]	573	571	574	
simulated	F_{max} [N]	5297	5677	5309	
	p [Ns]	612	612	610	
difference	F_{max} [%]	11.2	7.4	6.5	8.4 (2.5)
	p [%]	6.8	7.2	6.5	6.8 (0.4)

Table 2
Experimental and simulated horizontal and vertical maximal force (F_{max}) and force impulse (p) and differences for handspring (hs).

		vertical			horizontal		
		hs 1	hs 2	hs 3	hs 1	hs 2	hs 3
experimental	F_{max} [N]	7784	7522	8821	2693	3271	2988
	p [Ns]	532	520	522	177	179	164
simulated	F_{max} [N]	7729	8311	8127	2151	3589	2735
	p [Ns]	515	395	416	59	231	167
difference	F_{max} [%]	0.7	10.5	7.9	20.1	-9.7	8.5
	p [%]	3.2	24.0	20.3	66.7	-29.1	-1.8

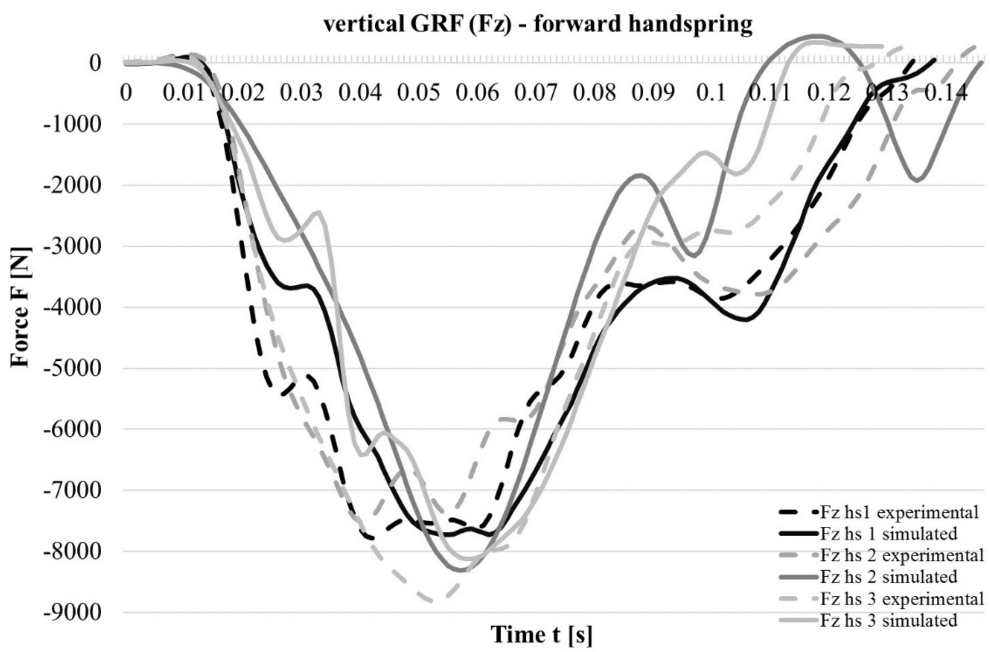

Figure 5. Comparison of simulated and experimentally determined vertical GRF of forward handsprings (hs).

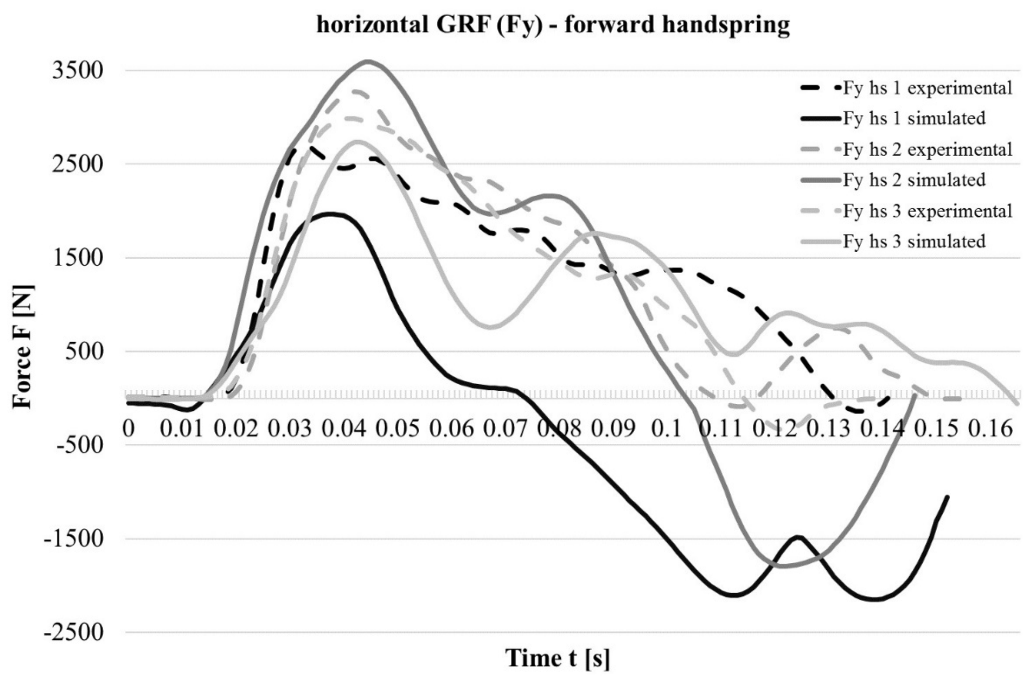

Figure 6. Comparison of simulated and experimentally determined horizontal GRF of forward handsprings (hs).

Sport-specific force impacts were generated in the vertical direction by performing three drop-jumps. For this purpose, the vertical upper-board movement was detected by 3-d acceleration sensors. The recorded data were two-fold integrated during the period of contact between the board and athlete. The calculated board position was transferred to alaska for rheonom condition simulations of drop-jumps. Considering the overall mean percent deviations, differences up to 8.4 % were shown for the vertical dynamic behavior of the board. Hao et al. also used the drop-jump for validation of a mathematic Gymnova springboard model. Hao founded acceptable differences between measured and calculated GRF and disadvantage that high-frequency video-based capturing of the boards movement takes much time (Hao et al., 2013).

The third method of model evaluation was realized by forward handsprings. The upper-board movement was also recorded by acceleration sensors and processed for the rheonomic conditioning of the model. So, the horizontal board movement and forces as well as the vertical GRF could be disclosed. The comparison between the simulated and the measured vertical and horizontal GRF showed differences. Notably, the analysis of the horizontal forces showed differences up to 66.7 %. It can be stated that for the simulation of horizontal "displacement" of the springboard, the application of a viscoelastic element was not appropriate. The force values increased necessarily according to the displacement of the board. Further investigations are required to determine the dynamic behavior (stiffness, damping, friction) between the springboard and the environment in the horizontal direction.

Small deviations (6.1 %) were achieved in the vertical displacement under static load for the main takeoff position (MP60). The resulting impulses for the falling mass tests as well as for the drop-jumps show low deviations in vertical orientation (< 7.2 %). For the handspring vaults these values rose (3.2–24.0 %), in contrast to the peak forces F_{max} showed deviations ranged between 0.7 and 10.5 % for the vertical direction. When comparing the GRF parameters in handsprings, there are still high uncertainties for the calculation of horizontal forces. These large discrepancies could be thought of as a reason for the unacceptable deviations of the vertical impulses for the handspring, as they influence the vertical dynamics indirectly (sum of torques). Further adaptations of the model will be necessary.

In the case of Yurchenko vaults, it should be noted that mainly vertical forces act on the board as in the case of drop-jumps. Due to the satisfactorily agreement of the model to the real board at the drop jump it is conceivable that high agreement of the GRF can also be achieved at Yurchenko vaults.

Another important issue is the quality of the acceleration sensors used to detect board movement. The 50 g acceleration sensors applied in this study seemed to be unsuitable because they didn't give any information about the orientation of the acceleration axes. In the future, inertial measurement units with yaw rate sensors have to be used to detect the initial axis alignment. Thus, it should be possible to generate more accurate input data for displacement control.

Finally the springboard model enables calculation of the forces acting on the athlete. Thus, for this purpose, the upper board movement is detected by acceleration sensors and processed as an input parameter for the simulation. Knowing the center of gravity (COG), entry velocity to the board, the current resulting point of force attack and the calculated vertical and horizontal forces on the upper board, the angular momentum and the take-off velocities of the board can be determined (Wank & Heger, 2009).

There are also some measuring systems (for example Xsens motion capture solution; XSENS, Netherlands) that can be used to provide the COG velocity via sensors and software-based human models. So, it is possible to calculate these take-off parameters in training process much faster than with the conventional kinematic procedures.

CONCLUSIONS

Through thorough evaluation on several stages, it was possible to develop a springboard model that is suitable to calculate the GRF under dynamic conditions successfully in 2-d. This evaluation was realized in four methods: First, in static fashion, to identify spring parameters. Second, with a falling mass in order to load the springboard with defined force impacts under laboratory conditions. The evaluation was done, comparing force-time curves of GRF between the model and the real board. Third, with drop-jumps, the focus was on sport-specific forces. The vertical board displacement was measured using acceleration sensors in order to control the models upper board displacement in simulation. And finally, fourth, with the aid of forwards handsprings, sports-specific loads with a large horizontal portion were generated. In this case, vertical and horizontal GRF were calculated and the parameters p and F_{max} were used as comparative variables, respectively. For the calculation of the vertical peak GRF, deviations of less than 11 % could be achieved. Further model optimization with respect to horizontal displacement and acting friction is necessary to increase accuracy of the horizontal and vertical GRF

In this report the model development and evaluation was presented using the example of the springboard of Gymnova (2012). The evaluation was simplified using drop jumps and handspring performed by one gymnast. The study was designed with an amateur athlete. At the time of the study, no professional athlete was available for laboratory testing. According to the training level of the gymnast and due to the safety of the laboratory conditions handsprings were performed. It was assumed that these simple jumps were sufficient to successfully test the application of the developed method in this pilot study. Since handsprings with following elements and as well as Kasamatsu and Yurchenko vaults will to be investigated in the future, the model must also be investigated and possibly adapted with regard to the transverse forces and force torque. The model will also be extended to the current types of springboards. It is also planned to include other gymnasts (male/female) in the model evaluation.

The method was developed for high-performance gymnastics. Of course, it could also be used in school, amateur sports or physical education. Due to the complexity in the application of the method, it is not recommended for using in non-performance gymnastics.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest whatsoever.

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TRAINING LOAD, RECOVERY AND INJURIES IN ELITE RHYTHMIC GYMNASTS DURING MAIN COMPETITIVE PERIODS: A CASE STUDY

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Case study

Abstract
Competitive periods are critical periods where elite rhythmic gymnasts experience higher training loads and insufficient recovery. The aim of this short report is to describe individual training load, recovery and injuries in elite group rhythmic gymnasts during competitive periods. Six gymnasts from the Brazilian senior rhythmic gymnastics group were monitored daily over a 126-day period comprising regular training and four competitions. Training load was measured using the session rating of perceived exertion (session-RPE). Daily load, chronic load, and acute:chronic workload ratio (ACWR) were assessed. The Total Quality Recovery (TQR) scale was used to monitor recovery and a 3-day rolling average (3RA) TQR was also measured. Injuries were diagnosed and reported by the medical staff and their reports were used in the analysis. Descriptive statistics were used. The gymnasts presented distinct daily load, ACWR, and recovery patterns, as well as injuries across the competitive periods. All athletes had rapid increase ("spike") in load. Three athletes were underrecovered more than 60% of the time. Four athletes sustained five injuries during the time of the study (all lower limb overuse injuries, two severe, two mild and one slight). Individual factors such as age and chronic load could moderate how each gymnast responds to training and tolerates spikes in load. Moreover, injuries sustained during competitive periods appear to affect the short and long-term careers of gymnasts, as well as impair training and competition organization of the team.

Keywords: *gymnastics, injury, ACWR, competition.*

INTRODUCTION

Rhythmic gymnastics is an aesthetic sport that demands high technical compliance, and well-developed physical and artistic capacities (Debien et al., 2020; Douda, Toubekis, Avloniti, & Tokmakidis, 2008). Group exercises are performed by five gymnasts at the same time mainly characterized by harmonic collective work (Ávila-Carvalho, Klentrou, & Lebre, 2012). The group competition format requires peak performance during one to four days. Each group presents two different routines in qualification phase and the first eight ranked groups perform these routines again at the finals. Elite groups involved in international competitions may have five or six events in one season including two or three main competitions (e.g., World Championship, Continental Games/Championship, Olympic Games).

Competitive periods in rhythmic gymnastics are associated with higher training loads, rapid increase ("spikes") in load (Debien et al., 2020), and insufficient recovery (Debien, Miloski, Timoteo, Ferezin, & Bara Filho, 2019). Spikes in load and an imbalance between load and recovery might expose the gymnasts to maladaptation and higher injury risk (Soligard et al., 2016). Moreover, injury sustained in competitive periods prevent athletes from training and performing, thereby impairing their chance of success (Drew, Raysmith, & Charlton, 2017). In a rhythmic gymnastics group, any changes in the starter squad due to injuries during the competitive period may affect the training load of the entire team by causing routine adjustments and more repetitions as each gymnast performs very specific roles in the routines.

In order to achieve peak performance and minimize injury risk, it is essential to manage training load and individual responses to that load. An interesting way to better understand training information from elite level athletes is through case studies. This format is a powerful tool to bridge the gap between science and practice (Halperin, 2018; Ruddock, Boyd, Winter, & Ranchordas, 2019). However, to date no study has analysed individual training load, recovery and injuries among elite level rhythmic gymnasts. Therefore, the aim of this short report is to describe individual training load, recovery and injuries in elite group rhythmic gymnasts during competitive periods.

METHODS

Six gymnasts from the 2015 Brazilian senior rhythmic gymnastics group participated in the current study (Table 1). This group comprised the best-selected gymnasts across the country, which represented Brazil in senior international competitions, including the Pan-American Games and World Championship. The study was approved by the University's Ethics Committee.

Data were collected across 126 days comprising regular training and four competitions. Regular training sessions started with a light warm up, followed by ballet, strength and conditioning, and technical training. Training load was assessed daily using the session rating of perceived exertion (session-RPE) method (Foster et al., 2001). Daily load was obtained by the sum of loads of all training sessions during that day. Acute and chronic loads were calculated by exponentially weighted moving averages (EWMA) using 7 and 28 days for time decays, respectively (Williams, West, Cross, & Stokes, 2017). The acute:chronic workload ratio (ACWR) (Gabbett, 2016) was also measured on a daily basis. This measure describes the size of the current training load (i.e., acute load) in relation to longer-term training load (i.e., chronic load) (Gabbett, 2020). ACWR$\geq$1.3 was considered a "spike" in load (Murray, Gabbett, Townshend, & Blanch, 2017). The Total Quality Recovery (TQR) scale (Panttä & Hassmén, 1998) was used to monitor recovery before the first training session of each day. A 3-day rolling average (3RA) TQR was calculated. A score of $\geq$13 (reasonable recovery) indicates a minimally adequate recovery state (Debien et al., 2020; Kenttä & Hassmén, 1998). On days of no training, training load was considered zero and TQR was not collected. Injuries were diagnosed and recorded by the medical staff, which provided individual reports containing body region, injury type, time-loss, date of occurrence, and observations regarding the impact of injuries on competitions and dismissals. All musculoskeletal injuries that required medical attention (Bahr et al., 2020) during the study period were reported and included in our analysis. Injury severity was classified based on time-loss (number of days that the athlete was unavailable for training and competition) as following: slight (no absence), mild (1 to 7 days), moderate (8 to 28 days), and severe (>28 days) (Bahr et al., 2020). Descriptive statistics were used.

Table 1
Gymnasts' characteristics at the beginning of the season.

	Age (yrs)	Experience in RG (yrs)	Height (m)	Weight (kg)
Athlete 1	26	17	1.64	53
Athlete 2	18	13	1.70	61
Athlete 3	22	12	1.60	50
Athlete 4	20	13	1.67	52
Athlete 5	20	17	1.67	54
Athlete 6	20	17	1.58	48

Note:Yrs- years; RG- rhythmic gymnastics.

RESULTS

Individual training load, recovery, injuries details, and status in competitions are described in Table 2. Figure 1 shows daily load, chronic load, EWMA ACWR, recovery and injuries of each gymnast across 126 days comprising the competitive periods of the season. Figure 2 presents EWMA ACWR in relation to chronic load and 3RA TQR score for each gymnast. Four athletes had five injuries during the time of the study, all of which were lower limb overuse injuries.

DISCUSSION

The aim of this short report was to describe individual training load, recovery and injuries of elite group rhythmic gymnasts during competitive periods. Our results illustrate the importance of individual training load management in this sport in order to minimize the risks of undesired outcomes during competitive periods preceding an Olympic season.

Athletes 1 and 4 sustained severe overuse injuries that resulted in absence from training and competition for several weeks. Athlete 1 was the oldest (26 years) and the only athlete who sustained two different injuries. She presented a few spikes (ACWR≥1.3) in training load at the same time as underrecovery (3RA TQR<13) in the first half of competitive periods (Figure 1A and 1G). Athlete 4 also showed spikes in load before the first main competition, but mainly in conjunction with low chronic load and decreasing recovery during her return to training post-injury (Figure 1D). Despite being starters before their injuries, they were not able to regain this position in the group and were waived at the end of the season. Athletes 2 and 3 presented mild and slight overuse injuries, respectively, which did not affect their position in both main competitions. Athlete 2 lost one day of training (day 49) followed by spikes in load on days 46 to 48. Athlete

3 was injured during the two principal events, however it was a chronic injury that recurrently occurred. This injury required constant treatment despite her ability to maintain full training. In this regards, Figure 2C illustrates how athlete 3 was frequently in a "safe zone" concerning adequate chronic load, recovery, and ACWR. Athletes 5 and 6 had no injuries during the study period and, despite not initially being starters, went to the Olympic Games as starters the following year. It is worth noting that Athlete 5 was underrecovered 74% of the time and athlete 6 had a few spikes in load, possibly when she started to train as a reserve.

High chronic loads are associated with fewer injuries, however, these loads must be progressively increased relative to the athlete's capacity to tolerate load (Gabbett, 2020). Moreover, the training load-injury relationship is moderated by several factors such as age, previous injury, and lifestyle (Gabbett et al., 2019). Previous investigations have found higher training loads, frequent spikes in load, and underrecovery during competitive periods in elite rhythmic gymnasts (Debien et al., 2020). All gymnasts in our study had at least one spike in load, yet each one may have tolerated this change in load differently based upon their age, chronic load, and recovery status. Some spikes occurred that did not result in injury, perhaps indicating that a combination of factors may need to occur for athletes to get injured (i.e., the "perfect storm"). Nevertheless, we highlight that the two athletes who sustained severe injuries also experienced more spikes in load. Both athletes presented spikes in load until competition 2, while athlete 4 also had spikes in load during her return to training, which might explain her inability to regain her position on the team (Gabbett, 2019). Despite the protective nature of high chronic loads, it is important to understand the chronic load of each athlete, the "ceiling" of safety, and the time available to safely reach the required loads for the sport (Gabbett, 2019). Our results reinforce how training load data should not be interpreted in isolation. The context and factors influencing load tolerance on an individual basis must always be taken into consideration in the decision-making process.

In order to achieve good technical performance, the main training content during competitive periods in rhythmic gymnasts are routine repetitions. Each group routine lasts 150 seconds and includes several jumps, rotations, balances, throws, and catches performed with high intensity effort (Ávila-Carvalho et al., 2012; Douda et al., 2008). Considering one heavy day with two sessions, four hours each (Debien et al., 2020), and a session-RPE score of 10 (maximal) for both sessions would result in a daily load of 4,800 AU. Nonetheless, all gymnasts reached more than this value at least once in our study. In addition, studies have shown that elite rhythmic gymnasts are regularly underrecovered during competitive periods (Debien et al., 2019, 2020). Recovery is essential to promote appropriate adaptation and achieve good performance (Kenttä & Hassmén, 1998; Soligard et al., 2016) however it should be noted that in this study spikes in load, low (or excessively high) chronic load and drops in recovery were not necessarily temporally aligned, and the lag effect for each is likely to be different among athletes. Future studies should focus on understanding the positive and negative effects of such high load in rhythmic gymnastics.

Albeit the pioneer findings, our study presents some limitations. We highlight that is also important to measure and analyse external training load data. However, this is a complex measure in rhythmic gymnastics training and future investigations should focus on quantifying it through repetition counting and wearable technology, for instance. Moreover, studies are needed to establish an accurate threshold of EWMA ACWR in regards to injury risk in elite rhythmic gymnastics.

Table 2
Individual training load, recovery, injuries, and status during each competition of elite group rhythmic gymnasts across competitive periods.

	Training load and recovery				Injuries			Competitions				
	Daily load (AU) Mean (SD) Max Min	Chronic load (AU) Mean (SD) Max Min	EWMA ACWR (%) ≥1.3	3RA TQR (%) <13	Body region	Type	Severity	1 Days 20 and 21	2* Days 68 to 71	3 Days 96 and 97	4* Day 125	Olympic Games* Following season
Athlete 1	1211 (1421) 5400 0	1296 (598) 2426 163	15%	64%	Hip Foot	Tendinopathy Bone stress fracture	Mild Severe	Starter	Starter	Starter	Injured	No
Athlete 2	1233 (1229) 5520 0	1312 (385) 2068 572	11%	65%	Hip	Bursitis	Mild	Starter	Starter	Starter	Starter	No
Athlete 3	1350 (1114) 5160 0	1366 (311) 2162 775	6%	18%	Foot	Tendinopathy	Slight	No	Starter	Starter	Starter	No
Athlete 4	1064 (1376) 5460 0	1166 (612) 2288 279	17%	6%	Lower leg	Bone stress injury	Severe	Starter	Injured	Injured	No	No
Athlete 5	1496 (1245) 4920 0	1559 (365) 2328 928	5%	74%	-	-	-	Reserve	Reserve	Reserve	Reserve	Starter
Athlete 6	1182 (1076) 6150 0	1208 (271) 1795 657	9%	37%	-	-	-	No	Reserve	Starter	Reserve	Starter

Note: AU- arbitrary units; SD- standard deviation; EWMA- exponentially weighted moving averages; ACWR- acute:chronic workload ratio; 3RA TQR- 3-day rolling average Total Quality Recovery score; %- percentage of days in relation to the total measured; Starter- compete in both routines; Reserve- compete in one routine; No- not selected to compete; Injured- unavailable to compete due to injury.

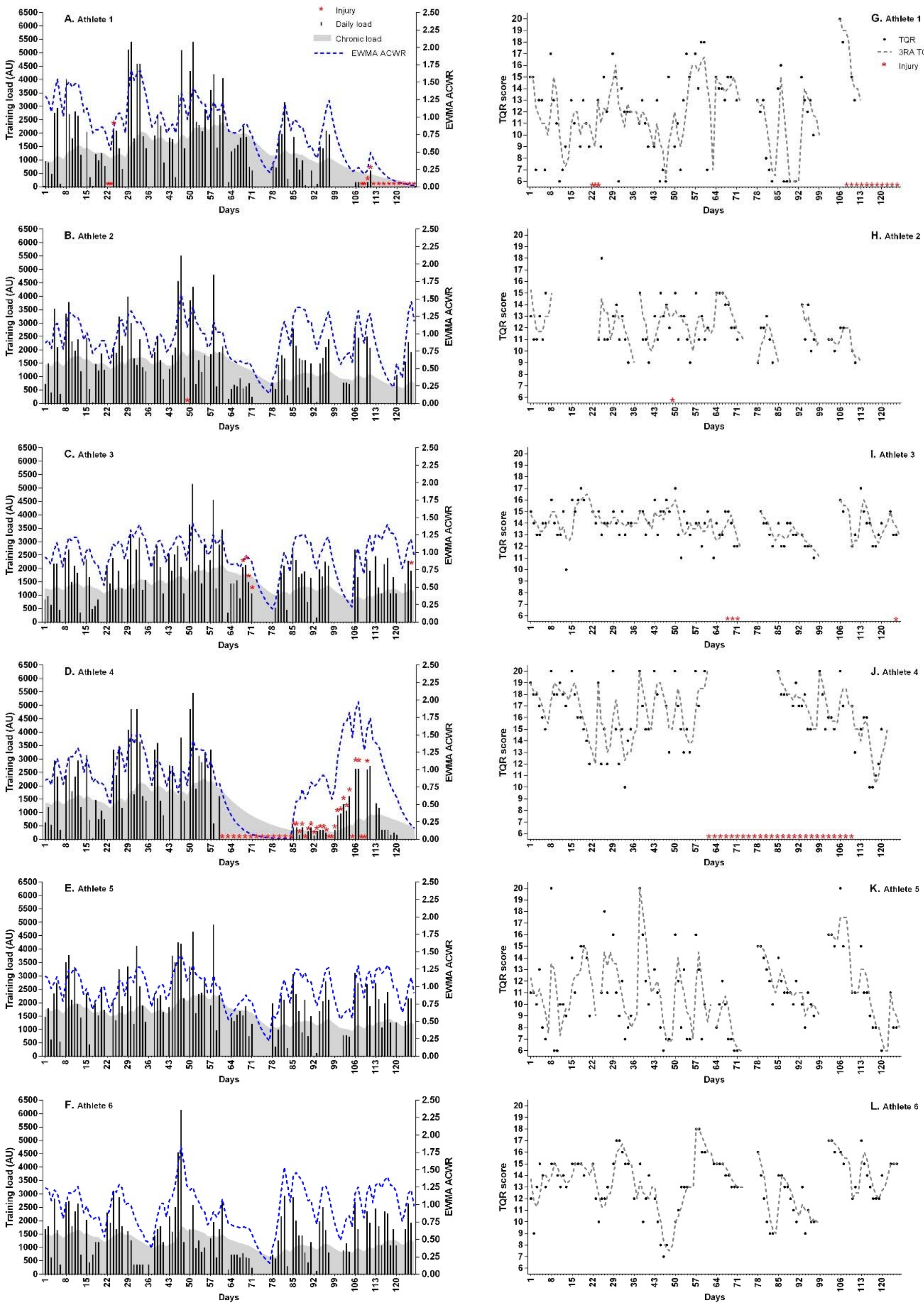

Figure 1. Individual daily load, chronic load, acute:chronic workload ratio, recovery and injuries throughout competitive periods in elite group rhythmic gymnasts.

Note: AU-arbitrary units; EWMA-exponentially weighted moving average; ACWR-acute:chronic workload ratio; TQR-Total Quality Recovery; 3RA-3-day rolling average.

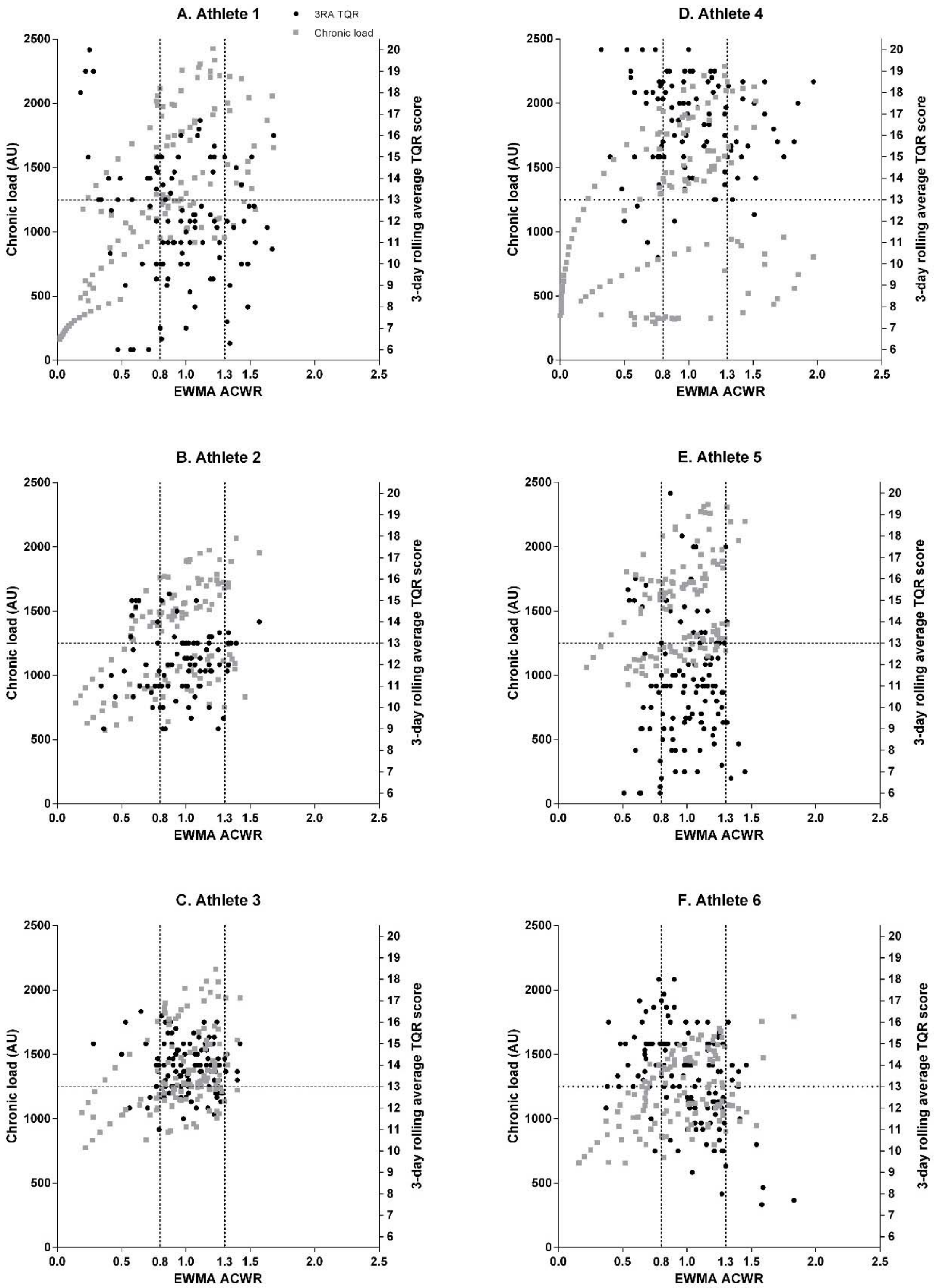

Figure 2. Individual daily acute:chronic workload ratio in relation to chronic load and recovery of elite group rhythmic gymnasts across competitive periods.
Note: AU-arbitrary units; EWMA-exponentially weighted moving average; ACWR-acute:chronic workload ratio; TQR-Total Quality Recovery.

Spikes in load in conjunction with underrecovery and low chronic load in elite group rhythmic gymnastics may represent a large-cost and low-benefit decision for most athletes, especially during the main competitive periods of a pre-Olympic season. Moreover, considering all injuries were lower limb overuse injuries, rhythmic gymnasts may benefit from specific injury prevention programs designed to reduce the risk of these injuries.

In general, coaches want their best athletes fit, fresh, and prepared for the main competitions. However, not all gymnasts can tolerate training load as a starter during competitive periods. Considering that national senior groups practice on a full-time basis, having a larger group of 10 to 12 gymnasts training together would allow the distribution of training load amongst starters and reserves, thereby reducing exposure to spikes in load close to important events.

CONCLUSIONS

Elite group rhythmic gymnasts present different injuries, load, and recovery patterns across competitive periods. Factors such as age and chronic load could moderate how each gymnast responds to training and tolerates spikes in load. Moreover, injuries sustained during competitive periods appear to affect the short and long-term careers of gymnasts, and impair training and competition organization of the team.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest whatsoever.

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GAZE BEHAVIOUR IN ELITE GYMNASTS WHEN PERFORMING MINI-TRAMPOLINE AND MINI-TRAMPOLINE WITH VAULTING TABLE – A PILOT STUDY

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Case study

Abstract
Visual system provides information from the environment, leading gymnasts to improve performance. The question of what sources of visual information from the environment contribute to performance, remains unclear. This study aims to analyse visual behaviour, as areas of interest, fixated by Teamgym elite gymnasts during the performance of techniques on mini-trampoline and mini-trampoline with vaulting table. We hypothesised that: a) gymnasts would fixate areas of interest in the environment to visually perceive relevant information, b) fixations on the area of interest "landing mat" would occur during the last part of flight phase and landing. Three teamgym elite gymnasts performed three tasks on mini-trampoline and one task on mini-trampoline with vaulting table. The variables were: fixation duration (FD), areas of interest (AOIs), ratio between total fixation duration and total task duration (TFD/TD) and ratio between total fixation duration per AOI and total fixation duration (TFDA/TFD). Results showed that TFD/TD increased with the decreased of complexity degree for all tasks. Mini-trampoline was the most fixated AOI (except for straight barani out on mini-trampoline) while wall was the less fixated. The run-up zone was the most fixated zone. For the task on mini-trampoline with vaulting table, participants reduced the time spent fixating run-up zone and increased time spent fixating mini-trampoline and vaulting table. Landing mat was the only AOI that was fixated during the flight phase. Results suggest that gymnasts may adapt their visual strategy to the degree of complexity of the task, as reflected in the results of TFD/TD and TFDA/TFD.

Keywords: *gymnastics, visual perception, eye-tracker.*

INTRODUCTION

Vision provides information from environment in relation to the person, being part of a cycle where the perception of affordances guides behaviour and behavior discovers new affordances (Gibson, 1986). One of the contexts where this relation can be observed is in sports and, more specifically, gymnastics. The challenge is to analyze visual behavior of gymnasts, in an ecological environment, similar to practice or competition contexts.

Vision is a dominant perceptual system assisting performance (Bardy & Laurent, 1998) on synchronize trampolining (Heinen & Czogalla, 2016), vaulting table (Heinen, Vinken, Jeraj, & Velentzas, 2013) and landing (Davlin, Sands, & Shultz, 2001; Luis & Tremblay, 2008). Also, the positions of springboard and vaulting table influence handspring kinematics (Heinen, Jeraj, Thoeren, & Vinken, 2011), suggesting that gymnasts visually perceive the positions of apparatus to adapt their movement. Such results were also confirmed for Yurchenko technique on vaulting table (Heinen, Brinker, Mack, & Hennig, 2017). Gymnasts perform better landings from back somersaults with full vision during performance, comparing to when vision is manipulated (Davlin et al., 2001). In synchronized trampolining, visual information from the other gymnast's arms seems to be a dominant cue to achieve synchronization (Heinen & Czogalla, 2016). These studies illustrate the importance of visual system to perform in diverse situations in gymnastics sport.

Additionally to studies that revealed the importance of visual system in performing gymnastics, other studies investigated experts versus non-experts. Differences were found regarding the duration and location of fixations (von Lassberg, Beykirch, Campos, & Krug, 2012), (Mann, Williams, Ward, & Janelle, 2007). Experts reveal more significant correlations between gaze behaviour and kinematics of somersault, comparing to novices (Heinen, 2011). Expert gymnasts use visual information to regulate kinematic variables in every phases of movement, as: contact time with apparatus, flight duration, landing deviation and moment of inertia. An interaction between eye, head, spine and joint movements was shown, when gymnasts perform multiple twisting somersaults, pointing to a functional relation that facilitates orientation in space (von Laßberg, Beykirch, Mohler, & Bulthoff, 2014).

Scientific evidences suggest a relationship between visual perception and movement adaptation in gymnastics. However, methodologies were conducted in a non-ecological way, which means that, it differs from practice/competition environments, namely in: similarity of the tasks performed, contextual constraints and in the use of indirect instruments to analyze visual behaviour. Some studies have manipulated visual behaviour by asking the gymnasts to fixate their gaze into a specific area (Heinen, Jeraj, Vinken, & Velentzas, 2012) or have occluded visual (Heinen, Koschnick, Schmidt-Maaß, & Vinken, 2014), (Luis and Tremblay, 2008) and auditory (Heinen et al., 2014) cues from the environment. Other studies measured gaze behaviour indirectly (not using an eye-tracker) and the tasks chosen were performed in isolation and not in a sequence as it is typical in training or competition contexts (Luis and Tremblay, 2008) (Heinen, Walter, Hennig, & Jeraj, 2018), (Davlin et al., 2001), (Bardy & Laurent, 1998), (Sato, Torii, Sasaki, & Heinen, 2017). Although this studies contribute to scientific knowledge in this domain, by evidencing a relationship between gaze behaviour and movement kinematics, analyze visual perception in real environment with direct instruments (ecological perspective), will provide more reliable details on visual patterns and on how gymnasts visually adapt to different contextual constraints.

The aim of this pilot study is to analyse visual behaviour, as areas of interest fixated by Teamgym elite gymnasts during the performance of techniques on mini-trampoline and mini-trampoline with vaulting table.

We hypothesised that: a) gymnasts would fixate areas of interest in the environment to visually perceive relevant information, b) fixations on the area of interest "landing mat" would occur during the last part of flight phase and landing.

METHODS

Three Teamgym elite gymnasts (male, senior elite category, mean age = 21.6 years, SD = 5.4 years) took part in this study. All gymnasts had participated in Teamgym European Championships for the last four years. They reported normal or corrected to normal vision, and signed the informed consent form. They were able to perform the study tasks autonomously and were free from injuries. The study followed the guidelines of the Declaration of Helsinki and had ethical approval from Ethics Committee of Faculty of Human Kinetics (6/2018).

The tasks were performed in i) mini-trampoline and ii) mini-trampoline with vaulting table. Three tasks on mini-trampoline and one task on mini-trampoline with vaulting table were analysed. The tasks included a 25 meters run-up towards the apparatus, the performance of the technique and landing. The techniques on mini-trampoline were: straight barani (SB), tucked barani out (TBO) and straight barani out (SBO). On mini-trampoline with vaulting table, participants performed handspring straight barani out (HSBO).

The tasks were chosen to represent characteristics of Teamgym discipline: 1) the two apparatus are performed in the same competition program (mini-trampoline). This program has a maximal duration of 2’45’’ and the team performs 3 rounds with 6 gymnasts in each round. At least one round is performed with vaulting table. This implies that, in a short period of time, some gymnasts from the team perform in the two apparatus; 2) tasks analysed are similar in regarding movement: the last somersault and the half twist of SBO and HSBO are similar to SB; 3) tasks on mini-trampoline are used as a pedagogical progression to learn other tasks on mini-trampoline and mini-trampoline with vaulting table (example: SB is used as a pedagogical progression to learn the last phase of SBO and HSBO). Additionally, this tasks have body rotations in transversal and longitudinal axis, different body positions (tucked and straight) and an increase in degree of complexity, which makes this analysis richer. Complexity degree (difficulty score in Code of Points, CoP) is determined by degrees of rotation in longitudinal and transversal body axis and body position (Sjostrand, Lemmetty, Hughes, Gryga, & Jónsdóttir, 2019) (Table 1).

The Gymnasium at Faculty of Human Kinetics was prepared with apparatus according to Teamgym Directives from European Union of Gymnastics (UEG) (Sjostrand et al., 2019) (Figure 1).

Tobii Pro Glasses 2 ® was worn by participants during the tasks. The system is a binocular eye tracker that records the point-of-gaze onto a video image of the scene, measuring the relative position of the pupil and corneal reflection. The recording process was undertaken using a Tobii Glasses Controller Software, running on a Dell Venue 11 Pro 7130, Windows 8/8.1 Pro tablet at a rate of 50 Hz. The image is transferred to a computer and analyzed by running the Tobii Glasses Analysis Software: Tobii Pro Lab. Being a direct method to study gaze behaviour, without manipulation of the visual stimulus (e.g. spatial occlusion), Tobii Pro Glasses 2 provided a higher level of ecology and revealed the expertise effects on gaze behaviour and decision-making (Kredel, Vater, Klostermann, & Hossner, 2017).

Participants used a vest with a pocket placed on their back with the record unit. The vest was used under a fit t-shirt, to minimize the displacement of the record unit.

Participants did a twenty-minute warm-up including general aerobic exercises of low intensity, specific exercises related to techniques of the study and some trials on mini-trampoline and mini-trampoline with vaulting table. The warm-up protocol was similar to warm-up in training sessions.

The eye-tracker was fitted onto de participant’s head to perform three familiarization trials. After the adjustments, calibration was made by asking each participant to stand still and to fixate a target on the centre of the calibration card, at a distance of approximately 1.25 meters during 5 seconds. After calibration, to ensure the best quality of data, we asked the subjects to look to five different points in the environment. The five points were part of AOIs and were at various distances, heights and widths of the subject. Besides this procedure is recommended, it gives us an idea if the calibration is good or if there is a necessity to repeat it.

Participants performed three trials of each technique, starting on mini-trampoline. They were encouraged to perform tasks as in a competition. Intervals between twenty to forty seconds between trials allowed to verify the eye-tracker and to recalibrate when necessary.

The gaze data were analysed frame by frame (sampling rate of 50Hz). Three gaze behaviour variables were considered for this study: number of fixations (NF), fixation duration (FD) and AOIs.

A fixation was considered when gaze remained stationary for at least 99.99 milliseconds (Vickers, 1992), with a tolerance of 0.5º (Williams, Davids, & Williams, 2005). An Area of Interest/visual reference point is an area/object from the environment (for example, the mini-trampoline) that is visually relevant for the participant when performing these tasks. Visual behaviour was analysed to calculate the percentage of viewing time, dividing the total fixations duration by task duration (ratio TFD/TD) and dividing the total fixations duration per AOI by total fixations duration (ratio TFDA/TFD).

In this study, seven AOI were defined previously to analysis, based on objects that the participants need to physically contact to perform the tasks. Also, AOIs where the subject possibly would search for visual information were included (example: front and lateral walls). Lastly, "undefined" was considered an AOI in case any participant fixate an area not considered in the others. The seven AOIs considered were: a) 1st part of run-up, b) 2nd part of run-up, c) hurdle, d) mini-trampoline, e) vaulting table, f) landing mat, g) front and lateral walls and h) undefined. 1st and 2nd parts of run-up were 10 meters long and 2 meters large each, while hurdle which is the zone were gymnasts did the last foot contact with floor, were five meters long and 2 meters large. Landing mat was 4 meters large and 7 meters length. Wall was considered as the front and lateral walls and undefined was categorized when the fixation was not in any of the mentioned AOIs (Figure 1).

Since this is a pilot study with an exploratory approach, with a small sample size and few repetitions, it was statistically underpowered, and only descriptive statistics were used (Field, 2018).

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Table 1
Complexity degree/Difficulty value for tasks analysed according to 2017-2021 Teamgym Code of Points - Juniors and Seniors.

Task	Straight barani (SB)	Tucked barani out (TBO)	Straight barani out (SBO)	Handspring straight barani out (HSBO)
Complexity degree/ Difficulty value	0.30	0.70	0.90	1.10

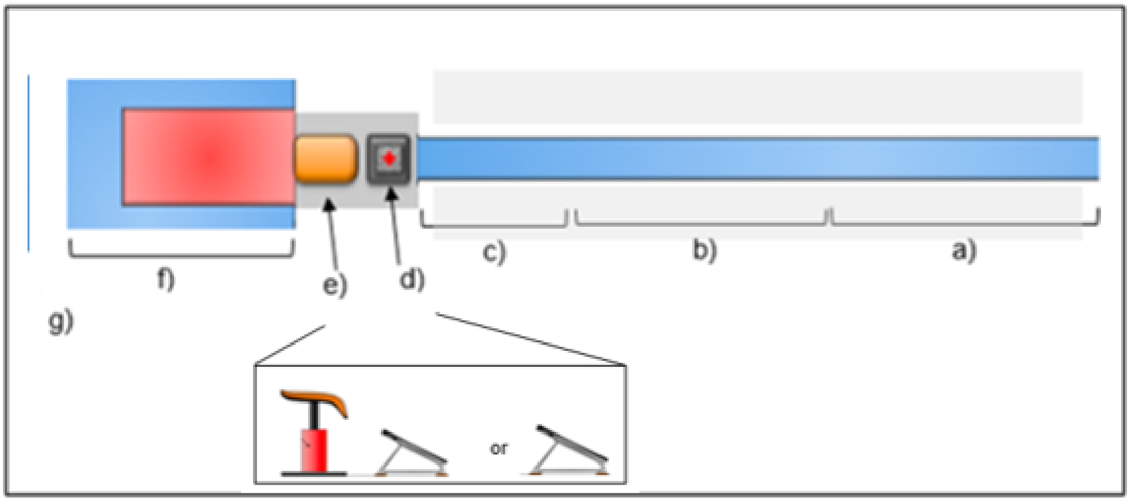

Figure 1. Apparatus setup and Areas of Interest considered for analysis: a) 1st part of run-up (10 x 2 meters), b) 2nd part of run-up (10 x 2 meters), c) hurdle (5 x 2 meters), d) mini-trampoline, e) vaulting table, f) landing mat (4 x 7 meters), blue line) front and lateral walls. Lateral detailed view for apparatus and AOI: d) mini-trampoline and e) vaulting table

Table 2
Characteristics of tasks: difficulty value according to Teamgym Code of Points, total task duration and fixations characteristics during the four different tasks: total fixation duration and ratio between total fixation duration and total task duration (m ± SD)

Complexity degree (CoP)	Task	Total task duration (sec)	Total fixation duration (sec)	Ratio Total Fixation Duration / Total Task Duration (%)
0.30	1 - Straight barani (SB)	5.85±0.41	2.86±0.71	48.88±12.30
0.70	2 - Tucked barani out (TBO)	5.98±0.48	2.52±0.53	42.14±9.04
0.90	3 - Straight barani out (SBO)	6.49±0.46	2.39±0.39	36.83±2.99
1.10	4 - Handspring straight barani out (HSBO)	4.73±0.13	1.15±0.48	24.31±10.70

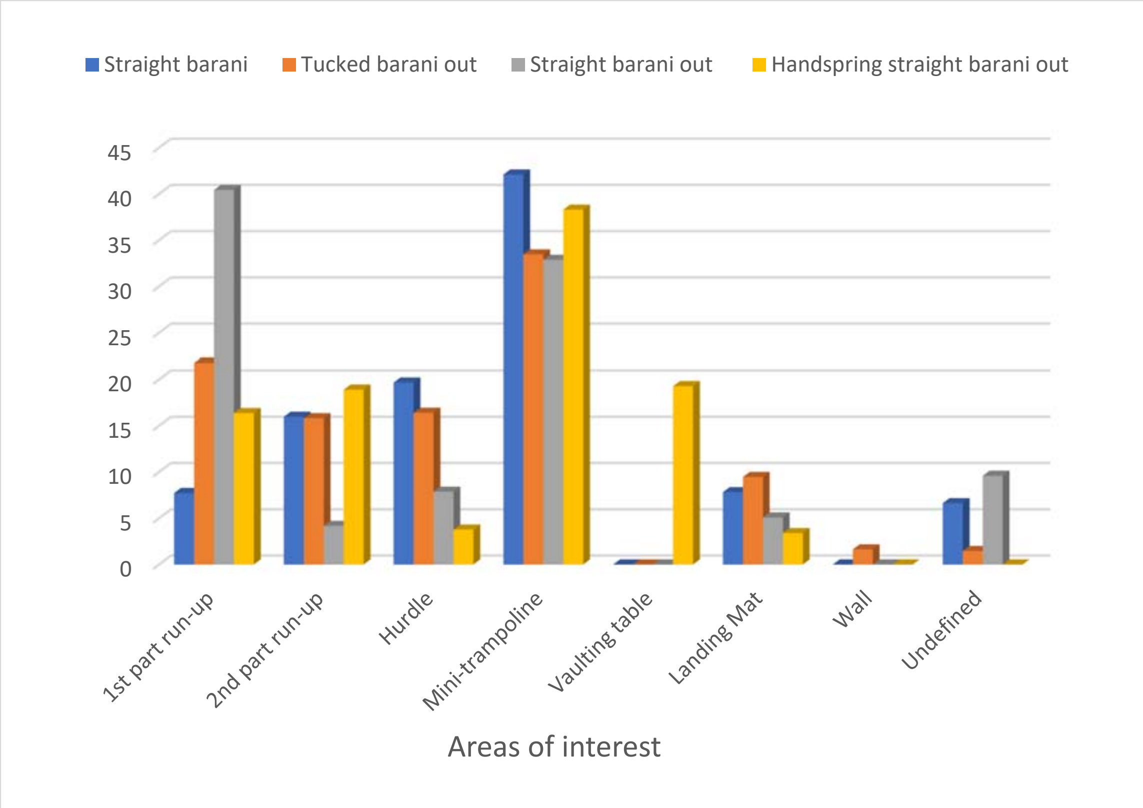

Figure 2. Ratio between Total fixation duration per AOI and Total fixation duration during the task (%).

RESULTS

Ecological validity. This pilot study aim to analyse visual behaviour, as areas of interest fixated by Teamgym elite gymnasts during the performance of techniques on mini-trampoline and mini-trampoline with vaulting table.

However, we think it is important to point out some aspects about the equipment: Tobii Pro Glasses 2 was able to collect gaze behaviour data during almost the entire tasks, except for small periods of time after the last contact with mini-trampoline or vaulting table and before landing, during rotations in transversal body axis were performed. It is an ecological instrument, allowing to study gaze behaviour in real context. It reveals to be easy for subjects to adapt to it, even if they never used glasses. The preparation of the subjects and calibration of the eye-tracker, takes between five to ten minutes. The investigator should guarantee that the calibration has the best quality possible, since it can affect data quality. Data analysis is time consuming process, which is a disadvantage for the investigator.

Number of fixations. Despite number of fixations can be an individualized parameter (Williams et al., 2005), we found smaller ranges for SBO and HSBO with values between 1-3 and 3-6 respectively. Contrary, we observed a larger range between 3-12 fixations for SB, and 2-13 for TBO.

Ratio Total fixation duration/ Total task duration (%). Ratio between total fixation duration and total task duration (TFD/TD) decreases with the increase in complexity degree for all tasks (see Table 2). For the less complex task (SB), participants spent approximately half of the time fixating AOIs (48.88±12.30%), while for the most complex task on mini-trampoline (SBO) participants spent approximately 36.83±2.99% of the total task duration fixating AOIs.

For the task on mini-trampoline with vaulting table (HSBO), with the higher complexity degree of all tasks analysed, participants spent 24.31±10.70% of the total task duration fixating AOIs (Table 2).

Ratio between Total fixation duration per AOI and total fixation duration (%). The most visited AOI was mini-trampoline for all tasks (relative percentage of 36.69%), followed by 1st part of run-up (21.57%) and vaulting table (19,28%). The less visited AOI was the wall (0.41%) that we considered as the front and side walls of the gymnasium. Although landing mat was not the less fixated AOI (6.44%), we expected that we would find higher values for this AOI (see Figure 2).

The run-up zone together (1st part, 2nd part and hurdle) registered the highest TFDA/TFD values, demonstrating the importance of this AOIs for visual perception and performance of the tasks analysed.

Mini-trampoline vs Mini-trampoline with vaulting table. For tasks on mini-trampoline (SB, TBO, SBO) values for TFDA/TFD between 32.87% and 42.09% were registered for the AOI mini-trampoline (the only apparatus). When performing HSBO, mini-trampoline and vaulting table together represented 57.58% of the time spent fixating AOIs, with a higher value for mini-trampoline (38,30%). Participants spent less time fixating run-up zone (39.04%) and more time fixating both apparatus (57.58%) for HSBO.

AOI fixated before flight phase vs during flight phase and landing. 1st part, 2nd part, hurdle, mini-trampoline, vaulting table and wall were fixated before the beginning of flight phase. Landing mat was fixated during contact with mini-trampoline until landing and, after last contact with vaulting table until landing. Undefined AOI were fixated during run-up.

DISCUSSION

This study analyses visual behaviour, namely areas of interest fixated, as mini-trampoline and vaulting table, by Teamgym elite gymnasts during the performance of techniques on mini-trampoline and mini-trampoline with vaulting table.

One main result of this study is that TFD/TD decreases when complexity degree increases for all tasks, which means that, when performing more complex techniques on mini-trampoline and mini-trampoline with vaulting table, participants tend to spend less time fixating AOIs (Table 2). First, this result can be due to the characteristics of the analysed tasks: the greater the complexity of the task, the more difficult it is to perform it, since gymnasts have to control more variables. This maybe indicates that gymnasts rely less in visual information and more on other sensory systems during more complex tasks. Additionally, during complex tasks, gymnasts increase velocity during run-up to produce strength during contact with mini-trampoline, resulting in higher and longer flight phases (Fernandes, Carrara, Serrão, Amadio, & Mochizuki, 2016). These higher and longer flight phases ensure that the gymnasts had enough time to perform the entire technique before landing (Fernandes et al., 2016). On the other hand, less complex tasks have the particularity that gymnasts had repeated it much more times during their practices, meaning that they have more control and possibly utilize more visual information rather than other sensory systems. In the most complex tasks on mini-trampoline and mini-trampoline with vaulting table (TBO, SBO and HSBO), participants known, due to experience, that there were certain phases of movement (flight phase) that they cannot fixate AOIs, due to body velocity. This fact led them to be more effective in selecting to where to look and for how long, in order to pick the relevant visual information (Raab, de Oliveira, & Heinen, 2009). Heinen et al., (2018) concluded that an increased in spatial orientation ability results from an optimized processing of sensory information that is dependent on gymnasts' experience. This supports that during flight phase, elite gymnasts may use other senses to obtain spatial information when vision is not available.

We expected to observe a higher value for TFD/TD (24.31±10.70%) during HSBO. Since the tasks were performed successfully, we can assume that these participants were more efficient in perceiving information from the environment, resulting in a low TFD/TD value but in an effective visual strategy, acquired with the experience.

Time spent fixating the 1st part of run-up increased with complexity degree of tasks performed on mini-trampoline. From what participants verbally reported and what we observed on data, participants tend to look down during the first steps of run-up, not to withdraw visual information but as a mechanism to focus on the task, which seems to be related with complexity degree. Several studies have proved that position of springboard (equivalent to mini-trampoline in Teamgym) and vaulting table were relevant for performance, influencing feet position during run-up and hands position during contact with vaulting table (Thomas Heinen et al., 2013; Heinen, Jeraj, Thoeren, & Vinken, 2011). This is in accordance with our results, showing higher values of TFDA/TFD for mini-trampoline. We suggest that, for being the first apparatus to visually contact, mini-trampoline it is the most important source of visual information to regulate velocity, length of steps, impulse and also time to contact with mini-trampoline and vaulting table (Lee, Lishman, & Thomson, 1982). Even though TFDA/TFD values for landing mat are lower than expected, fixations in this AOI occur during the longitudinal body axis rotation, at the end of flight phase. Higher TFDA/TFD values for landing mat during TBO when the body is in a tucked position (i.e. knees in front of the face), may reflect the less level of visibility in this task, when comparing with tasks in straight body position, and the need to search for visual information in the last part of flight phase. In addition, a lateral rotation of their heads previous to the longitudinal rotation of the body is perceptible. This head movement occur even for SBO where no fixations on landing mat were registered. Despite there is no investigations, we think that there might be two reasons for this factor: a) the head lateral movement occurs as a natural movement of the body to start the rotation on longitudinal body axis; b) it occurs as an attempt to visually perceive information about the landing mat, allowing participants to orientate themselves in space and time. Participants mentioned that they try to look at the landing mat when they start the rotation on longitudinal body axis, to help them to anticipate landing. However, even that fixations on landing mat were registered for some tasks, it is not possible to say if they can perceive visual information from the landing mat in a short period of time, and if yes, what information was perceived, and how it helped gymnasts to adjust their motor actions.

We observed that, when comparing tasks performed on mini-trampoline and mini-trampoline with vaulting table, participants reduced the time spent fixating the three areas of run-up to spend more time fixating mini-trampoline and vaulting table (TFDA/TFD = 39.04% for run-up areas on mini-trampoline versus 57.58% on mini-trampoline and vaulting table). We can be in the presence of a strategy to use the relevant sources of visual information when an apparatus (vaulting table) is added. Despite mini-trampoline continues to be the most fixated apparatus, it seems that participants fixated vaulting table to adjust their motor actions, meaning that vaulting table could influence run-up phase.

Finally, the majority of time spent fixating AOI occurred before flight phase. We propose that this result was due to the larger time spent on run-up, which reinforces the importance of this phase to visually perceive the environment and to adapt the movement.

Since this is a pilot study, we would like to leave some notes and questions. First of all, about the eye-tracker Tobii Pro Glasses 2, since this kind of equipment is rarely used in gymnastics. The eye-tracker Tobii Pro Glasses 2 was able to collect gaze data with limitations when the rotational body velocities reach high values. Several reasons can cause this problem: eye blinks, looking down in a way that the system can not identify the pupils or due to the movement of the eye tracker relative to participant's face. We recommend that future studies analyse eyes images during tasks, and that investigators be sure that the eye tracker is well fixed to the participant's face. Also, we advise investigators to ensure a good calibration procedure (as described in methods - procedures) to guarantee the data quality, and to analyse raw data since there is no evidence for the suitability of other filters included in the software. A balance between external validity of the experimental conditions (ecology) and the reliability of the measurements is essential (Kredel et al., 2017).

Second, some questions were raise during this study that we recommend to be taken into account in future research:

- Can we observe a consistent visual pattern regarding variables analysed in individual elite gymnasts, when repeating the same task? (intra-subject analysis)
- How is visual behavior related with body kinematics as velocity, step length during run-up, movement of the arms during contact with mini-trampoline and vaulting table?

We believe that research in this field of study will provide precise conclusions and will allow to give recommendations to coaches working with gymnasts of any level of expertise.

CONCLUSIONS

The results of this pilot study, being acknowledged of its limitations (sample size and number of repetitions performed), lead to questions on visual perception of elite gymnasts. We suggested that investigators analyse visual perception in gymnastics to understand visual strategies and visual references, in order to give recommendations to help gymnasts and coaches improving performance. The importance of future studies in this field relies on encourage gymnasts to use relevant visual information from the environment, that could assisted them in becoming more efficient and successful in practising and learning new techniques.

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IMPLEMENTATION OF THE GYMNASTICS CURRICULUM IN THE FIRST THREE-YEAR CYCLE OF THE PRIMARY SCHOOL IN SLOVENIA

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Original article

Abstract

Throughout the world, gymnastics is an essential part of physical education (PE) curricula, especially in the first years of schooling. In this period, PE is taught by the general teachers (GTs) with low levels of experience about how to teach gymnastics. Our study aimed to find out how GTs complied with the prescribed gymnastics curriculum contents. The sample included 90 GTs from 21 primary schools from Ljubljana, the capital of Slovenia. A self-administered questionnaire was designed to examine the opinions of GTs about some factors of importance and implementation of gymnastics contents on a five-level Likert scale. A one-way ANOVA, Tukey post hoc test, and Mann-Whitney U test were used in the data processing. GTs allocated more time to those contents of the PE curriculum that rank higher regarding the importance of child development and are easier to teach. They spent only 16.93 lessons on gymnastics per academic year, ranked gymnastics at fourth place (out of 7) regarding its importance for children's development, and gymnastics seemed to be the most challenging content to teach. Within gymnastic content, the least implemented elements were those mentioned as the most difficult to learn for children (acrobatics, hang and support, and vaults). GTs believed that teaching methods (4.29) were less important for successful gymnastics performance than children's motor efficiency (4.73) and self-activity (4.57). The outcomes of this study may aid in the future updating of GT education study programmes and designing a creative system of continuous professional development.

Keywords: *primary school, educational gymnastics, importance, difficulties, general teachers.*

INTRODUCTION

According to the legislation of the Republic of Slovenia (Primary School Act, 2007), compulsory nine-year general education for all children is divided into three periods. Physical education (PE) is an obligatory subject throughout; it serves as a venue to prepare children to be physically educated people: to teach them the importance of regular physical activity for health and to build skills that support active lifestyles (European Commission/EACEA/Eurydice, 2013). PE is allocated 834 lessons in total (105 lessons/year from Year 1 to Year 6, 70 lessons/year in Years 7 and 8 and 64 lessons/year in the Year 9) and implemented according to curricula that prescribe its scope and structure, general and operative objectives and skills and knowledge standards for selected movements and sport disciplines (Kovač et al., 2011). In the first three-year cycle, like in most European countries (European Commission, EACEA, Eurydice, 2013), all subjects are taught by general teachers (GTs). If schools can provide additional funding by parents or local authorities, PE can be taught together by GTs and PE teachers (PETs) (Primary School Act, 2007).

Gymnastic contents appeared in the Slovenian basic school curriculum in 1874 (at that time, Slovenia was a part of Austro-Hungarian monarchy) when PE was first introduced and included the compulsory SPIESS system (Kompara & Čuk, 2006). In the recent Slovenian PE curricula for primary school (Kovač et al., 2011), gymnastics is still one of the most important contents. Also in European and throughout the world PE curricula, gymnastic is, along with ball games, track and field, swimming and dancing, one of the obligatory contents (European Commission, EACEA, Eurydice, 2013; Hardman, Murphy, Routen, & Tones, 2014), as it offers a great range of locomotive, stability and body control movements, which are highly important for the motor, cognitive, affective, and social development of children (Baumgarten & Pagnano-Richardson, 2010; Kovač, 2012; Nilges-Charles, 2008; Novak, Kovač, & Čuk, 2008; Pehkonnen, 2010; Sloan, 2007; Živčić Marković, 2010).

From the perspective of child development, gymnastics is one of the key physical activities as it requires a great diversity of movements. It includes elements that can be performed on three levels (head, hip, and horizontal), in different directions (forward, sideward, and backward), around three axes (frontal, sagittal, and vertical), and in two different phases, the support phase and the no-support phase (Ávalos Ramos, Martínez Ruiz, & Merma Molina, 2014; Kovač, 2012; Živčić Marković, Sporiš, & Čavar, 2011). Successful performance of each gymnastic element requires the accurate muscular activity of a specific intensity, through space and at the right moment, the coordination of the whole body, flexibility, and balance. Children must overcome the weight of their own body on all gymnastics equipment, which is the most natural way to strengthen the body. With repetitive gymnastic practice, they can develop endurance in strength, which is also needed in other sports. Non-elite gymnastics participation is associated with musculoskeletal benefits in upper limb bone geometry, strength, and muscle function (Erlandson, Kontulainen, & Baxter-Jones, 2011).

Due to the previously mentioned importance of gymnastics for child development, the current Slovenian PE curriculum details some practical and theoretical gymnastic themes to be implemented in all nine years of primary school to provide logical progression and development continuity of children's gymnastics skills (Kovač et al., 2011). The contents to be implemented in the first three-year cycle are presented in Table 1.

At the end of the first three-year cycle, the skills and knowledge standards are presented at two different levels (basic and minimal) (Table 2).

The quality of PE programmes depends on several factors, such as actual teaching, which means how teachers interact with their students and the contents (Kyriakides, Tsangaridou, Charalambous, & Kyriakides, 2018). Tome (1983) found that 8.8% of Slovenian PE teacher education (PETE) students did not perform forward rolls, and 38.2% of them did not perform cartwheels in primary school. Twenty years later, 56.5% of 1st-year PETE female students reported, they did not encounter cartwheels during PE at all (Pajek, 2003). Štemberger (2003) reported that children's skills in 1st three-year cycle are the best in athletics, following with gymnastics and elements with balls. Pajek, Čuk, Kovač, and Jakše (2010) were determining the realisation of gymnastic content in the third three-year cycle where PE is taught by specialised PETs. They determined that PETs mostly taught easy contents (roll forward, roll backward, cartwheel, handstand, etc.) for which supporting assistance is not necessary, and the likelihood of falls and injuries is small; they avoided gymnastic elements that include a flight phase, turns, or have a small support area as they thought such elements were not appropriate for primary school. At the same time, PETs also reported that pupils did not attain gymnastics skills prescribed in the curriculum in the first and second three-year cycles.

Since children need to encounter gymnastic contents as soon as possible to become competent and confident in their gymnastics ability (Nilges-Charles, 2008), the aims of our study are: i) to determine what proportion of PE lessons is allocated to gymnastics compared to other PE contents; ii) to determine what proportion of time GTs devote to different contents of gymnastics; iii) to distinguish GTs' opinion about the importance of different PE contents for child development; iv) to distinguish the difficulty of the teaching of different PE contents; v) to determine the difference in the difficulty of teaching regarding teachers experience; vi) to distinguish the difficulty of learning of different contents of gymnastics; and vii) to distinguish the importance of factors attributed to pupils' gymnastics performance.

Table 1

Gymnastic contents in the first three-year cycle of primary school (Kovač et al., 2011).

	YEAR 1	YEAR 2 AND 3
	Practical contents	
	Calisthenics (also with different equipment and with music).	
	Training courses (overcoming apparatus as obstacles).	
Basic acrobatic	Rolling, rocking, bunny jumps, shoulder stand, roll forward.	Rolling, rocking, bunny jumps, shoulder stand, roll forward and roll backward. Cartwheel.
Spring and vault	Hops over a bench and low balance beam with arm support (crouch jumping). Box horse (to 80 cm height): jump up on front support on knee or squat.	Hops over a bench and low balance beam with arm support (crouch jumping). Box horse (to 80 cm height): jump up on front support on knee or squat.
Hang and support	Climbing on different wooden ladders, leaning bench, bar climbing, etc. Swing in hang and pike inverted hang.	
Balance exercises on a narrower surface	Bench: crawling, climbing, and walking in different directions, jumps in different directions, dismount straight.	Bench or low beam: crawling, climbing, and walking in different directions, jumps and leaps in different directions, simple hold elements, turn on both legs, dismounts.
Rhythmic elements (with music)	Rope jumping. Hops, leaps, and jumps. Different simple holds.	Rope jumping. Hops, jumps and leaps, turns, different hold elements (scale etc.).
	Specific theoretical contents	
Orientation in the space	Forward, backward, up, down, sideward, left, and right.	
Names of basic movements	Different arm, leg, and trunk positions. Handstand, lying and sitting positions, squat, kneeling positions, hang, support etc.	

Table 2
Basic and minimal skills and knowledge standards at the end of the first three-year cycle (Kovač et al., 2011).

Basic level	The students correctly perform calisthenics. They competently and safely perform: roll forward, roll backward on a slope, shoulder stand, crawls, drag their bodies along the floor, walks and jumps on a narrow surface (low balance beam), performs a squat jump on box, climbs on various climbers (birch, bark, etc.) and performs a jump rope activity. The student is aware of terms related to body postures and the direction of movement in space.
Minimum level	The student correctly performs calisthenics. They perform: roll forward, shoulder stand, crawls, drag their bodies along the floor, walk and jump on a narrower surface (bench), with the support (of teacher or height position of take-off), performs jumps up on a lower box in front support on the knee or squat, climbs on the batten, climbing frame and slopping bench, skips the jumping rope. The student is aware of terms related to body postures and the direction of movement in space.

METHODS

This work was designed as a cross-sectional observational study. The study was approved by the commission for student affairs of the Faculty of Sport, University of Ljubljana. We enrolled 90 uninjured (2 male and 88 female) GTs who taught PE in the first three-year cycle of the primary schools in Ljubljana, Slovenia, in the 2012/2013 academic year. The 149 questionnaires with an accompanying newsletter (information on the study) were sent by e-mail or personally delivered to all 43 primary schools in Ljubljana; 21 schools (49%) accepted invitations to participate in the study. Altogether, 93 (62.4%) questionnaires were returned, of which 90 (60.4%) were entirely resolved. Participants were informed about the purpose of the study, and written informed consent was obtained from all GTs and headmasters of selected schools.

The questionnaire titled 'Implementation of gymnastics in the first three-year cycle of the primary school' was anonymous and was made solely for this study. It included three parts: the first part related to demographic characteristics (gender, age, length of service, education, the class they teach, participation of continuous professional development (CPD) with gymnastics content); the second part related to the implementation of gymnastic contents comparing to other PE contents (fundamental movement skills – FMS, basic athletics – abcA, basic gymnastics – abcG, games with balls – GwB, dance games – abcD, water games and swimming – abcS, and obligatory physical fitness testing at national level – Slofit), and third part related to the implementation of specific gymnastics contents (calisthenics, training course, acrobatics, vaults, hang and support – H&S, balance on narrower surface – BNS, and rhythmic elements – RE). Results are presented on an ordinal scale from 1 to 5, in which 1 represents the lowest and 5 the highest level of significance.

All data were analysed using the Statistical Package for Social Sciences (SPSS, version 25.0 for Windows) and Microsoft Excel 2016. Basic descriptive statistics (mean and median) and the frequencies were calculated. Differences between average allocated time to different contents of PE and to different gymnastics' contents were evaluated with one-way ANOVA and Tukey post hoc test. The same tests were used to calculate i) the differences in GTs opinions about the importance of different contents of PE curriculum for child development, the difficulty of different contents of PE curriculum for teaching, and the difficulty of different gymnastics' contents for learning for children; and ii) the differences between GTs' opinions regarding the different grades they were teaching. Differences between more (over 20 years of experience) and less (under 20 years of experience) experienced teachers, and their opinions were evaluated using the Mann-Whitney U test.

RESULTS

Altogether, 90 GTs participated (2.2% male and 97.8% female), aged 42.70 $\pm$ 7.96 yrs (median 43 yrs). Half of them were between 41 and 50 years old, 27.8% between 31 and 40 years, 14.4% over the age of 50, and 7.8% were younger than 30 years of age. The majority of GTs completed university education (72.2%), followed by those with finished two-year post-secondary pedagogical school (23.3%). An only a small percentage of GTs finished doctoral, scientific master's degree, or a specialisation (3.3%), and one person (1.1%) had finished only high school. More than one third of GTs in sample taught 1st grade (37.8%), 31.1% taught 2nd grade, and the same percentage 3rd grade. The sample of included GTs had 18.80 $\pm$ 9.37 yrs (median 19.50) working experiences at primary school. Most of the GTs were teaching alone (78.9%), 18.9% were teaching together with PETs one hour per week, and only 2.2% of GTs are teaching all PE lessons (three hours per week) together with PETs. Only 20% of the sample attended CPD with gymnastics content during their professional career. All schools in Ljubljana have the appropriate gym halls with good equipment for realisation the gymnastic contents and GTs implemented all PE lessons in observed academic years.

Table 3 showings the average allocated time (in lessons and percentage) that GTs dedicate different contents of PE in each grade of the first three-year cycle: FMS, abcA, abcG, GwB, abcD, abcS and SLOfit. GTs spent the most time during school year on FMS (23.86 hours/year; 22.7% of allocated average time), GwB (20.58; 19.6%), abcA (17.13; 16.3%) and abcG (16.93; 16.1%). A statistically significant difference in allocated average time between different contents of PE (F=108.31, p=0.00) is revealed. Post-hoc analysis also showed significant differences in allocated time between all contents of PE (p<0.02). One-way ANOVA did not show significant differences between the allocated average time for different contents of the PE curriculum in the 1st, 2nd, and 3rd grades (p>0.05).

GTs believed that the most important contents for child development were FMS (4.98), abcS (4.73), and GwB (4.51); abcG was ranked at 4th place (out of 7) with an average score of 4.30 (Table 4). Significant differences in the contents of PE regarding their importance for child development were found (F=22.36, p=0.00). Tukey's post hoc test revealed there were differences in the importance of different contents between (p<0.05): FMS and abcA, FMS and abcG, FMS and GwB, FMS and SLOfit, abcA and GwB, abcA and abcS, abcG and abcS, GwB and abcD, abcD and abcS, abcD and SLOfit. There was no statistical difference (p>0.05) regarding their opinions between those taught in 1st, 2nd, or 3rd grades (Table 4).

For GTs, the most difficult content to teach in the first three-year cycle was abcS (4.52), which was followed by abcG (4.18) and SLOfit (3.64) (Table 5). We found significant differences between the contents of PE regarding difficulty for teaching (F=39.71, p=0.00). Tukey's post hoc test revealed there were differences (p=0.00) in difficulty for teaching between FMS and all other contents except GwB (p=0.18); abcA and abcG, abcA and GwB, abcA and abcS; abcG and GwB, abcG and abcD, abcG and SLOfit; GwB and abcS, GwB and SLOfit; abcD and abcS; and abcS and SLOfit. A one-way ANOVA test showed no significant differences in opinions about the difficulty of teaching between 1st, 2nd, and 3rd grade teachers (p>0.05).

Table 3
Allocated average time (lessons/yrs, %) for different contents of PE curriculum.

	FMS	abcA	abcG	GwB	abcD	abcS	SLOfit
Average time	23.86	17.13	16.93	20.58	9.72	9.99	6.79
	22.7%	16.3%	16.1%	19.6%	9.3%	9.5%	6.5%
1st grade	24.00	17.23	17.18	20.31	9.75	9.70	6.83
	22.9%	16.4%	16.4%	19.3%	9.3%	9.2 %	6.5%
2nd grade	23.71	16.41	15.53	21.76	9.59	11.18	6.82
	22.6%	15.6%	14.8%	20.7%	9.1%	10.7%	6.5%
3rd grade	20.00	20.00	20.00	20.00	10.00	10.00	5.00
	19.1%	19.1%	19.1%	19.1%	9.5%	9.5%	4.8%

Note: FMS – fundamental movement skills; abcA – abc athletics; abcG – abc gymnastics; GwB – games with balls; abcD – abc dance; abcS – abc swimming; Slofit – physical fitness testing.

Table 4
Importance of different contents of PE curriculum for child development.

	FMS	abcA	abcG	GwB	abcD	abcS	SLOfit
Average score	4.98	4.21	4.30	4.51	4.06	4.73	4.17
1st grade	4.97	4.17	4.25	4.51	4.06	4.69	4.15
2nd grade	5.00	4.29	4.41	4.53	4.06	4.88	4.12
3rd grade	5.00	5.00	5.00	4.50	4.00	5.00	5.00

Note: FMS – fundamental movement skills; abcA – abc athletics; abcG – abc gymnastics; GwB – games with balls; abcD – abc dance; abcS – abc swimming; SLOfit – physical fitness testing.

Table 5
Difficulty for teaching.

Difficulty for teaching	FMS	abcA	abcG	GwB	abcD	abcS	SLOfit
Average score	2.81	3.60	4.18	3.06	3.34	4.52	3.64
1st grade	2.80	3.56	4.21	2.97	3.30	4.52	3.65
2nd grade	2.88	3.65	4.00	3.35	3.47	4.47	3.59
3rd grade	2.50	4.50	4.50	3.50	4.00	5.00	4.00

Note: FMS – fundamental movement skills; abcA – abc athletics; abcG – abc gymnastics; GwB – games with balls; abcD – abc dance; abcS – abc swimming; SLOfit – physical fitness testing.

Table 6
The difficulty for teaching different contents of PE regarding GTs' experiences.

	FMS	abcA	abcG	GwB	abcD	abcS	SLOfit
average score	2.81	3.60	4.18	3.06	3.34	4.52	3.64
	Z=-0.38 (p=0.71)	Z=-0.77 (p=0.44)	Z=-1.45 (p=0.15)	Z=-0.26 (p=0.79)	Z=-0.60 (p=0.55)	Z=-0.76 (p=0.45)	Z=-1.54 (p=0.12)
under 20 years of experience	2.84	3.67	4.29	3.07	3.40	4.60	3.49
more than 20 years of experience	2.78	3.53	4.07	3.04	3.29	4.44	3.80

Note: FMS – fundamental movement skills; abcA – abc athletics; abcG – abc gymnastics; GwB – games with balls; abcD – abc dance; abcS – abc swimming; SLOfit – physical fitness testing.

Table 7
Allocated average time to different contents of abcG and ANOVA results.

	calisthenics	training course	acrobatics	vaults	H&S	BNS	RE
Allocated average time (%)	23.7% F(2)=3.20 (p<0.05)	18.1% F(2)=15.11 (p=0.00)	9.9% F(2)=3.62 (p=0.03)	14.2% F(2)=0.91 (p=0.41)	9.6% F(2)=1.28 (p=0.28)	12.8% F(2)=0.78 (p=0.463)	11.7% F(2)=1.83 (p=0.17)
1st grade	24.7%	17.9%	9.0%	14.2%	9.5%	13.1%	11.6%
2nd grade	21.2%	16.4%	12.2%	14.7%	10.4%	12.0%	13.1%
3rd grade	10.0%	40.0%	20.0%	10.0%	5.0%	10.0%	5.0%

Note: H&S – hang and support; BNS – balance on narrower surface; RE – rhythmic elements.

Table 8
How difficult are gymnastics' contents for children to learn.

Difficulty for children	calisthenics	training course	acrobatics	vaults	H&S	BNS	RE
Average score	3.53	3.39	4.18	4.06	4.08	3.58	3.84
1st grade	3.51	3.42	4.11	3.93	4.03	3.52	3.83
Difference between 1st and 2nd grade	H=0.37 (p=0.55)	H=0.29 (p=0.59)	H=2.87 (p=0.09)	H=4.79 (p=0.03)	H=0.78 (p=0.38)	H=0.76 (p=0.38)	H=0.03 (p=0.85)
2nd grade	3.65	3.24	4.47	4.47	4.24	3.71	3.82
Difference between 2nd and 3rd grade	H=0.18 (p=0.67)	H=0.13 (p=0.72)	H=1.54 (p=0.22)	H=1.49 (p=0.22)	H=0.13 (p=0.72)	H=0.94 (p=0.33)	H=1.11 (p=0.29)
3rd grade	3.50	3.50	4.00	5.00	4.50	4.50	4.50
Difference between 1st and 3rd grade	H=0.41 (p=0.82)	H=0.36 (p=0.84)	H=3.20 (p=0.20)	H=7.47 (p=0.02)	H=1.25(p =0.54)	H=2.70 (p=0.26)	H=1.20 (p=0.55)

Note: H&S – hang and support; BNS – balance on narrower surface; RE – rhythmic elements.

The Mann-Whitney U test showed no differences ($p>0.05$) in opinions about how difficult the different contents of PE are for teaching between more (more than 20 years of experience) and less (under 20 years of experience) experienced GTs (Table 6).

Within abcG, GTs allocated the most time to calisthenics (23.7%), training course (18.1%), and vaults (14.2%) (Table 7). They allocated the most time to calisthenics and training courses in the 1st (24.7%; 17.9%) and 2nd grades (21.2%; 16.4%), and to training courses (40.0%) and acrobatics (20.0%) in the 3rd grade. One-way ANOVA revealed significant differences between the average allocated time to abcG content ($F=56.12$, $p<0.05$). Tukey's post hoc test revealed there was a significant difference between following the contents of abcG ($p<0.05$): calisthenics and all other contents; training course and all other contents; acrobatics and vaults, acrobatics and rhythmic elements (RE); vaults and hang and support (H&S) and H&S and balance on a narrower surface (BNS). We established significant differences between the time allocated to calisthenics, training course, and acrobatics in the 1st ($p<0.05$), 2nd ($p=0.00$), and 3rd grades ($p=0.00$) (Table 7). Tukey's post hoc analysis showed GTs allocate significantly more time to calisthenics in the 1st than in the 3rd grade, significantly more time to training courses in the 3rd grade compared to the 1st and the 2nd grades ($p<0.05$). GTs allocate significantly more time to acrobatics in the 3rd grade compared to in the 1st grade ($p<0.05$).

GTs believed that the most difficult contents for children's learning were in 1st grade acrobatics (4.11), H&S (4.03) and vaults (3.93); in 2nd grade acrobatics, vaults (both 4.47) and H&S (4.24); in 3rd grade vaults (5.00), H&S, BNS and RE (all three 4.50) (Table 8). We found statistical differences between different contents of abcG regarding difficulties to learn ($F=56.12$, $p<0.05$). Tukey's post hoc test revealed, there were differences ($p<0.05$) in the difficulty of learning between: calisthenics and all other contents; training course and all other contents; acrobatics and vaults; vaults and H&S; and H&S and BNS. There were also statistically significant differences between the difficulty for pupils of vaults between the 1st and 2nd grades ($p<0.05$) and between the 1st and 3rd grades ($p<0.05$).

The teachers attributed the most significant importance for pupils' gymnastics performance to motor efficiency (4.73), followed by the self-activity of the pupils (4.57), and teaching methods (4.29). They also highlighted other factors regarding gymnastics performance, such as material conditions, the support of family, physical characteristics, and the influence of classmates (Kavčič, 2015). We did not find any significant differences ($p>0.05$) in GTs' opinions regarding the mentioned factors between those, teaching at the 1st, 2nd, or 3rd grades.

DISCUSSION

One significant result of this study was that GTs allocated more time to the specific contents of PE curriculum that they rank higher regarding their importance to child development. Their opinion about the importance of different contents was not dependent on the GTs' experiences. GTs rated abcG as less relevant PE content for child development (4.30) than FMS, abcS, and GwB; therefore, they also spent less time on this content. They devoted only 16% (16.93 lessons) of PE to gymnastics, which is partly in contrast to the findings of the studies in the past. It was estimated that Slovenian GTs and PETs allocate 20% of lessons for the implementation of gymnastics from the total amount of PE lessons per year, regardless of the lower or upper part of primary school (Medved, 1985; Sever, 1985). It was also found that 56% of PETs from Ljubljana, Slovenia devoted 16-30% of the PE to gymnastics, 29.7% of them devoted 0-15% of the time, and 14.3% more than 31% of the time in relation to other contents in the PE curriculum (Rogelja, 1985). Pajek et al. (2010) determined that gymnastics contents accounted for 10.6 school lessons in the 7th grade, 9.7 school lessons in the 8th grade, and 9.2 school lessons in the 9th grade in Slovenian schools. Živčić-Marković (2010) reported that among 106 types of educational content in the Croatian PE curriculum from 1st to 4th grade, 47 (44.4%) include different gymnastics structures. The latest research conducted in Osijek, Croatia, indicated that 97% of GTs devoted about 30% of PE content to gymnastics (Badić, Živčić-Marković, Sporiš, Milanović, & Trajković, 2012).

As open-ended curricula provide teachers with a higher level of autonomy, it often happens that contents that are difficult to teach because they require more management and, where injuries are more likely, are not allocated enough lessons in the teacher's annual work plan (Pajek et al., 2010; Kovač, 2006; Štemberger, 2003). Furthermore, in this study, GTs spent only 16.93 lessons per year on gymnastic contents but, at the same time, they highlighted abcG as one of the most difficult types of content to teach. With an average score of 4.18, abcG was ranked immediately after swimming, which is organised by external associates in Ljubljana, and GTs do not teach it during PE (Javni zavod Šport Ljubljana, 2020). There are many reasons for this opinion of GTs:

a) GTs teach different school subjects, and they need to prepare for different content simultaneously (Štemberger, 2003);

b) a small amount of obligatory European Credit Transfer System (ECTS) for Didactics of PE during the study programme for GTs (12 to 13 ECTS). In

Slovenia, three initial teacher education providers (faculties of education at the universities in Ljubljana, Maribor and Koper/Capodistria) prepare GTs for teaching all subjects on the curriculum from Grades 1 to 5 at primary school. Initial teacher education consists of a four-year undergraduate programme across all curricular areas and an additional one-year master's programme in Primary School teaching. A four-year undergraduate programme is required to accumulate 240 ECTS; among them, only 12 or 13 ECTS (depending on the university) are obligatory for PE. All programmes also include options for elective subjects, such as athletics and racket sports, gymnastics in primary school, and similar. The primary school teaching professional master's programme is required to accumulate 60 ECTS. The Faculty of Education, at the University of Ljubljana offers only two elective subjects on PE programmes, Selected topics in didactics of PE and Research in PE, each with six ECTS (University of Ljubljana. Faculty of Education, 2020);

c) lack of the content knowledge (CK), since 30% GTs in this study reported that they had not encountered gymnastics during their studies and only 20% of them attended CPD with gymnastics content in their professional career; according to Ward (2009) CK consisting of common CK (how to perform in a content area, e.g., knowing how to perform a gymnastic element as a forward roll or swing on bars) and specialised CK (didactic knowledge how to teach gymnastic elements, e.g., knowing that an inclined mat will help students to learn the backward roll) are both are necessary for successful teaching;

d) fear of injuries (Štemberger, 2003): gymnastics has one of the highest injury rates (the number of injuries sustained per 1000 participants per year for the ages 6 to 11 years was 3.6) and 40.0% of gymnastics' injuries in the United States occurred in school settings (Singh, Smith, Fields, & McKenzie, 2008).

e) their age (the average age was 42.7 yrs).

Štemberger (2003) and Pajek et al. (2010) noted that GTs spend too few lessons on gymnastics, which leads to very modest knowledge of the subject in children. Within abcG, GTs seemed to allocate the most time to elements that are technically easier to perform: calisthenics (23.72%) and training courses (18.07%) for which supporting assistance is not necessary, and the appropriate organisation of the learning process is simple. The least implemented were H&S and basic acrobatics elements (less than 10% of allocated time). GTs also stated that those elements were the most difficult for children to learn correctly (acrobatics 4.18; H&S 4.08, vaults 4.06). At the same time, GTs attributed motor efficiency (4.73) the greatest importance for children's gymnastics performance. Šturm and Strel (2002) reported poor results in the muscular strength in arms and shoulders of Slovenian primary school students in the period between 1971 and 1980 as a consequence of negligent attitudes toward gymnastic elements in school programmes. Starc et al. (2016) also found that in recent decades there has been a very significant decline in this ability among Slovenian students. Many authors (Ávalos Ramos et al., 2014; Pajek et al., 2010; Živčić-Marković, 2010) reported that H&S and acrobatics are especially effective in building up strength in arms and shoulders.

For this reason, GTs should include more climbing and other basic H&S and acrobatics elements on PE lessons. Climbing demands the highest degree of good physical condition, while requiring strength of the flexing muscles and a certain level of movement coordination as the child needs to coordinate the movement of legs and arms and find support on different wooden ladders, leaning bench, or bar (Novak et al., 2008; Pajek et al., 2010; Živčić-Marković, 2010); therefore, those preparatory exercises are necessary for child development. Slovenian PETs also often avoided those elements while they reported that H&S and acrobatics elements that include a turn of the body around different axes, a reduction in the support surface or require more muscular strength of arms and shoulders are very difficult to teach (Pajek et al., 2010).

The second main result of the present study is about the GTs' perceptions of what is important for pupils' gymnastics performance. They believe that the most important is children's motor efficiency (4.73), followed by children's self-activity (4.57). Teaching methods were put only on third place (4.29). This order indicates that they did not emphasise their role as very important for pupils' achievements compared to pupils' performance factors. Nonetheless, it shows the lack of the CK, since 30% GTs in this study reported that they did not encounter gymnastics during their studies, and only 20% of them attended CPD with gymnastics content in their professional career. As a result, the skill level attained by children is frequently stagnated, as they received little more than exploratory simple gymnastics elements (Nilges, 1997). Therefore, Slovenian PETs reported problems in teaching gymnastics while children did not attain gymnastics skills prescribed in the curriculum in the first and second three-year cycles (Pajek et al., 2010). Due to significant declines in arm and shoulder strength among Slovenian children (Starc et al., 2016), GTs should also adequately differentiate goals regarding pupils' motor efficiency and thus, in more interesting ways, bring gymnastics contents to various target groups of children. They should also include more climbing, simple hangs and support elements, and acrobatics in the PE lessons.

In the European Union, at the primary education level, schools usually pursue a single-teacher model, in which non-specialist teachers are allowed to teach PE. Nilges (1997) and Štemberger (2003) reported that GTs lacked knowledge about how to teach some difficult content, such as gymnastics; therefore, they often feel unprepared to address progression within the educational gymnastics setting. It has been shown that PEs are more effective for children's physical development and sports skills compared to GTs, especially in the pre-adolescent period (Jurak, Cooper, Leskošek, & Kovač, 2013; Jurak, Strel, Leskošek, & Kovač, 2011; Štihec & Kovač, 1992). Studies of the effects of joint teaching on the physical fitness of children have also shown that those taught by GTs and PETs together are more motor efficient than those taught only by GTs (Starc & Strel, 2012; Štihec & Kovač, 1992), which is expected due to the differences in the competencies of the two profiles (Jurak, Kovač, & Strel, 2004); therefore, both the European Commission and the Council of Europe recommended that 'Qualified and specialised PE teachers should be preferred at all educational levels. When not possible, as a minimum, qualified PE teachers or certified coaches should counsel and support GTs' (European Commission/EACEA, 2017). PETs and GTs can together offer a large amount of knowledge and skills to children; therefore, it is unfortunate that joint teaching is offered only as a higher school standard in Slovenia.

CONCLUSIONS

Gymnastics is one of the key physical activities as it requires a great diversity of movements (Ávalos Ramos et al., 2014; Nilges-Charles, 2008; Novak et al., 2006; Živčić-Marković, 2010); therefore gymnastic contents are an important part of PE curricula throughout the world (Hardman et al., 2014).

The decision to make the first three-year cycle the focus of our research was based on the reports of PETs that children in the last three-year cycle did not attain the gymnastics skills prescribed in the curriculum in the first and second three-year cycles (Pajek et al., 2010). In this age group, it is particularly important that teachers insist on the performance of simple organic forms of movements, preparatory exercises, and exercises to strengthen specific groups of muscles, as this is the only way to successfully maintain or even improve the level of children's movement abilities. Children in the first stages of schooling must develop basic gymnastic skills and learn to incorporate these skills into a variety of self-designed combinations and sequences to develop a broad movement repertoire (Nilges-Charles, 2008).

This study represents an important contribution toward understanding the implementation of the gymnastics curriculum in the first three-year cycle of primary schools in Slovenia. The findings show that GTs did not spend enough lessons on gymnastics per academic year. Moreover, contents that are difficult to learn because they require a higher level of children's physical fitness were not allocated enough lessons in the GTs' annual work plan. Their perception of what is the most important for children's gymnastics performance is contrary to the results of some studies (Ward, 2009); they believe that specialised CK (teaching methods) is less important than children's motor efficiency and self-activity are.

The results warrant debate on the organisation of schoolwork; therefore, the following recommendations are suggested to schools and policymakers on the level of educational policies:

- implement the gymnastics programme in such a way that gymnastic contents are implemented in all stages to realise the educational objectives of the PE curriculum;
- transform and reconcile study programmes regarding gymnastics in all three teaching faculties in Slovenia;
- relevant sophisticated system of CPD for GTs should be designed, which will equip GTs with both common CK (how to perform in a content area) and a specialised one (how to teach gymnastic elements) as this would probably increase the quality of abcG teaching and make gymnastics lessons more efficient;
- prepare web pages with guidelines and examples of good productive learning activities by Gymnastic Association of Slovenia and the Faculty of Sport, University of Ljubljana, to show how GTs could improve their practice with including different gymnastics elements in PE lessons;
- qualified PETs' should support GTs as their mentors;
- promote joint teaching with GT and PET in the first three-year cycle, especially in PE lessons with gymnastics content, which is considered by GTs to be one of the most challenging types of content to teach.

LIMITATIONS

The limitations of this study are in the considerable differences in the organisation and contents of PE curricula and teacher education systems worldwide; therefore, readers should be careful when generalising findings to different countries. As we predefined the scale of the answers in the questionnaire, the respondents were not able to contribute their own opinions on their realisations of PE lessons. Another issue to consider is that only GTs from the capital city Ljubljana were included in the sample.

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TECHNOLOGIES AND SELF-ASSESSMENT AS STRATEGIES FOR COLLABORATIVE GYMNASTIC LEARNING

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Original article

Abstract
The acrosport is an ideal content to work in physical education classes due to its cooperative and integrating characteristics and the multiple benefits it can bring to the students. The aim of this research is to analyze the perception of 81 students of High School after carrying out an acrosport unit using the technologies and involving the students in the evaluation process. For this, a qualitative methodology with descriptive character was used. The instrument for the collection data was the semi-structured interview where questions were addressed about the benefits and difficulties encountered in the development of the unit, as well as about the usefulness perceived by adolescents of the use of video during the development of the unit and self-evaluation. The qualitative data were coded according to the narrative content of the students and analysed with the AQUAD 7 programme. The results show that the students perceive benefits in terms of enjoyment and companionship in this practice. Regarding the difficulties encountered, the lack of time and the specific requirements for the development of this modality are the most outstanding aspects. Furthermore, the student's value positively the use of video in the acrosport classes and the self-evaluation supported by rubrics. In this way, the practice of acrosport contributes numerous affective-social benefits, concluding in addition, that the use of the video and the inclusion of the students in the evaluation allow them to be participants of their teaching-learning process, being able to contribute to the formation of more critical and autonomous people.

Keywords: *acrobatic gymnastics, rubric, video recording, learning management, High School.*

INTRODUCTION

Acrosport is a discipline with innumerable educational and socializing possibilities, because it is a physical activity carried out in a group and, therefore, it can favour the cooperation of students, where creative, artistic and acrobatic factors are in force (Barba, 2010; Cabo, 2011). Likewise, it is a physical activity that due to its cooperative and integrating characteristics allows its use within physical education classes, thus offering numerous possibilities of motor exploration, stimulating space-time notions, developing physical and creative capacities, enjoyment, autonomy and confidence in oneself and in others (Cabo, 2011; Dowdell, 2013). This gymnastic modality, already in the Primary Education stage, is considered an excellent cooperative and integrating proposal for motor and attitude development (Barba, 2010; López Pintor, 2010). In addition, the physical education teachers in the High School stage identify the Acrosport as the most appropriate modality to develop personal and social values in the students and that can favour their teaching-learning process due to its high collaborative component, minimizing the personal differences between classmates (Ávalos, Martínez, & Merma, 2015a). In addition, Reguera and Gutiérrez (2015) argue that the Acrosport improves self-concept levels in those subjects with physical and/or emotional problems, since the students, feeling they participate in the activity they are carrying out and cooperating with their classmates, feel enriched corporally and emotionally.

In spite of all these benefits that this sporting activity could bring within the scope of physical education (PE), there is still a resistance on the part of the teacher to include some gymnastic modalities in his or her programmes, since an erroneous conception of them predominates, an insufficient gymnastic knowledge in the initial training of the teacher and the application of inadequate teaching-learning methodologies (Ávalos, Martínez, & Merma, 2015a). In addition, referring to the problems related to students, we highlight the negative dispositions towards gymnastic practice, mainly focused on fear, insecurities, rejection (Duarte, Carbinatto, & Nunomura, 2015), and negative experiences in PE classes (Ávalos, Martínez, & Merma, 2015b). Along these lines, Stylianou, Kulinna, Cothran and Kwon (2013) focus on strengthening the pedagogical content in the initial training of PE teachers. In relation to the student body, teaching methodologies must be considered, in accordance with their characteristics and thus favouring the most collaborative and social models. Therefore, considering factors linked to personality and interests, differences in motor development and the maturity of students would allow for more effective learning (Nunomura, Okade, & Carrara, 2012).

Acrosport evaluation in Physical Education. Evaluation in PE, as well as educational evaluation in general, should be understood as the ability to identify difficulties, errors, actions that are performed well, in order to analyse them, make judgments and make decisions (Sanmartí, 2010). For this reason, evaluation should be a process of dialogue between all those involved and not be limited to the simple application of examinations, tests or quizzes. When assigning responsibilities to students in this evaluation process, it is very important that the evaluation strategy chosen (such as the rubrics, or checklists) take into account the definition of success criteria and indicate different levels of achievement of objectives (López Pastor et al., 2007). The students are the protagonists of their own learning and the teacher facilitates the success of this process, fostering the critical spirit (Figueiredo, Lago, & Fernández, 2008). The contribution of the students in the evaluation processes in PE passes through the active participation of the students in their own learning through evaluation processes that they themselves carry out on that same learning. There is also peer evaluation, where a student evaluates a colleague and, in turn, is evaluated by the latter (López Pastor et al., 2007). The evaluation has to be shared by all the agents that intervene directly or indirectly in the teaching-learning process, especially between the teacher and the student. The participation of students in assessment processes is not only possible and viable, but also contributes to greater social development, strengthening their autonomy and responsibility and their critical sense (Dorado, 2011; López Pastor et al., 2007). Likewise, in order to carry out the different types of evaluations, there are instruments for making an evaluation in which the students participate in a more oriented, precise and objective way (Sanmartí, 2010).

For this reason, the rubrics are being developed as an interesting resource for an integral and formative evaluation (Gallego & Raposo, 2014; Wolf & Stevens, 2007). Generally, they are designed in such a way that the students can be evaluated objectively and consciously, allowing the teacher to clearly specify what he expects from the student and which are the criteria with which a previously established objective will be qualified (Reddy & Andrade, 2010). Additionally, the internal perception we have of our own actions often does not correspond to the external perception of others (Palao, Hernández, Guerrero, & Ortega, 2011). Thus, the video is for the student an audio-visual medium to show his performance, reinforced by verbal information from the teacher (Ávalos & Vega, 2018) and supported by a rubric. These tools can contribute to the training of people who are more autonomous, critical and capable of making their own decisions. In this sense, Del Pozo (2012) aims to provide new tools to facilitate the evaluation within the subject of PE, more specifically to evaluate the technique in body expression. For this reason, it proposes the rubric as a novel instrument. It points out the importance of being able to show students what is expected of them, as well as knowing the levels of achievement they can reach. In addition, it allows students to carry out a self-assessment, feedback their learning, as well as encourage peer evaluation. The rubric, in the field of gymnastic skills, is already an effective tool in their evaluation (Gutiérrez & Vernetta, 2007). In addition, the use of video allows students to see their own action, providing a greater number of feedbacks and a better learning of the contents, increasing their involvement and motivation for the practice (Potdevin, Bernaert, Huchez, & Vors, 2013). It is an extrinsic channel that can give information both for the knowledge of the execution and for the knowledge of the results, taking more and more importance in the strategies of the teacher to develop the self-assessment of the students (Palao et al., 2011).

In order to contribute to the improvement of the educational process of Acrosport, the purpose of this study was, on the one hand, to analyze the benefits, difficulties and proposals for improvement in the development of Acrosport. And on the other hand, to evaluate the usefulness of the video and self-evaluation through the rubric as strategies for the teaching-learning process of Acrosport, all under the perception of secondary education students.

METHODS

This qualitative research with a descriptive approach is framed in the educational field. In this sense, it is essential to analyse the contributions and perceptions that the participants express in order to go deeper into a specific situation and in a specific context such as, in this case, the educational one (Enright, Coll, Ní Chróinín, & Fitzpatrick, 2017; Pereira, 2011).

This study has been carried out based on available sampling and for convenience. The initial sample was made up of 90 secondary education students from a public educational centre in the province of Alicante (Spain), who were studying the subject of PE. Finally, a total of 81 students (55.55% female; 44.44% male) between the ages of 12 and 13 participated. All the subjects who formed part of the final sample of the study agreed to participate voluntarily under the prior consent of their parents and the management of the educational centre. In addition, the students were informed about the purpose of the study and that it was carried out according to the Helsinki declaration.

The instrument designed and used for data collection was a semi-structured interview composed of five open-ended questions, as shown below:

- What positive or beneficial aspects of the Acrosport stand out?
- What difficulties have you had throughout the Acrosport sessions?

- Did you find it useful to carry out a self-assessment of your work through the rubric and recordings of the group work?
- Has the use of technologies during the development of the Acrosport teaching unit helped you in your teaching-learning process?
- What aspect would you improve in the development of the Acrosport sessions?

Another necessary tool to be able to carry out the Acrosport sessions was the provision of a Smartphone by the students, an issue that was not a problem as it is now a very accessible tool for teenagers.

At first, nine Acrosport sessions were held in February and March 2019. The first two sessions were dedicated to familiarization games, learning gymnastic elements and pyramids in which the complexity increases little by little. They also work on basic issues such as help and safety in practice. The following five sessions were carried out in mixed groups of 4-6 students, formed by the teacher herself to be balanced according to abilities, forming a total of 16 groups. These five sessions were used to elaborate and prepare the final practical exam, with each student and group being able to use the mobile phone and the technological possibilities it offers to record or register their learning when the student considers and thus be able to observe their faults and the improvements achieved in their creation process. The final exam consisted of designing a group composition of Acrosport prepared by themselves, under guidelines set by the PE teacher. In the eighth session the final composition was made, the delivery of the edited recording of the final composition of Acrosport by the students and the recording of the same by the teachers in the execution of the test. The last class was used so that students could evaluate themselves in working groups, using rubric and recording as instruments to analyse and assess their final composition and learning. In addition, parallel to this self-evaluation, the teacher also evaluated the different groups in the same way as the students. The use of the rubric was the same for both the pupils and the PE teacher; they only differ in the data they collect (the group on their own self-evaluation and the teacher on the group). And finally, they were given the semi-structured interview, which they answered individually, in writing and in the gym. The written and anonymous interviews lasted an average of 20 minutes.

The following hypotheses were considered for the qualitative analysis of the information:

- Acrosport can be a motivating content that encourages the development of social and personal skills.
- The use of technology can help the teaching-learning process of the contents of gymnastics.
- The rubric as a self-evaluation tool can involve students in their teaching-learning process by promoting decision making and responsibility.

First, all the information provided and extracted from the interviews was read and analysed in detail, in order to find the first relationships between the students' answers and the hypotheses raised. Subsequently, a coding process was carried out with the frequencies of the students' answers. The definitive code map was obtained, after the triangulation of the codes with two teachers specialized in gymnastic modalities and a PE teacher. We used the *AQUAD 7* software (Huber & Gürtler, 2015) to count the frequencies. The most relevant information was collected in two main themes:

- Theme I: Student perception of the Acrosport implementation.
- Theme II: Student perception of the use of video and self-assessment in the Acrosport learning process.

RESULTS

The findings found are presented under the two main themes of the study. The results are presented in the form of codes together with their absolute frequencies (AF) and the corresponding percentage thereof (%AF), where AF corresponds to the total number of appearance of the concept, found in each of the questions, and the %FA is related to the total of the absolute frequency. These data are also collected in tables and supplemented with some fragments written by the students.

Theme I: Students' perception of the Acrosport implementation. This theme collects the benefits, the difficulties and the proposals for improvement that the students bring in relation to the practice of Acrosport.

The findings referring to the benefits that the Acrosport provides (Table 1) showed that the aspect most frequently valued by students is teamwork (26.43%) pointing out the importance of cooperation, companionship and trust placed in their peers. Additionally, they indicated positively the affinity; enjoyment and amusement (23.56%) perceived in the sessions, followed by the freedom and creativity (18.39%) that awakens in the students the Acrosport. With less presence, are identified as satisfactory aspects gymnastic learning (17.24%) such as tumbling or extended hand support, as well as the innovative character (12.64%) of the discipline. Finally, in a minority of cases, manifestations emerged that claimed not to find any type of benefit or positive aspect in the practice of Acrosport (1.72%).

Table 1
Benefits of Acrosport work in physical education sessions, by students.

Codes	AF	AF%
Team work	46	26.43%
Affinity and enjoyment	41	23.56%
Freedom and creativity	32	18.39%
Gymnastic apprenticeships	30	17.24%
Innovation	22	12.64%
None	3	1.72%
TOTAL	174	

Note: AF- absolute frequency; AF%-absolute frequency percentage.

Table 2
Difficulties encountered in the Acrosport practice, according by students.

Codes	AF	AF%
Lack of time	49	32.02%
Specific requirements	38	24.83%
Lack of material resources	29	18.95%
Colleagues with few workers	25	16.33%
Fear and physical contact	7	4.57%
None	5	3.26%
TOTAL	153	

Note: AF- absolute frequency; AF%-absolute frequency percentage.

Table 3
Student's improvement proposals.

Codes	AF	AF%
Longer practice time	31	30.69%
Auto group choice	26	25.74%
Increase in resources	18	17.82%
Small groups	11	10.89%
Fewer choreographic components	6	5.94%
Variety of exercises	5	4.95%
No proposal	4	3.96%
TOTAL	101	

Note: AF- absolute frequency; AF%-absolute frequency percentage.

Table 4
Use of video recording in Acrosport sessions, according to students.

	Codes	AF	AF%
Yes	Error identification	44	34.64%
	Correction of errors	32	25.19%
	Innovative learning	21	16.53%
	Facilitating progression and comprehension of learning	16	12.59%
	Personal memory	9	7.08%
None		5	3.93%
TOTAL		127	100%

Note: AF- absolute frequency; AF%-absolute frequency percentage.

Table 5
Use the rubric for the self-assessment, according to students.

		AF	AF%
For...	Take into account your criteria	51	52.04%
	To be the protagonists of their own evaluation	20	20.40%
	Facilitate learning progression	16	16.32%
	Greater responsibility	11	11.22%
TOTAL		98	100%

Note: AF- absolute frequency; AF%-absolute frequency percentage.

Below are some of the students' stories about the positive aspects they found in this practice:

I liked teamwork, spending time with my classmates and gaining confidence with myself and my classmates (student_04).

It's something different, fun and very creative (student_16).

I have enjoyed working with music, it is different from other sports that we do in school and in high school and I have learned to do the pine without help (student_22).

We had a lot of freedom and autonomy in the classes, to choose the music, the costume, the dance and some figures (student_31).

I have learned to do the back flip and the pine without help (student_57).

In contrast, in the difficulties linked to the practice of Acrosport (Table 2), problems arise that are associated with the lack of time: short duration of classes (30.02%), specific requirements: gymnastic difficulty (24.83%), and also the lack of material resources: mattresses and loudspeakers (18.95%). Less frequently, other negative factors such as lack of work by peers (16.33%), along with fear and physical contact (4.57%) are found. Finally, a minimal part of the students did not find any problems in the practice of Acrosport (3.29%).

Students highlighted these difficulties in the following paragraphs drawn from their interviews:

We have almost no material, few mattresses and loudspeakers and then we find that there are fellow workers more than others (student_7).

It has been very difficult for us to memorize the figures, order them and invent somersaults, turns and dance steps (student_12).

Some figures are difficult to make, and we can fall, creating insecurity (student_29).

There is a lot of physical contact and I find this uncomfortable. Also, in my group my classmates have been very lazy and not very hardworking (student_40).

Little time to rehearse and my classmates couldn't stay at recess or at home to practice, classes should last longer (student_65).

Additionally, the students expressed proposals for improvement of the Acrosport (Table 3). Among them, it was important to have more practice time (30.69%), to be able to choose the work group (25.74%), to increase material resources (17.82%) and to create smaller groups of students (10.89%). With a lesser presence, the decrease in choreographic components (5.64%) and the increase in the variety of exercises (4.95%) were identified. A smaller percentage did not propose any improvement (3.96%). Students pointed out some of these suggestions in the following sentences:

To have longer classes to be able to practice or more time at recess would be very good (student_03).

To be able to choose the group ourselves or to be able to change groups (student_33).

To be able to choose groups those are smaller (student_72).

More variety in games and buy more mats and speakers (student_37).

Let the final work have less choreography and more figures (student_56).

Theme II: Student perception of the use of video and self-assessment in the Acrosport learning process. As for the importance and use of video recordings (Table 4) with their Smartphones, the majority of students state that they found the use of this tool useful during the teaching unit and as a complement to the rubric (96.03%). The reasons they gave were that video recordings have allowed them to identify errors (34.64%), correct them (25.19%), provide new learning (16.53%), facilitate the progression and understanding of learning (12.59%) and, finally, serve as a personal reminder (7.08%). The students highlighted these aspects in the following sentences:

The video has helped me to see my bugs and correct them (estudiante_12).

With the video we realized that there were things that did not fit as well as we thought, especially the positions and supports (student_26).

The recordings have seemed to me a different way of learning. It's fun and motivating (student_39).

The video and the recordings during the classes have helped me to see the mistakes, learn from them and have the *video of remembrance of the final work (student_44).*

Thanks to the recordings I have been able to observe the improvement from one class to another (student_65).

In addition, there were minimal manifestations in which the students had not found any usefulness to the use of the recording (3.93%).

In relation to the assessment of the use of self-assessment as a learning strategy (Table 5), all students stated that it is important for the development of Acrosport carried out. The reasons given for this were that self-assessment had allowed them to express their personal perception within the evaluation process (52.04%), to be protagonists of their own evaluation (20.40%), to progress in their learning (16.32%), and finally, to have greater responsibility (11.22%). The students highlighted these aspects in the following sentences:

Being able to evaluate myself with the rubric and seeing myself in the video has helped me to know how to do it well next time (student_5).

I liked that we are considered in the evaluation (estudiante_21).

Thanks to the self-assessment I can give my opinion and put a note (student_36).

It is not only the teacher's note that counts (student_51).

We take the evaluation seriously because we have a responsibility and it motivates us (student_76).

DISCUSSION

The aim of this study has been to know the perception of the implementation of Acrosport using video and self-assessment through the rubric as strategies for the teaching-learning process of gymnastic content, all from the point of view of high school students.

The results obtained confirm that the development of the Acrosport content in PE classes' favours teamwork, generates freedom in decision-making and improves the creative abilities of the students, while at the same time working on the activity in a playful environment. Along these lines, Cabo (2011) and Dowdell (2013), among others (Reguera & Gutiérrez, 2015; Vernetta, López, & Gutiérrez, 2008), highlight in the practice of this sport the cooperation between peers, autonomy and enjoyment, developing physical and creative skills. Likewise, Ávalos, Martínez and Merma (2015a), support these benefits by stating that PE teachers perceive the development of gymnastic skills as a content that could guarantee the integral development of students, favouring the acquisition of attitudes such as responsibility, effort, confidence and self-esteem.

However, difficulties arise for students in the practice of this discipline. The most notable is the lack of free time that young people have outside school hours to practice. Although the practice of extracurricular activities (reinforcement, languages, physical activity) could improve academic performance, when they are practiced in excess, they occupy too many hours a day, often leaving little free time to today's youth and adolescents (Rosa & Maria, 2016).

In relation to the specific requirements, linked to the difficulty when performing the somersaults and/or the extended support of hands, among others, Fernández and Méndez (2013) point out that these difficulties could be counteracted using more collaborative methodologies, teaching gymnastic skills in a way appropriate to the development of students and not through very directive and rigid teaching methods. Another way to compensate for these difficulties would be to include and develop the gymnastic skills correctly from the early stages of training so that in later stages learning is not so complicated (Culjak, Miletic, Kalinski, Kezic, & Zuvela, 2014). Within this same section, they also point out the lack of resources. The main problem of the scarcity of material resources is given in the majority of occasions by the cut in economic aids to the different educational centres, which causes a limited provision of specific equipment in the PE classes, reaching to foment in many PE teachers the use of self-built materials as solution to this problematic (Méndez, Fernández, & Méndez, 2012).

Because they consider the lack of practice time and materials to be a problem, the students point out these aspects in the proposals made to improve the development of the Acrosport. At the same time, they emphasize being able to choose themselves the working group in the sessions. When the teacher does not intervene, the students end up grouping by friendship, affinity or sex, and may create situations of discrimination or unequal groups (Ramos & Hernández, 2014). For this reason, on many occasions, the creation of small mixed groups is recommended, taking advantage of the diversity of the existing students in the classroom and promoting inclusion (Velázquez, Fraile, & López, 2014).

With regard to the results of the use of video and recording via Smartphone in PE classes, the majority of students answer that they found useful, highlighting their use in identifying and self-correcting errors for later learning and facilitating the progression and understanding of the same in a different and novel way. Palao et al. (2011) state that better learning results are produced when verbal information is combined with a video system, since the use of video allows students to see their own action, increasing their involvement and motivation through practice, bringing students closer to a more objective assessment of its execution.

Similar studies exist (Aiken, Fairbrother, & Post, 2012; O'Loughlin, Chróinín, & O'Grady, 2013; Potdevin et al., 2013; Trujillo, 2008) where they also use video as an auxiliary instrument in PE classes for self-correcting performance and as a self-assessment system reinforcing motor learning and the achievement of specific skills, in this case gymnastics (Ávalos & Vega, 2018). With respect to the self-assessment of Acrosport's work through the rubric, high school students value this participation as satisfactory since it has allowed them to manifest their criteria, feel protagonists in the evaluation of their work, perceive an improvement in their learning and develop greater responsibility. In this line, Del Pozo (2009) and Gallego and Raposo (2014), see in the rubric an interesting resource for a formative and integral evaluation, considering its motivating and participative use, making possible the autonomy and personal initiative of the students. Additionally, Trujillo (2008) uses the self-assessment cards together with the filming of the assemblies elaborated by the students as an instrument of analysis, in order to enrich the teaching-learning process. Furthermore, Ávalos and Vega (2018) use observation forms together with audio-visual media and conclude that the use of both instruments has made possible a better knowledge and assimilation of diverse gymnastic skills by university students. Involvement in the student assessment process constitutes greater social development, strengthening their autonomy and responsibility, and they are the protagonists of their teaching-learning process (Figueiredo et al., 2008; López Pastor et al., 2007). Haerens et al. (2018) and Ryan and Deci (2019) identify these aspects as basic needs in students whose attention is a priority for teachers.

CONCLUSIONS

Taking into account the results obtained, we can conclude that raising the content of Acrosport using technologies within the teaching-learning process as well as involving students in their assessment in an educational context of High School as applied in this study, can positively favour the teaching-learning process of the students involved, facilitating rewarding experiences and providing numerous benefits in terms of teamwork, creative capacity and the acquisition of attitudes such as responsibility, autonomy and trust, among others. Hence, the importance of students' voices, these must be taken into account to improve and progress in teaching practice and thus optimize student learning.

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THE EFFECTS OF VIDEO MODELING AND SIMULATION ON TEACHING / LEARNING BASIC VAULTING JUMP ON THE VAULT TABLE

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Original article

Abstract
The purpose of this study was to compare the effects of different teaching / learning strategies (i.e., verbal feedback, video feedback with modeling, and video feedback with simulation) on performing basic vaulting skills on the vault table. Three male groups of undergraduate students in physical education (i.e., 135 students, divided into 3 groups of 45 subjects) took part in this study. The groups (i.e., traditional, modeling and simulation groups) were divided on equal terms; students are not gymnasts, have the same level and taught by the same teacher. All participants were pretested to determine initial skill level (i.e., direct piked vault). This study covers 24 stoop direct vault sessions, 21 learning and three evaluations spread over 12 weeks (i.e., 2 sessions per week). A video motion analysis (i.e., using Kinovea software) was used to evaluate direct piked vault skills/performance. The results indicate a better improvement of performance in the modeling group compared to the simulation and traditional groups (vault score, 11.80±1.22 pts, 10.85±1.50 pts and 9.01±1.30 pts, respectively with p<0.01). In addition, the analysis of delta-percentage revealed a considerable enhancements of technical performance in the modeling group (46.93%) compared to simulation (27.62%) and traditional (21.64%) groups. In conclusion, video feedback with model's superposition had led to better learning improvements in vault jump compared with simulation and verbal feedback methods. The video return with the overlay of the model enabled a lot of basic skills learning improvement at the vault table.

Keywords: *video feedback, modeling, simulation, learning, vault table, physical education.*

INTRODUCTION

Following the evolution of new information and communication technologies (ICT), the use of video and appropriate software's has been evaluated in many research areas over the last decades (Casey & Jones, 2011). Also, the video modeling and simulations of the human body has been the subject of many sports studies (Yang, 2015). In fact, the use of technology in the gymnastics learning allows the student to have additional resources to mobilize, learn, and reflect on their learning, production, or even communication. Using video systems in the gymnastics sector, reflects on two distinct approaches to performance: visualization of performance (i.e., qualitative approach) and performance analysis (i.e., quantitative approach) (Mkaouer, Chaabene, Amara, Nassib, Negra, & Jemni, 2018; Potdevin, Vors, Huchez, Lamour, Davids, & Schnitzler, 2018). While totally different, these two procedures for using video work together for a common goal which is improving performance. The use of the various video modes (i.e., modeling and simulation) provides both learners and teachers with an important background information.

In gymnastics, video recordings are mostly used for technical analysis and measurement of kinematic variables (Mkaouer et al., 2018). However, works on motor education have recognized another potential use of this technique, which is modeling and simulation.

The literature exposes several forms of video feedback that inspire the modeling method (Harvey & Gittins, 2014; Potdevin et al., 2018). More recently, three modeling forms have been presented: (1) self-modeling, is a procedure of observational learning with the distinction that the observed and the observer, the object, and the subject, are the same person, (2) expert-modeling, where the observed and the observers are not the same person, and (3) model's superposition (self vs. expert model), were the observer and the observed are superposed in the same video for comparison (Amara, Mkaouer, Nassib, Chaaben, Hachana, & Ben Salah, 2015; Baudry, Leroy, & Chollet, 2006; Boyer, Miltenberger, Batsche, & Fogel, 2009; Le Naour, Ré, & Bresciani, 2019). Likewise, there is a video-simulation, which is a kind of video-modeling, it is a virtualization of the ideal movement (i.e., self-modeling with error correction and technical optimization). Video-simulation, is a virtual reality of learner perfect movement, based on their own abilities (Zhou, 2016).

In the last decades, athletes' knowledge and motor performance are developed with modeling sports skills through simulation and motion analysis software as Human Movement Bulider, Skill Spector and Kinovea (Harvey & Gittins, 2014; Stanescu & Stoicescu, 2012).

The modeling of sports techniques would be a key issue in optimizing performance (Laffay, & Orsay, 2008). Used in combination with video feedback, video modeling shows a significant effect on the behaviour measured in various studies (Boyer et al., 2009; Le Naour, Ré, & Bresciani, 2019; Nielsen, Sigurdsson, & Austin, 2009). This tool also offers an interesting flexibility of use for learning movement: the action can be viewed several times, at different speeds. It can also be stopped on a specific element to be analysed. All these possibilities allow the practitioner to better discern the different phases of the movement and, thus, facilitate its acquisition (Laffay, & Orsay, 2008). Therefore, we can say that the video-modeling would be a very effective teaching tool. It allows both teacher / trainer and taught / athlete to improve their knowledge of body in motion and mental representation during the didactic act (Le Naour et al., 2019). In addition to modeling, there is also a new complex teaching tool, which is video simulation. It is a virtualization of the learner's movement to correct / improve these skills. In the literature, only one study has been carried out in teaching / learning gymnastics skills, more precisely teaching choreography (Zhou, 2016).

Many studies presented a positive effect of video feedback in different physical activities (Clark & Ste-Marie, 2007; Roosink et al., 2015; Weir & Connor, 2009; Veličković, Petkovic, & Petkovic, 2011). Boyer et al. (2009) studied the effectiveness of a video sequence treatment including modeling and feedback on the acquisition of three gymnastic skills in a multiple basis in behavioural design. There was a clear increase in the acquisition of a skill set with the introduction of the video sequence processing. Nielsen et al. (2009) evaluated a procedure in which participants marked the video models and received feedback on the scores. However, only four studies have examined the effectiveness of the combination of video feedback and video modeling by experts and or novices. Baudry et al. (2006) has studied the effect of combined self- and expert-modeling on the gymnast performance of double leg circle on the pommel horse. Amara et al. (2015) has studied the effect of different methods of video feedback on teaching / learning hurdles clearance. Arbabi and Sarabandi (2016) have made known the effect of performance feedback with three different video modeling methods on acquisition and retention of badminton long service. Le Naour et al. (2019) have assessed the effect of 3D feedback and observation (i.e., using model's superposition) for motor learning in teaching gymnastics skills.

However, few researchers have examined the use of video-simulation and feedback for improving the execution of complex athletic skills such as gymnastics routines that require multiple precise body movements and positions. Only Zhou (2016) focused on virtual technology (i.e., simulation), when he studied the effects of automatic choreography software on the gymnastics teaching/learning process. The didactic interest of such study is to determine the extent of the deep learning carried out by physical education students engaged with ICT in the teaching / learning process. Therefore, it is essential for teachers to integrate video teaching / learning activities (i.e., self-modeling, expert-modeling, model-overlay and simulation) into training programs and provide students with specific knowledge from modeling by video feedback and particularly by simulation which provides a link to specific areas of sports training of the human body.

Thus, since the use of simulation in teaching / learning is very rare, the purpose of this study was to compare the effects of different teaching / learning strategies (i.e., verbal feedback, video feedback with modeling, and video feedback with simulation) on performing basic vaulting skills in the vault table. Also, a qualitative and quantitative measure was associated to simplify the complexity of vaulting jump and detect the determinants of performance.

Besides, our hypothesis, based on the previous studies (Baudry, 2003; Boyer et al., 2009; Le Naour et al., 2019; Veličković et al., 2011; Zhou, 2016), was that video-modeling could be better than video-simulation in teaching / learning gymnastics skills for beginner's.

METHODS

Three male groups (age 20.45±1.14 years old, height 1.87±0.32 m, and body mass 80.2±12.3 kg) of undergraduate students in physical education (i.e., 135 students, divided into 3 groups of 45 subjects) and an expert gymnast (i.e., national team male elite gymnast, age 21.54 years, height 1.67 m, and body mass 60.8 kg) took part in this study. The groups (i.e., traditional, modeling and simulation groups) were divided on the basis that students are not gymnasts, have the same level, taught by the same teacher and followed the same training program in the same working conditions (i.e., same hourly, volume and gym). The participants are divided as follows:

- Traditional group (TG) followed a classical learning based on verbal-feedback, technical instructions, safety, explanatory drawings / sketches and partial demonstrations of the teacher.
- Modeling group (MG) followed learning with self-modeling, expert-modeling and model's superposition at each session, in addition to a classical learning based on verbal feedback.

- Simulation group (SG) followed learning with self-modeling and mathematical simulation / virtualisation of their movement, in addition to a classical learning based on verbal feedback.

The expert gymnast participated as a model for the kinematic analysis / modeling of direct piked vault at the vault table.

None of them had received specific intervention before performing the experimental task. It was made clear for them that participation was entirely voluntary and anonymous and that their answers would remain strictly confidential. They were latter informed that the data will only be of used to serve scientific research. The experimental protocol was performed in accordance with the Declaration of Helsinki for Human Experimentation and was approved by the local Ethical Committee.

This study was carried out in two stages (i.e., determination of kinematic model and effects of video-feedback). In the first, a 2D kinematic analysis of direct piked vault was performed (i.e., for the expert gymnast) with two mutually synchronized [Time Code Synchronization, TC-Link] digital cameras [PNJ Cam AEE, Action Cam SD18, 5MP CMOS optical sensor, f / 2.8 lens, 135° wide angle, shutter speed 1 / 4-1 / 10000s, acquisition frequency 120Hz, 720p]. Cameras were placed 5-m away and 1.80 m above the floor with an angle of 60° and 120° for the first and the second camera, respectively. To collect kinematic gymnast vaulting data, twenty markers were attached to the body for digitization. Body markers, using the Hanavan model modified by De Leva (1996), were digitized using the video-based data analysis system SkillSpector® 1.3.2 [Odense SØ – Denmark], (Mkaouer et al., 2018). Similarly, the body segments' COM was computed using the Hanavan model modified by De Leva (1996). In the second, participants, from the three groups (i.e., traditional, modeling and simulation groups), have followed 24 stoop direct vault sessions (i.e., 1h 30min / session), 21 learning and three evaluations spread over 12 weeks (i.e., 2 sessions per week) (Figure 1). Video motion analysis was used through Kinovea software (Jurak, Kiseljak, & Rađenović, 2020; Nassib, Mkaouer, Riahi, Wali, & Nassib, 2017) using an AEE PNJ camera (i.e., Action Cam SD18, 5MP CMOS optical sensor, f / 2.8 lens, 135° wide angle, shutter speed 1 / 4-1 / 10000s, acquisition frequency 120Hz, 720p). The camera was placed at a distance of 5 m of the vault table with a height of 1.80 m. The data simulation, from 2D kinematic analysis (i.e., centre of mass trajectory, take-off angle and speed), was performed using MS Excel and Regressi® Open Source software (Mkaouer, Amara, Tabka, 2012; Trudel, Métioui, & Arbez, 2016) (Figure 2). All participants were pretested to determine initial skill level (i.e., direct piked vault).

This study examined the effect of video modeling (i.e., self-modeling and expert-modeling) and simulation on learning direct piked vault at the vault table by involving the student in problem solving regarding error correcting skills. Mathematical simulation of data, from 2D kinematic analysis, was used to visualize the trajectory of the centre of mass (COM), the angle of attack (i.e., legs / trunk on spring board and arms / trunk on vault table), the position of the trunk, the vertical and horizontal velocity and displacement; all this is done to identify the strengths and weaknesses to improve the direct piked vault (Figure 3).

The experiment was conducted in a gymnastics area of university with the usual conditions of gymnastic sessions of practice. Predictive assessment (i.e., taking performance) took place before the start of the experiment. Arranged situations was organized to learn about this vaulting element (i.e., direct piked vault). During the viewing, the criteria for success in each skill of the vaulting sequence was clearly explained. So, in performing this task, subjects observe partial demonstrations. They visualize key positions of vaulting from postures and rhythmic movements.

The research has begun with four sessions of adaptation with the equipment and the procedure and then a pre-test: it is a predictive evaluation to determine the initial level of gymnastics practice of the students. A formative evaluation has carried out at the fourteenth session and finally the teaching / learning cycle was completed by a summative evaluation test.

Before each experiment, participants were familiarized with the experimental equipment and protocol in order to be able to accurately answer research questions and follow the recommendations given.

During the study, the learning sessions was conducted at the same time of the day for each subject and in their regular class sessions. After the completion of the evaluation sessions, participants were informed about their interventions and received feedback on their performance.

Each vault in gymnastics can be divided into the following seven phases: (a) running, (b) jumping on springboard, (c) springboard support, (d) first flight phase, (e) table support, (f) second flight phase, and (g) landing (Atiković & Smajlović, 2011; Fernandes, Carrara, Serrão, Amadio, & Mochizuki, 2016; Čuk & Karácsony, 2004; Ferkolj, 2010; Prassas, 2002). In the FIG code of points (2017), the evaluation criteria of the vault table are: (a) first flight phase, up to the support with two hands, (b) 2nd flight phase, including the pushing off from the table up to the landing in a standing position, (c) body position in the momentary support on the table, (d) deductions with regard to the deviation from the extended axis of the table, (e) technical execution during the entire vault, and (f) landing. So, the student was scored according to a measure inspired by the FIG code of point (2017) in the principal phases of vault (Figure 4). Table 1 and 2 present the difficulty and execution values of the direct piked vault.

In addition, a scorecard was designed to evaluate vaulting technique (i.e., direct piked vault; figure 4) before and after teaching / learning programs, with a maximum score of 20 points [Technical criteria of assessment (10 pts); Execution Criteria of assessment (10 pts)] for the different phases of vault [Very good (2 pts); good (1.5 pts); medium (1 pts); low (0.5 pts) for each variable] based on kinematic model data (Table 3). Three national judges ensured the assessment of all students during all vaulting evaluations.

Data are reported as mean ± standard deviation and confidence intervals at the 95% level (95% CI). Effect size (*dz*) was calculated using GPOWER software (Bonn FRG, Bonn University, Department of Psychology). The following scale was used to interpret *dz*: < 0.2, trivial; 0.2 – 0.6, small; 0.6 – 1.2, moderate; 1.2 – 2.0, large; and > 2.0, very large (Hopkins, 2002). The normality of distribution, estimated by the Shapiro-Wilk test, was acceptable for all variables. Therefore, a 3 (group: MG, SG, and CG) × 2 (time: pre, post) ANOVA with repeated measures on test was computed. For pairwise comparison, a post hoc / Bonferroni was established. Similarly, the delta-percentage ($\Delta\% = [(G1 - G2) / G2] \times 100$) was calculated to estimate the percentage change between the three methods. The results were considered significantly different (significant) when the probability is less than or equal to 0.05% ($p \leq 0.05$). The statistical study was performed by SPSS® 20.0 software (SPSS Inc., Chicago, IL, USA).

Table 1
Technical Criteria of Assessment.

Phases*	Direct Piked Vault	
	Requirement	Values (pts)
First flight	Minimum attack at 15 ° from the horizontal surface of the vault table, stretched body	4.00
Second flight	Elevation of the body above the vault table, parabolic trajectory	4.00
Landing	In the minimum landing area after 1m from the vault table	2.00

Note: (*) Maximum 10 points.

Table 2
Execution Criteria of Assessment .

Errors*	Deduction (pts)	Description
Small Error	0.25	Deviation <15 ° from the standard position
Medium Error	0.50	Deviation <30 ° from the standard position
Large Error	1.00	Deviation> 30 ° from standard position
Non recognition / Fall	2.00	Falling at the beginning or end of the movement

Note: (*) Maximum 10 points

Table 3
Kinematical Criteria of Assessment.

Technical Score	Take Off		1st Flight			2nd Flight			Landing	
	Angle (°)	Angle trunk/legs (°)	Angle of attack (°)	Angle arms/trunk (°)	Angle trunk/legs (°)	Vertical displacement (m)	Angle of trunk (°)	Angle trunk/legs (°)	Distance (m)	Stability (m)
Very Good (2 pts)	60°-70°	166°-180°	36°-45°	166°-180°	166°-180°	>0.03m	30°-45°	30°-45°	>2m	0 Step
Good (1.5 pts)	71°-80°	151°-165°	26°-35°	151°-165°	151°-165°	0.02m-0.03m	46°-60°	46°-60°	1.6m-2m	1 Small Step
Medium (1 pts)	81°-90°	121°-150°	16°-25°	121°-150°	121°-150°	0.01m-0.02m	61°-75°	61°-75°	1m-1.5m	1 Big Step
Week (0.5 pts)	> 90°	90°-120°	0°-15°	90°-120°	90°-120°	0.00 m-0.01m	76°-90°	76°-90°	<1m	Several Step

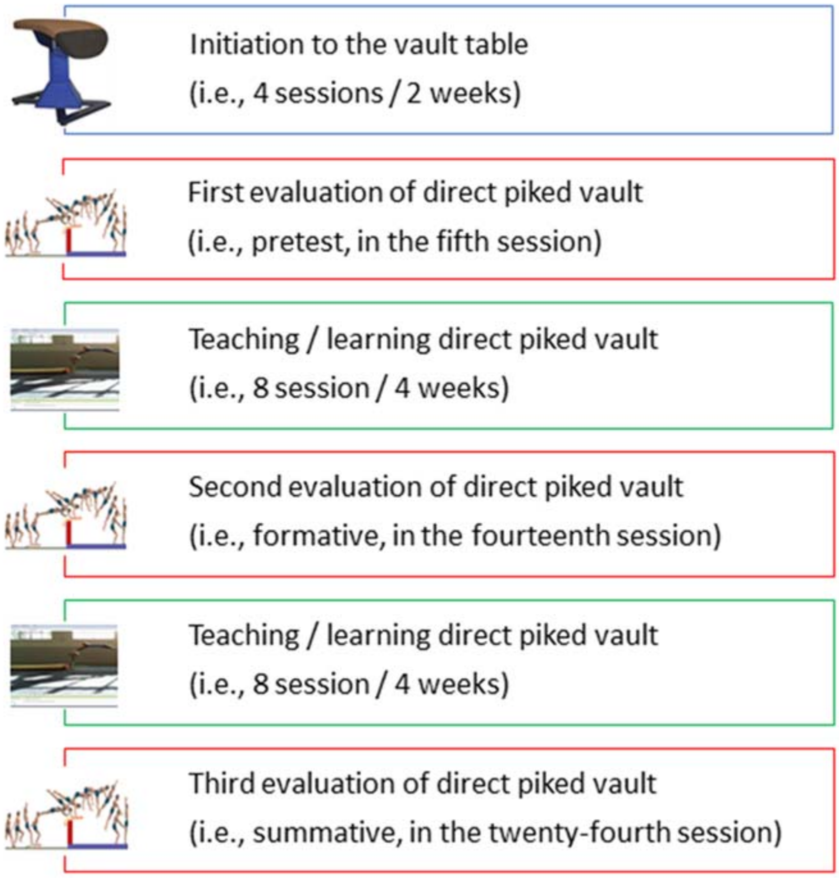

Figure 1. Experimental design of the study.

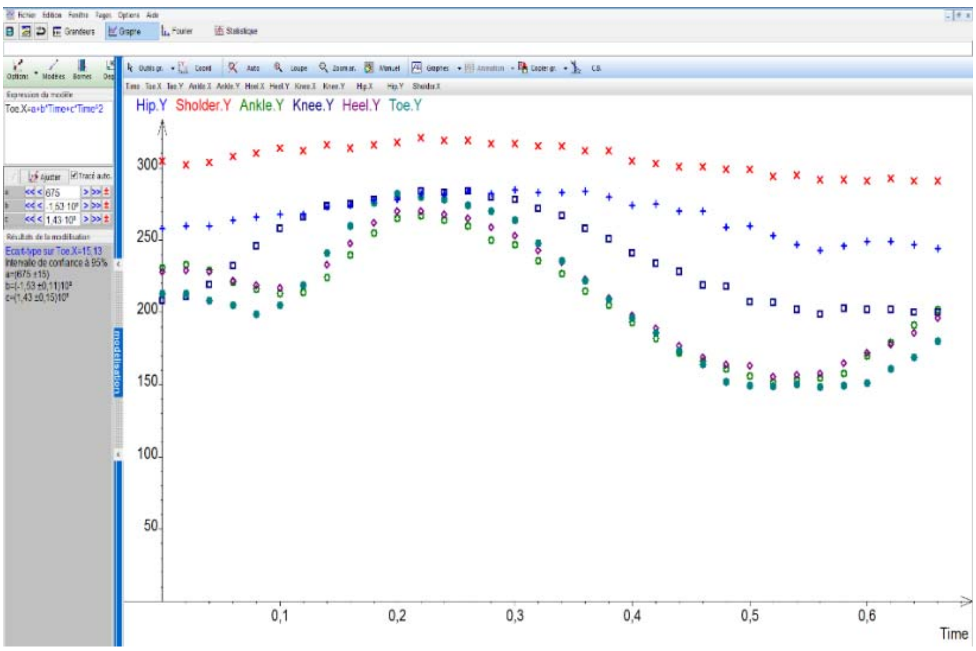

Figure 2. Interface of the Regressi® mathematical simulation software.

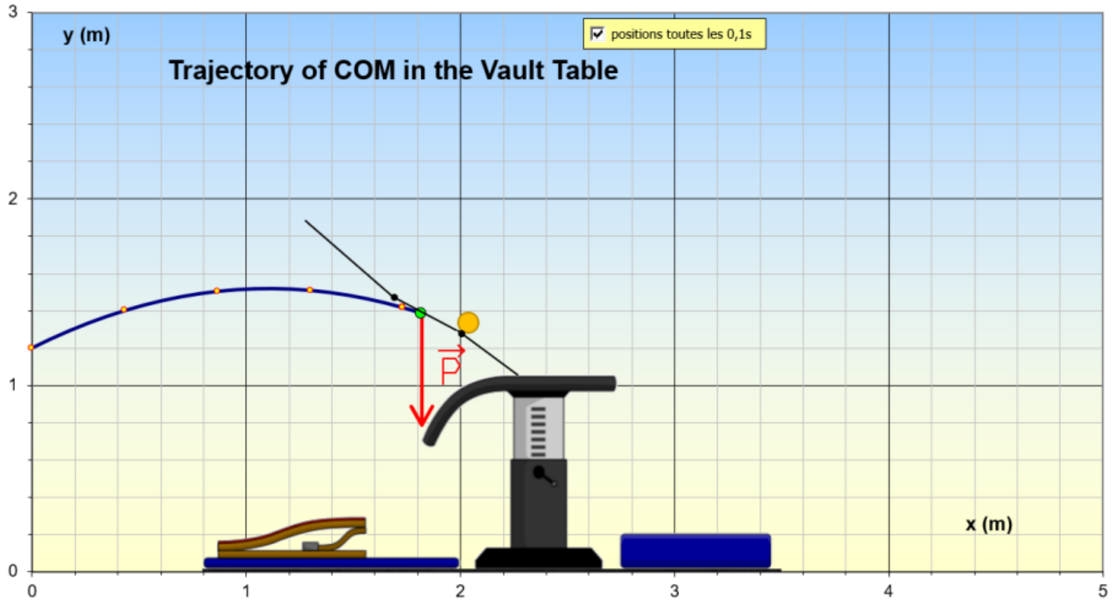

Figure 3. Simulation of the center of mass trajectory in the MS Excel.

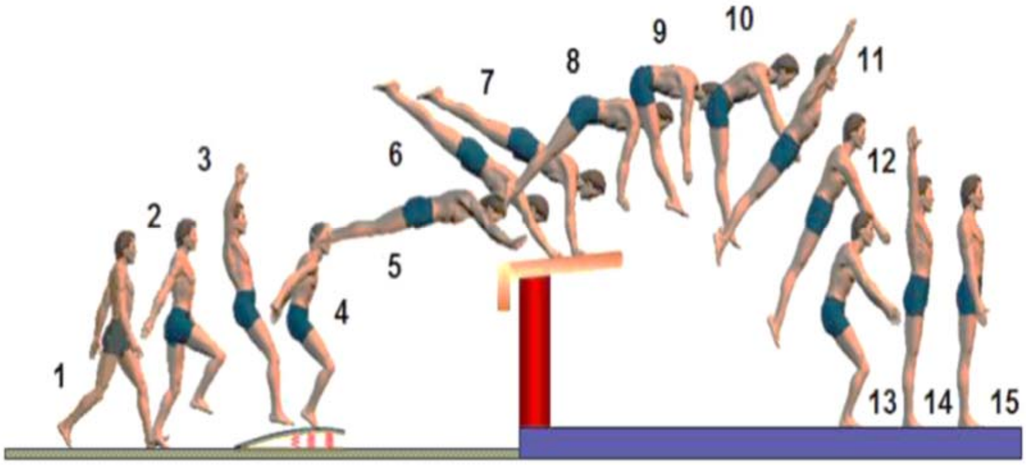

Figure 4. Chronograph of Direct Piked Vault.
Note: Positions [1 - 4] take- off; [5 - 7] 1st flight; [8 - 11] 2nd Flight; [13 - 15] Landing.

RESULTS

Table 4
ANOVA Repeated Measure of Kinematic Variables.

Variables	Traditional Group			Modeling Group			Simulation Group			ANOVA *p* value (*dz*)		
	Pre-test	Post-test	Change (%) (95% CI)	Pre-test	Post-test	Change (%) (95% CI)	Pre-test	Post-test	Change (%) (95% CI)	Time	Group	Group × Time
TO ang SB (°)	72.2±5.3	70.3±4.7	-2.70 (-2.65 to -1.25)	72.8±4.72	65.1±3.1	-10.62 (-9.18 to -6.27)	69.40±5.3	68.20±4.4	-1.76 (-2.59 to 0.14)	0.000 (1.809)	0.012 (0.527)	0.000 (1.484)
Tc/Lg ang TO (°)	128.13±9.77	129.04±8.69	-0.44 (0.88 to 0.01)	124.84±9.58	144.12±8.41	15.82 (15.74 to 23.41)	135.57±9.78	143.20±7.36	5.62 (4.38 to 10.85)	0.000 (1.902)	0.000 (1.216)	0.000 (1.688)
Att ang FF (°)	22.53±4.54	24.57±3.79	9.05 (1.28 to 2.80)	21.26±4.40	30.33±2.65	42.62 (7.54 to 10.59)	22.80±6.49	26.60±4.75	16.67 (1.76 to 5.83)	0.000 (1.972)	0.023 (0.487)	0.000 (1.293)
Am/Tc ang FF (°)	106.20±13.53	115.48±8.08	8.74 (5.87 to 12.70)	105.53±13.49	118.08±9.67	11.89 (7.74 to 17.36)	101.55±13.85	113.51±7.24	11.77 (7.84 to 16.06)	0.000 (1.650)	0.062 (0.413)	0.492 (0.211)
Tc/Lg ang FF (°)	148.48±8.97	151.02±8.51	1.70 (1.34 to 3.17)	148.55±14.24	157.97±10.99	6.34 (3.89 to 14.94)	156.15±17.17	159.02±11.92	1.84 (-1.66 to 7.39)	0.000 (0.717)	0.002 (0.636)	0.033 (0.458)
dy SF (m)	0.172±0.058	0.209±0.044	21.51 (0.026 to 0.049)	0.185±0.051	0.228±0.035	23.24 (0.026 to 0.061)	0.154±0.055	0.182±0.041	18.18 (0.014 to 0.043)	0.000 (1.506)	0.000 (0.762)	0.350 (0.255)
Tc ang SF (°)	108.35±11.10	112.75±7.90	4.06 (2.38 to 6.14)	106.93±10.78	125.86±9.36	17.70 (14.78 to 23.07)	114.11±13.89	120.51±9.60	5.61 (2.35 to 10.45)	0.000 (1.701)	0.001 (0.685)	0.000 (1.102)
Tc/Lg ang SF (°)	64.17±10.04	62.51±10.66	-2.59 (-2.45 to -0.87)	66.44±5.71	51.33±5.94	-22.74 (-17.48 to -12.74)	55.80±12.89	51.66±7.25	-7.40 (-7.91 to -0.35)	0.000 (1.619)	0.000 (0.901)	0.000 (1.359)
Ld dx (m)	1.281±0.201	1.316±0.156	2.73 (0.013 to 0.058)	1.304±0.202	1.582±0.116	21.40 (0.216 to 0.342)	1.268±0.251	1.445±0.189	13.88 (0.092 to 0.261)	0.000 (1.599)	0.000 (0.749)	0.000 (0.974)

Note: (TO ang SB) Take-off angle on spring board; (Tc/Lg ang TO) Trunk/legs angle in take-off; (Att ang FF) Attack angle in first flight; (Am/Tc ang FF) Arm/trunk angle in first flight; (Tc/Lg ang FF) Trunk/legs angle in first flight; (dy SF) Vertical displacement in second flight; (Tc ang SF) Trunk angle in second flight; (Tc/Lg ang SF) Trunk/legs angle in second flight; (dx Ld) Landing Distance.

Table 5
Groups, Bonferroni Post Hoc of Kinematic Variables.

Measures	Groups		Change (%) (95% CI)	Standard Error	Sig.	Effect Size (*dz*)
TO ang SB (°)	Modeling	Simulation	-4.77 (-2.02 to 2.31)	0.893	1.000	0.157
	Modeling	Traditional	-7.91 (-4.43 to -0.10)	0.893	0.037	3.587
	Simulation	Traditional	-2.99 (-4.57 to -.024)	0.893	0.024	3.814
Tc/Lg ang TO (°)	Modeling	Simulation	-4.75 (-8.68 to -0.83)	1.619	0.012	4.153
	Modeling	Traditional	11.28 (2.57 to 10.42)	1.619	0.000	5.676
	Simulation	Traditional	10.52 (7.33 to 15.18)	1.619	0.000	9.830
Att ang FF (°)	Modeling	Simulation	12.31 (-0.84 to 3.04)	0.804	0.521	0.234
	Modeling	Traditional	18.97 (0.29 to 4.19)	0.804	0.018	3.950
	Simulation	Traditional	7.60 (-0.80 to 3.09)	0.804	0.471	0.259
Tc/Lg ang FF (°)	Modeling	Simulation	-4.32 (-9.53 to 0.89)	2.150	0.139	0.375
	Modeling	Traditional	4.40 (-1.70 to 8.72)	2.150	0.314	0.247
	Simulation	Traditional	5.30 (2.62 to 13.04)	2.150	0.001	5.153
dy SF (m)	Modeling	Simulation	20.14 (0.01 to 0.06)	0.009	0.000	6.500
	Modeling	Traditional	8.27 (-0.01 to 0.03)	0.009	0.224	0.258
	Simulation	Traditional	-14.68 (-0.04 to -0.01)	0.009	0.034	3.833
Tc ang SF (°)	Modeling	Simulation	-4.25 (-5.41 to 3.59)	1.859	1.000	0.186
	Modeling	Traditional	10.42 (1.33 to 10.35)	1.859	0.006	4.444
	Simulation	Traditional	6.44 (2.24 to 11.26)	1.859	0.001	5.136
Tc/Lg ang SF (°)	Modeling	Simulation	5.15 (1.04 to 9.26)	1.695	0.009	4.607
	Modeling	Traditional	-21.77 (-8.56 to -0.34)	1.695	0.029	3.981
	Simulation	Traditional	-20.99 (-13.72 to -5.50)	1.695	0.000	8.588
Ld dx (m)	Modeling	Simulation	8.70 (0.01 to 0.16)	0.034	0.034	3.625
	Modeling	Traditional	16.80 (0.06 to 0.22)	0.034	0.000	6.041
	Simulation	Traditional	8.87 (-0.02 to 0.14)	0.034	0.271	0.298

Note:(TO ang SB) Take-off angle on spring board; (Tc/Lg ang TO) Trunk/legs angle in take-off; (Att ang FF) Attack angle in first flight; (Tc/Lg ang FF) Trunk/legs angle in first flight; (dy SF) Vertical displacement in second flight; (Tc ang SF) Trunk angle in second flight; (Tc/Lg ang SF) Trunk/legs angle in second flight; (dx Ld) Landing Distance.

Table 6

Groups × Time, Bonferroni Post Hoc of Kinematic Variables (Differences Pre-test vs Post-test).

Measures	Groups		Change (%) (95% CI)	Standard Error	Sig.	Effect Size (*dz*)
Δ TO ang SB (°)	Modeling	Simulation	6.51 (4.43 to 8.59)	0.858	0.000	1.385
	Modeling	Traditional	5.77 (3.70 to 7.86)	0.858	0.000	1.519
	Simulation	Traditional	-0.73 (-2.81 to 1.35)	0.858	1.000	0.123
Δ Tc/Lg ang TO (°)	Modeling	Simulation	-11.95 (-16.89 to -7.02)	2.034	0.000	0.648
	Modeling	Traditional	-19.57 (-24.51 to -14.65)	2.034	0.000	1.023
	Simulation	Traditional	-7.62 (-12.55 to -2.69)	2.034	0.001	1.008
Δ Att ang FF (°)	Modeling	Simulation	-5.26 (-7.87 to -2.66)	1.076	0.000	0.184
	Modeling	Traditional	-7.02 (-9.63 to -4.41)	1.076	0.000	0.645
	Simulation	Traditional	-1.75 (-4.36 to 0.85)	1.076	0.315	0.154
Δ Tc/Lg ang FF (°)	Modeling	Simulation	-6.55 (-13.67 to 0.56)	2.934	0.081	0.115
	Modeling	Traditional	-6.88 (-14.00 to 0.23)	2.934	0.061	0.138
	Simulation	Traditional	-0.33 (-7.45 to 6.78)	2.934	1.000	0.096
Δ Tc ang SF (°)	Modeling	Simulation	-12.53 (-18.56 to -6.51)	2.486	0.000	0.261
	Modeling	Traditional	-14.53 (-20.56 to -8.51)	2.486	0.000	0.521
	Simulation	Traditional	-2.00 (-8.03 to 4.03)	2.486	1.000	0.087
Δ Tc/Lg ang SF (°)	Modeling	Simulation	10.97 (6.53 to 15.43)	1.834	0.000	0.245
	Modeling	Traditional	13.44 (9.00 to 17.89)	1.834	0.000	0.696
	Simulation	Traditional	2.46 (-1.98 to 6.91)	1.834	0.543	0.107
Δ Ld dx (m)	Modeling	Simulation	-0.10 (-0.21 to 0.01)	0.044	0.062	0.076
	Modeling	Traditional	-0.24 (-0.35 to -0.14)	0.044	0.000	0.752
	Simulation	Traditional	-0.14 (-0.25 to -0.04)	0.044	0.005	0.686

Note: (Δ) delta change; (TO ang SB) Take-off angle on spring board; (Tc/Lg ang TO) Trunk/legs angle in take-off; (Att ang FF) Attack angle in first flight; (Tc/Lg ang FF) Trunk/legs angle in first flight; (Tc ang SF) Trunk angle in second flight; (Tc/Lg ang SF) Trunk/legs angle in second flight; (dx Ld) Landing Distance.

Table 7
ANOVA Repeated Measure of Technical Variables.

Variables	Traditional Group			Modeling Group			Simulation Group			ANOVA p value (dz)		
	Pre-test	Post-test	Change (%) (95% CI)	Pre-test	Post-test	Change (%) (95% CI)	Pre-test	Post-test	Change (%) (95% CI)	Time	Group	Group × Time
TO ang SB	1.67±0.26	1.77±0.25	5.99 (0.03 to 0.16)	1.63±0.26	2.00±0.01	22.09 (0.28 to 0.44)	1.78±0.24	1.85±0.22	3.78 (0.01 to 0.12)	0.000 (1.585)	0.058 (0.434)	0.000 (1.197)
Tc/Lg ang TO	0.91±0.22	0.93±0.20	2.20 (-0.01 to 0.05)	0.82±0.24	1.12±0.21	36.59 (0.20 to 0.39)	1.01±0.16	1.07±0.18	5.94 (0.01 to 0.12)	0.000 (1.182)	0.005 (0.581)	0.000 (1.111)
Fall TO	0.62±0.29	0.49±0.21	-20.97 (-0.18 to -0.6)	0.61±0.30	0.36±0.12	-40.98 (-0.34 to -0.16)	0.61±0.29	0.37±0.12	-37.70 (-0.32 to -0.15)	0.000 (1.572)	0.178 (0.326)	0.055 (0.429)
Att ang FF	1.00±0.21	1.12±0.24	12.00 (0.05 to 0.18)	0.95±0.20	1.51±0.13	57.89 (0.47 to 0.63)	1.04±0.31	1.30±0.28	24.04 (0.14 to 0.36)	0.000 (2.180)	0.000 (0.745)	0.000 (1.268)
Am/Tc ang FF	0.57±0.18	0.65±0.23	21.28 (0.02 to 0.13)	0.57±0.18	0.73±0.25	26.32 (0.06 to 0.25)	0.53±0.12	0.55±0.15	3.77 (-0.01 to 0.05)	0.000 (0.783)	0.005 (0.581)	0.071 (0.305)
Tc/Lg ang FF	1.16±0.26	1.27±0.32	9.48 (0.04 to 0.17)	1.17±0.30	1.48±0.31	26.50 (0.18 to 0.43)	1.50±0.41	1.54±0.36	2.67 (-0.07 to 0.15)	0.000 (0.905)	0.000 (0.876)	0.001 (0.659)
Fall FF	0.57±0.29	0.50±0.23	-12.28 (-0.12 to -0.23)	0.56±0.29	0.36±0.12	-35.71 (-0.28 to -0.12)	0.54±0.29	0.35±0.12	-35.19 (-0.26 to -0.12)	0.000 (1.372)	0.071 (0.402)	0.012 (0.527)
dy SF	0.68±0.24	0.82±0.24	-19.12 (0.05 to 0.20)	0.75±0.25	1.02±0.10	34.67 (0.18 to 0.34)	0.63±0.22	0.67±0.24	6.35 (-0.02 to 0.11)	0.000 (1.188)	0.000 (1.127)	0.000 (0.731)
Tc ang SF	0.91±0.37	1.04±0.31	14.29 (0.05 to 0.20)	0.82±0.30	1.48±0.29	80.49 (0.55 to 0.78)	1.15±0.47	1.34±0.36	15.65 (0.04 to 0.33)	0.000 (1.765)	0.000 (0.745)	0.000 (1.281)
Tc/Lg ang SF	1.12±0.32	1.18±0.37	5.36 (0.01 to 0.12)	1.02±0.23	1.46±0.16	43.14 (0.35 to 0.53)	1.37±0.44	1.53±0.26	10.95 (0.02 to 0.28)	0.000 (1.387)	0.000 (0.943)	0.000 (1.009)
Fall SF	0.65±0.31	0.52±0.22	-18.46 (-0.18 to -0.05)	0.61±0.29	0.33±0.15	-44.26 (-0.35 to -0.19)	0.57±0.29	0.33±0.19	-42.11 (-0.31 to -0.17)	0.000 (1.780)	0.007 (0.557)	0.009 (0.544)
dx Ld	0.96±0.16	1.01±0.74	4.17 (0.01 to 0.08)	1.03±0.22	1.32±0.24	27.18 (0.19 to 0.38)	0.98±0.16	1.15±0.25	16.33 (0.07 to 0.26)	0.000 (1.247)	0.000 (0.993)	0.000 (0.745)
Ld St	0.94±0.66	1.35±0.42	43.62 (0.24 to 0.57)	0.60±0.53	1.35±0.48	125.00 (0.52 to 0.98)	1.31±0.48	1.43±0.53	9.16 (-0.02 to 0.26)	0.000 (1.419)	0.000 (0.706)	0.000 (0.853)
Fall Ld	1.05±0.66	0.64±0.42	-39.05 (-0.57 to -0.24)	1.40±0.65	0.64±0.48	53.57 (-0.98 to -0.52)	0.68±0.51	0.56±0.53	-17.65 (-0.26 to 0.02)	0.000 (1.419)	0.000 (0.706)	0.000 (0.853)
Score	7.06±1.85	9.01±1.30	27.62 (1.57 to 2.33)	6.20±2.40	11.80±1.21	90.32 (4.88 to 6.13)	8.92±1.38	10.85±1.50	21.64 (1.49 to 2.37)	0.000 (3.608)	0.000 (1.167)	0.000 (1.964)

Note: (Tc/Lg ang TO) Trunk/legs angle in take-off; (Att ang FF) Attack angle in first flight; (Am/Tc ang FF) Arm/trunk angle in first flight; (Tc/Lg ang FF) Trunk/legs angle in first flight; (dy SF) Vertical displacement in second flight; (Tc ang SF) Trunk angle in second flight; (Tc/Lg ang SF) Trunk/legs angle in second flight; Fall SF; (dx Ld) Landing Distance; (Ld St) Landing Stability; (Fall Ld) fall in landing; Score.

Table 8
Groups, Bonferroni Post Hoc of Technical Variables.

Measures	Groups		Change (%) (95% CI)	Standard Error	Sig.	Effect Size (*dz*)
Tc/Lg ang TO	Modeling	Simulation	-3.96 (-0.16 to -0.01)	0.037	0.157	0.467
	Modeling	Traditional	-16.83 (-0.03 to 0.13)	0.037	0.533	0.154
	Simulation	Traditional	-13.4 (0.03 to 0.21)	0.037	0.004	3.133
Att ang FF	Modeling	Simulation	13.97 (-0.38 to 0.16)	0.041	0.407	0.194
	Modeling	Traditional	25.74 (0.7 to 0.27)	0.041	0.000	5.733
	Simulation	Traditional	13.68 (0.12 to 0.21)	0.041	0.022	3.700
Am/Tc ang FF	Modeling	Simulation	24.24 (0.02 to 0.19)	0.034	0.004	4.666
	Modeling	Traditional	10.61 (-0.04 to 0.12)	0.034	0.757	0.098
	Simulation	Traditional	-18.07 (-0.15 to 0.1)	0.034	0.104	0.501
Tc/Lg ang FF	Modeling	Simulation	-3.73 (-0.33 to -0.04)	0.060	0.006	4.395
	Modeling	Traditional	14.18 (-0.03 to 0.25)	0.060	0.201	0.326
	Simulation	Traditional	17.27 (0.15 to 0.44)	0.060	0.000	6.976
dy SF	Modeling	Simulation	33.70 (0.13 to 0.32)	0.039	0.000	8.321
	Modeling	Traditional	19.57 (0.03 to 0.22)	0.039	0.003	4.750
	Simulation	Traditional	-21.31 (-0.19 to -0.01)	0.039	0.035	3.571
Tc ang SF	Modeling	Simulation	9.70 (-0.25 to 0.06)	0.065	0.438	0.189
	Modeling	Traditional	29.85 (0.02 to 0.33)	0.065	0.020	3.869
	Simulation	Traditional	22.31 (0.11 to 0.42)	0.065	0.000	5.913
Tc/Lg ang SF	Modeling	Simulation	-4.50 (-0.34 to -0.07)	0.057	0.001	5.300
	Modeling	Traditional	18.94 (-0.04 to 0.22)	0.057	0.363	0.348
	Simulation	Traditional	22.46 (0.16 to 0.43)	0.057	0.000	7.500
Fall SF	Modeling	Simulation	16.40 (-0.09 to 0.22)	0.045	1.000	0.012
	Modeling	Traditional	-55.74 (-0.22 to -0.01)	0.045	0.038	3.562
	Simulation	Traditional	-58.33 (-0.24 to -0.02)	0.045	0.011	4.156
dx Ld	Modeling	Simulation	12.61 (0.02 to 0.18)	0.033	0.006	4.608
	Modeling	Traditional	23.53 (0.10 to 0.26)	0.033	0.000	8.217
	Simulation	Traditional	12.5 (0.01 to 0.16)	0.033	0.040	3.608
Ld St	Modeling	Simulation	-5.74 (-0.63 to -0.15)	0.097	0.000	5.710
	Modeling	Traditional	-0.17 (-0.40 to 0.06)	0.097	0.237	0.306
	Simulation	Traditional	-5.43 (-0.01 to 0.45)	0.097	0.072	0.587
Fall Ld	Modeling	Simulation	12.07 (0.15 to 0.63)	0.097	0.000	5.710
	Modeling	Traditional	0.17 (-0.06 to 0.40)	0.097	0.237	0.306
	Simulation	Traditional	5.54 (-0.45 to 0.01)	0.097	0.072	0.587
Score	Modeling	Simulation	8.05 (-1.55 to -0.21)	0.276	0.005	4.528
	Modeling	Traditional	23.62 (0.29 to1.63)	0.276	0.002	4.958
	Simulation	Traditional	16.94 (1.18 to 2.51)	0.276	0.000	9.487

Note: (Tc/Lg ang TO) Trunk/legs angle in take-off; (Att ang FF) Attack angle in first flight; (Am/Tc ang FF) Arm/trunk angle in first flight; (Tc/Lg ang FF) Trunk/legs angle in first flight; (dy SF) Vertical displacement in second flight; (Tc ang SF) Trunk angle in second flight; (Tc/Lg ang SF) Trunk/legs angle in second flight; Fall SF; (dx Ld) Landing Distance; (Ld St) Landing Stability; (Fall Ld) fall in landing; Score. Flight; (Tc ang SF) Trunk angle in second flight; (Tc/Lg ang SF) Trunk/legs angle in second flight; Fall SF; (dx Ld) Landing Distance; (Ld St) Landing Stability; (Fall Ld) fall in landing; Score.

Table 9
Groups × Time, Bonferroni Post Hoc of Technical Variables (Differences Pre-test vs Post-test).

Measures	Groups		Change (%) (95% CI)	Standard Error	Sig.	Effect Size (*dz*)
Δ TO ang SB	Modeling	Simulation	-30.00 (-0.42 to -0.18)	0.048	0.000	1.896
	Modeling	Traditional	-26.67 (-0.38 to -0.15)	0.048	0.000	1.413
	Simulation	Traditional	3.30 (-0.08 to 0.15)	0.048	1.000	0.333
Δ Tc/Lg ang TO	Modeling	Simulation	-23.33 (-0.35 to -0.12)	0.047	0.000	1.231
	Modeling	Traditional	-27.78 (-0.39 to -0.16)	0.047	0.000	2.256
	Simulation	Traditional	-4.40 (-0.16 to 0.07)	0.047	1.000	0.275
Δ Att ang FF	Modeling	Simulation	-30.00 (-0.45 to -0.15)	0.061	0.000	0.859
	Modeling	Traditional	-43.33 (-0.58 to -0.29)	0.061	0.000	0.664
	Simulation	Traditional	-13.30 (-0.28 to 0.01)	0.061	0.091	0.156
Δ Tc/Lg ang FF	Modeling	Simulation	-26.67 (-0.44 to -0.09)	0.073	0.001	1.309
	Modeling	Traditional	-20.00 (-0.38 to -0.02)	0.073	0.022	0.843
	Simulation	Traditional	6.70 (-0.11 to 0.24)	0.073	1.000	0.300
Δ Fall FF	Modeling	Simulation	1.11 (-0.11 to 0.13)	0.049	1.000	0.151
	Modeling	Traditional	13.33 (0.01 to 0.25)	0.049	0.022	0.843
	Simulation	Traditional	12.22 (0.01 to 0.24)	0.049	0.041	0.577
Δ dy SF	Modeling	Simulation	-22.22 (-0.35 to -0.09)	0.053	0.000	1.681
	Modeling	Traditional	-13.33 (-0.26 to 0.01)	0.053	0.040	0.580
	Simulation	Traditional	8.90 (-0.04 to 0.22)	0.053	0.292	0.414
Δ Tc ang SF	Modeling	Simulation	-47.78 (-0.67 to -0.28)	0.080	0.000	1.334
	Modeling	Traditional	-53.33 (-0.73 to -0.34)	0.080	0.000	0.546
	Simulation	Traditional	-5.60 (-0.25 to 0.14)	0.080	1.000	0.308
Δ Tc/Lg ang SF	Modeling	Simulation	-28.89 (-0.45 to -0.12)	0.068	0.000	0.885
	Modeling	Traditional	-37.78 (-0.54 to -0.21)	0.068	0.000	2.128
	Simulation	Traditional	-8.90 (-0.25 to 0.08)	0.068	0.585	0.531
Δ Fall SF	Modeling	Simulation	2.77 (-0.10 to 0.15)	0.051	1.000	0.126
	Modeling	Traditional	15.00 (0.03 to 0.27)	0.051	0.012	2.121
	Simulation	Traditional	12.20 (0.01 to 0.25)	0.051	0.054	0.759
Δ dx Ld	Modeling	Simulation	-12.22 (-026 to 0.02)	0.057	0.102	0.533
	Modeling	Traditional	-24.44 (-0.38 to -0.11)	0.057	0.000	1.006
	Simulation	Traditional	-22.20 (-0.26 to 0.02)	0.057	0.102	0.533
Δ Ld St	Modeling	Simulation	-63.33 (-0.95 to -0.32)	0.129	0.000	2.136
	Modeling	Traditional	-34.44 (-0.66 to -0.03)	0.129	0.026	0.031
	Simulation	Traditional	28.90 (-0.02 to 0.60)	0.129	0.081	0.560
Δ Fall Ld	Modeling	Simulation	63.33 (0.32 to 0.95)	0.129	0.000	0.533
	Modeling	Traditional	34.44 (0.03 to 0.66)	0.129	0.026	0.577
	Simulation	Traditional	-28.90 (-0.60 to 0.02)	0.129	0.081	0.315
Δ Score	Modeling	Simulation	-36.66 (-4.75 to -2.76)	0.374	0.000	2.480
	Modeling	Traditional	-34.64 (-4.55 to -2.74)	0.374	0.000	2.527
	Simulation	Traditional	2.22 (-0.88 to 0.93)	0.374	1.000	0.606

Note: (Tc/Lg ang TO) Trunk/legs angle in take-off; (Att ang FF) Attack angle in first flight; (Am/Tc ang FF) Arm/trunk angle in first flight; (Tc/Lg ang FF) Trunk/legs angle in first flight; (dy SF) Vertical displacement in second flight; (Tc ang SF) Trunk angle in second flight; (Tc/Lg ang SF) Trunk/legs angle in second flight; Fall SF; (dx Ld) Landing Distance; (Ld St) Landing Stability; (Fall Ld) fall in landing; Score.

The results of the ANOVA repeated measure, for the kinematic variables (Table 4), revealed very significant difference during the studied vaulting phases (i.e., take off, first flight, second flight and landing). Within groups analysis showed that the three groups improved their kinematic variables throughout the diverse phases of vaulting such as distance in landing and stability. Also, between groups showed a significant difference in favour to MG (Table 5). Similarly, groups × time interaction presented a very significant difference (Table 6).

Likewise, for the technical variables, ANOVA repeated measure results (Table 7) showed very significant difference during technical execution. The between groups pairwise comparison (i.e., Bonferroni post hoc), for technical variables, presented significant difference in favour of MG (Table 8). Equally, groups × time interaction results (i.e., differences pre-test vs post-test), for the technical variables, showed significant variance in the learning (Table 9).

DISCUSSION

This study aimed to compare the effects of different teaching / learning strategies (i.e., verbal feedback, video feedback with modeling, and video feedback with simulation) on performing basic vaulting skills in the vault table. After 21 teaching / learning sessions, the primary results showed that the MG enhanced significantly these performances ($p<0.01$) better than SG and TG. This result demonstrated the effectiveness of learning by video modeling procedures for the acquisition and improvement of vaulting skills for students. Indeed, several studies (Horn, Williams, & Scott, 2002; Baudry et al., 2006) demonstrated that video viewing of a model or its own performance is efficient for immediate and long-term learning (Guadagnoli, Holcomb, & Davis, 2002). SG revealed positive impact on performances ($p<0.01$) as compared to TG. Nevertheless, after receiving the learning by classical teaching / learning based on verbal-feedback, TG also enhanced the appropriate movement patterns, which subsequently leads to better outcomes (Hebert & Landin, 1994). However, this group did not use any video support (i.e., self-modeling, expert-modeling and model-overlay or motion simulation), but they may have information, during the vault learning, from their peers who perform the same exercises during the session, this is "inexperienced modeling".

The kinematic study of take-off phase on springboard showed that the take-off angle of attack reveals a significant difference between MG and TG. Also, in this phase, the trunk/legs angle presented a significant difference between groups where MG had the best posture. In fact, MG seems to perform a fast and intense impact on springboard compared to other groups. This enhancement appears to be due to the different forms of video feedback (i.e., expert-modeling, self-modeling and model's superposition), that provide significant information of take-off angle to optimize their performance (Giroud & Debû, 2004; Le Naour et al., 2019; Palao, Hastie, Cruz, & Ortega, 2013; Potdevin et al., 2018). Indeed, it is noted that learning with video modeling of gymnastic skills has a positive effect on improving student performance. These results are confirmed by the research of Baudry et al. (2006) who argue that the video modeling helps the gymnast to develop a cognitive representation of movement. So, by viewing sequences, the subject will analyse the steps necessary to achieve the motor performance.

Similarly, the attack angle in the first flight was significantly increased in favour of MG more than SG and TG. Likewise, SG improved the support phase better than TG. This proves that the video feedback helps students enormously to build a mental image of the gesture (Rymal & Ste-Marie, 2017).

Furthermore, vertical displacement, in the second flight, has significantly increased for MG better than SG and TG. It appears that the fast and intense impact on springboard and the support phase pushing arms might increase height of 2nd flight for MG (Veličković et al., 2011).

Trunk angle in second flight was also more important for the MG compared to the TG. Similarly, for SG and TG, we note better trunk straightening for SG. The trunk straightening in the second flight is better for MG and SG, due to a better understanding / representation of the movement (Le Naour et al., 2019; Potdevin et al., 2018; Rymal & Ste-Marie, 2017). In addition, our investigation showed that the trunk/legs angle, in second flight, has been also improved for MG vs TG and for SG vs TG. Perhaps an excellent 2nd flight depends on the characteristics of previous phases (Aticović & Smaljović, 2011; Heinen, Vinken, Jeraj & Velentzas, 2013).

Lastly, in kinematic study, the MG displayed better improvements in landing distance followed by SG compared to TG. The video observation of a reference model (i.e., expert gymnast) is interesting for several reasons. Indeed, when the model is an expert gymnast, the convenient skill execution on performance was served as a source of information for observers (Rymal & Ste-Marie, 2017). In this context, the expert-model provides the learner with information to reach the task goal (Magill & Schoenfelder-Zohdi, 1996; Rymal & Ste-Marie, 2017). A visual model may serve as the best mechanism for encoding and retrieving information from memory (Meany, 1994). In addition, the simulation model is an interactive feedback with error correction and technical optimization. It allows students to learn with initiative, instead fo passive memorization, and promotes understanding and motion knowledge (Zhou, 2016).

Otherwise, the most important finding of the technical study is the advantage of video-feedback with model's superposition, which allows a better perfection in the technical learning (Baudry et al., 2006; Le Naour et al., 2019). The results signposted a better improvement in the performance for MG compared to SG and TG. For instance, the take-off phase shows that MG is more effective in reducing the deduction score than SG and TG. Also, the spring board take-off angle score was increased in favour of MG in comparison with SG and TG. Similarly, MG increase their trunk/legs angle score, in take-off, than the other groups (i.e., SG and TG). Moreover, we note an increase for SG compared to TG. This enhancement can be allocated to the different forms of video feedback (i.e., expert-modeling, self-modeling and model's superposition), that provide significant information to optimize performance (Giroud & Debû, 2004; Le Naour et al., 2019; Palao et al., 2013; Potdevin et al., 2018).

Other enhancement was noted in favour of MG, we found an increase of the attack angle score at the first flight in comparison with SG and TG. Similarly, the largest enhancement for arm/trunk angle score was noted in the MG compared to SG and TG.

Regarding, the vault second flight, MG increased his score better than the others groups (i.e., SG and TG) in vertical displacement and trunk angle. MG and SG reached better score compared to TG. Also, in the landing phase score (i.e., stability and landing distance), MG is more effective in increasing his score followed by SG and TG.

In an earlier study (Amara et al., 2015), the modeling form has proven in promoting student learning technical gesture. So, the technical score of MG is significantly higher than the SG and TG. Nevertheless, SG improved his score better than TG.

The repeated observation of a reference model would facilitate the development of internal reference (Magill & Schoenfelder-Zohdi, 1996) or cognitive representation (Carroll & Bandura, 1990), necessary for appropriation of essential coordination to perform a complex motor skill. In addition, the information attained by self-modeling, can influence the development of a memory representation of the skill and facilitate technical faults correction and subsequent learning (Giroud & Debû, 2004; Palao et al., 2013; Rymal & Ste-Marie, 2017).

This finding has been validated as well, in previous studies in the field of motor skills particularly by the study of Carroll and Bandura (1987). The authors prove that the observation of an external model is effective at the beginning of the new coordination acquisition that consists of a complex motor sequence. This will allow students to have a better understanding of the driving task and monitor the progress because after viewing the images, they are better able to understand the movement, particularly in terms of sequence. In a second phase, knowledge of performance, delivered through a video feedback, enables the refinement of the internal model (Le Naour et al., 2019; Potdevin et al., 2018; Rymal & Ste-Marie, 2017). Students observe the expert-model, the self-model, the model's superposition and or the model simulation then practise and remember the skill information, which is used to correct their movement and enhance their technical abilities compared to students with verbal feedback (Clark & Ste-Marie, 2007; Giroud & Debû, 2004; Palao et al., 2013). In fact, video modeling and video feedback for gymnasts are highly effective for increasing the execution of a skill that has already been learned at a basic performance level, as was found by Rikli and Smith (1980).

It has been previously shown that deep learning with a video feedback using model's superposition and / or model's simulation is better than verbal feedback in teaching / learning gymnastics skills (Baudry et al., 2006; Boyer et al., 2009; Le Naour et al., 2019; Potdevin et al., 2018; Zhou, 2016). Therefore, using video modeling with model's superposition provides educators with pedagogical tools to promote a deeper understanding of the human movement and its relationship with athletic performance.

CONCLUSIONS

The findings of this study highlighted the positive effect of the three methods (i.e., verbal feedback, video feedback with modeling, and video feedback with simulation) in improving the learning and performance of direct piked vault in the vault table. However, students assigned to the video feedback have reported a greater enhancement in comparison with students assigned to the other methods, particularly video feedback with modeling. The outcome of our study gives the ample evidence that ICT plays a key role in teaching technical skills for physical education students and demonstrated the benefits of using digital technologies in physical education when integrated into a pedagogical approach. This enables the educators and the students to find the right solution to a similar problem or situation. For instance, it is important for educators and coaches to integrate video learning activities (i.e., self-modeling, expert-modeling, model's superposition and model's simulation) in students / gymnasts training programs to give learners the opportunities to improve the specific knowledge through video modeling.

Finally, the present results have an important practical implication for students / gymnasts, teachers / coaches who can benefit from the importance of model's superposition and simulation process that revealed effectiveness of technologies in the pedagogical field of gymnastics and in the enhancement of athletic performance.

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THE EFFECTS OF DIFFERENT GYMNASTICS TRAININGS ON BODY COMPOSITION AND SOME PERFORMANCE COMPONENTS IN ADULT MALE NON-GYMNASTS

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Original article

Abstract

The aim of this study was to compare the effects of artistic and trampoline gymnastics training on body composition and some of the physical fitness components in adult non-gymnasts. Forty-eight adult non-gymnasts were randomly assigned to three groups: a trampoline gymnastics group (TG) (n = 16), an artistic gymnastics group (AG) (n = 16), and a control group (CG) (n = 16). Two of the group except the CG performed different gymnastics training, including artistic and trampoline gymnastics twice a week during 12 weeks. The control group performed only a warm-up exercise twice a week along the study. To determine the effects of each gymnastics training on body composition, Y dynamic balance test that including six postural tasks, vertical jump, standing long jump and two different flexibility tests, were performed before and after the study for all groups. The AG and TG were significantly (p<0,05) improved when it comes to all bio-motor abilities in adult non-gymnasts after 12 weeks of training. But the trampoline gymnastics exercises may be seen to be more efficient compared to the artistic gymnastics exercises. The trampoline exercises may be recommended as an alternative mode of exercise for improving bio-motor abilities.

Keywords: *gymnastics, balance, vertical jump, standing long jump, flexibility.*

INTRODUCTION

In daily life, while walking, stepping up the stairs, and in sports activities like in football, rugby, judo, and wrestling etc., the control of body posture is critical and necessary. All the activities associated with movements require both the control of posture and the control of a steady posture (Asseman, Caron, & Crémieux, 2008). Today it is believed that it is necessary to begin the training in early childhood to perform a high level of complex motor performance in many sports disciplines (Boraczyński, Boraczyński, Boraczyńska, & Michels, 2013). Strength, flexibility, and muscular endurance, combined with speed and coordination are required for the sport of gymnastics (Bencke et al., 2002; Jemni, Sands, Friemel, Stone, & Cooke, 2006). Artistic gymnastics training leads to develop the natural postural control in most gymnasts who start their training at an early age of 6-7 years (Kochanowicz, Boraczynska, & Boraczynski, 2009; Garcia, Barela, Viana, & Barela, 2011). The studies' result presents that modern artistic gymnasts need to have an essential greater strength and power because of the ever-increasing technical difficulties (French et al., 2004). Trampoline is described by a dynamic movement pattern (Atilgan, 2013). Different types of jumps are performed on trampoline equipment. There are different sizes and shapes, and according to the elementary division it is distinguished as large, double mini and a mini trampoline (Atiković, Mujanović, Mehinović, Mujanović, & Bilalić, 2018). The lower extremities are used mostly in trampoline exercises and it particularly includes balance and movement control. The body position control is important at the time of jumps, and to use convenient balanced landing and jumping techniques in trampoline exercises (Atilgan, 2013).

There have been no published studies about the different gymnastics training effects with respect to characteristics of fitness in adult groups. The aim of this study was to compare the effects of artistic and trampoline gymnastics training on body composition and some selected components of physical fitness in adult non-gymnasts, who started an introductory level of gymnastics and after the completion of gymnastics training. It has been hypothesized that trampoline gymnastics training would affect the jumping and dynamic balance performance more than artistic gymnastics. However, artistic gymnastics would affect the flexibility more than trampoline gymnastics.

METHODS

48 healthy males who did not perform any sports activity regularly participated voluntarily in this study. Subjects who have any lower extremity injury past 3 months were excluded from this study. Before starting the study, all subjects were informed about it and signed an informed consent form. The study was approved by the Ethical Committee of Hitit University.

Subjects were randomly assigned to 3 groups as follows: Artistic Gymnastics Group (AG), Trampoline Gymnastics Group (TG) and Control Group (CG). All subjects participated in training twice a week through 12 weeks. Subjects in the CG performed only warm up and cool down activities. Subjects in the AG and TG performed gymnastics training which differs from the CG. The gymnastics exercises for the AG and TG are described below.

Warm up and cool down exercises. All subjects started every training session with 5 minutes of walking and jogging. After that, they performed gymnastics stretching exercises including upper and lower body extremities for 10 minutes. Subjects performed 5 minutes jogging for a cool down at the end of each training session.

Artistic gymnastics exercises. Subjects in the AG performed 30 minutes training programs which included forward-backward acrobatics and non-acrobatic exercises on the floor mat after the warm up protocol. International Gymnastics Federation (FIG) approved mat (Spieth/ Germany) was used as a floor. Subjects performed each move 8 times in one session. Artistic gymnastics exercises are described in Table 1.

Trampoline gymnastics exercises. Subjects in the TG performed 30 minutes training programs which included basic jumps, landing, rolling and twisting exercises on a mini trampoline to a mat after the warm up protocol. The International Gymnastics Federation (FIG) approved mini trampoline (Minitramp 125, Article ID: 60500, Eurotramp/Germany) was used as a mini trampoline. Subjects performed each move 8 times in one session. Trampoline gymnastics exercises are described in Table 2.

In this study subjects performed performance tests twice throughout 12 weeks. The first one was performed before starting the training program and the second one was performed by the end of the 12 weeks training program. Performance tests were carried out on 3 separate days. The subjects performed a familiarization session for all the performance tests before the formal testing to eliminate the learning effect. First day: The subjects' body weight, height and body composition analysis were measured. Second day: The subjects' sit and reach and trunk flexibility tests were performed. Third day: balance, vertical and standing long jump tests were carried out. All performance tests were performed at the same time of the day (10:00-12:00 a.m.) by the same researcher. Subjects were instructed to avoid consuming caffeine or any other stimulant before the performance tests. 5 minutes of running and 2 minutes of walking were carried out by subjects before the performance tests.

Body composition. The subjects' body height was measured by using Seca 213 stadiometer. Body weight and body composition were measured by using the Tanita BC-418 body composition analyzer.

Flexibility tests. Sit and reach, trunk flexibility tests were used to obtain subjects' flexibility scores. Subjects performed two trials within 1-minute rest period between the trials for flexibility tests. The best score was recorded. The subject was asked to wait at least 2 seconds at the maximum reached distance. The trial was not considered successful if the subject: a) failed to maintain the contact with the target (e.g. kicking the target), b) failed to maintain position at least 2 seconds at maximum reached distance.

The subject lied down on a mat with a prone position and the researcher stabilized the subject from the hip. The subject was asked to raise slowly the chest and head to the maximum height with interlaced fingers behind the head. The maximum chin height from the mat was measured and recorded as trunk flexibility (Miller, 2006).

Dynamic balance test. Y balance test was used to obtain subjects' dynamic balance performance. The Y balance test tool consists of a footplate to which three pieces of cylindrical wooden are attached in the anterior, posteromedial, and posterolateral directions. There is a 135 degrees angle between the posterior parts and the anterior part. The angle between the posterior parts is 45 degrees. The subject pushes the target on the cylindrical wooden part along the all directions (Plisky et al., 2009).

All subjects performed the test without shoes. The subjects stood on one leg on the footplate so as not to cross the starting line. While standing with the single leg on the footplate, the subjects were asked to reach a maximum distance with the free limb along the anterior, posteromedial and posterolateral directions respectively. The trial was considered successful when the free limb was brought back to the starting line on the footplate. The trial was not considered successful if the subject: a) failed to maintain single leg stance on the platform, b) failed to maintain free limb contact with the target on the wooden part while it was in motion, c) used the target for stance support, d) failed to return the free limb to the starting position under control. The trial was repeated when the subject failed (Plisky et al., 2009). All subjects performed 3 successful trials for each direction. After 3 successful trials, the maximum distance reached by the subject was recorded as a centimeter. This procedure was repeated for both legs. The reached distance was normalized by the length of the limb. The normalized value was calculated by dividing the reached distance by the length of the limb and then multiplying by 100 to express as a percentage.

Lower limb length measurement. Lower limb length was measured while the subjects lied down with the supine position on a mat table. The subjects' limb length was measured in centimeters with a cloth tape measure. The measurement was performed from the anterior superior iliac spine to the most distal portion of the medial malleolus (Plisky, Rauh, Kaminski, & Underwood, 2006).

Vertical jump test. A tape measure was taped on the wall to obtain the subjects' vertical jump heights. The subject stood with the dominant side towards to wall. The subject was asked to reach as high as possible and make a mark on the wall and then jump as high as possible and make another mark on the wall. The difference between reached and jumped marks wasmeasured and recorded as a vertical jump height. All subjects performed 3 trials. The best trial was recorded as a centimeter (Sargent, 1921).

Standing long jump test. A tape measure was taped to the floor. The subject stood with feet shoulder width apart and toes just behind the starting line. The subject jumped forward as far as possible with both feet by bending the knees and swinging the arms. Maximum distance from the starting line was recorded as a standing long jump score. 3 trials were performed by all subjects. The best trial was recorded as a centimeter (Adam, Klissouras, Ravazzolo, Renson, & Tuxworth, 1988).

The data were described by mean ± standard deviation (SD). The normal distribution and homogeneity of data were confirmed by the Shapiro-Wilk test and Levene's test respectively. Paired sample t-test was used to compare the difference between pre-test and post-test values of body composition, flexibility, vertical jump and standing long jump for all groups. One-way ANOVA test applied to compare the differences between pre-test and post-test values of groups. Tukey post-hoc test was used to determine the difference between groups. Wilcoxon signed rank test was used to compare the pre-test and post-test values of dynamic balance for all groups. Kruskal Wallis test was used to compare the differences between pre-test and post-test values of groups. IBM SPSS 25 package program was used for statistical analysis. For statistical analysis, the significance level was set up as $p \leq 0,05$.

Table 1
Artistic gymnastics training program.

Week	Exercises
1	Forward and backward roll
2	Forward and backward straddle roll
3	Straddle cartwheel with help
4	Straddle cartwheel
5	Handstand with help
6	Handstand and handstand walking
7	Backward block fall from handstand hoop on the springboard
8	Front handspring with help
9	Cartwheel with help
10	Cartwheel
11	Back handspring with help
12	Back handspring

Table 2
Trampoline gymnastics training program.

Week	Exercises
1	Running to mini trampoline on basic jump exercise on trampoline
2	Learning body position during jumping on mini trampoline
3	High jump from mini trampoline and landing on the floor
4	Jumping with straight body position from mini trampoline and landing
5	Jumping with tucked body position from mini trampoline and landing
6	Straddle jump from mini trampoline and landing
7	Jump with 180° twist from mini trampoline and landing
8	Jump with 360° twist from mini trampoline and landing
9	Jump to handstand from mini trampoline to high mat
10	Jump from mini trampoline to handstand and handstand forward roll on the mat
11	Dive roll from mini trampoline to the mat
12	Salto forward from mini trampoline to the mat

RESULTS

The subjects' body composition changes presented in Table 4. The AG and CG groups showed a significant increase in body weight, body mass index, the fat percentage from pre-test to post-test. No significant differences were found in fat-free masses for all groups from pre-test to post-test. There were significant differences between groups in body weight, body mass index, and fat percentage. Post hoc analysis showed that there were significant differences between the TG and CG in body weight and body mass index. Besides, there were significant differences between the training groups (AG, TG) and the CG in fat percentage.

The Y balance test results showed a significant increase in the balance performance for the AG and TG groups, in comparison to a significant decrease for the CG from pre-test to post-test (Table 5). Significant differences were founded between all groups, such as the TG showed a strong increase for Y balance test results.

Significant differences were observed for all groups from pre-test to post-test values for vertical jump, standing long jump, sit and reach, and trunk flexibility (Table 6). Significant differences between groups were observed for vertical jump and standing long jump results. Although strong significant differences were observed between the training groups (AG, TG) and control group, there were none between the AG and the TG groups in regard to sit and reach trunk flexibility results.

DISCUSSION

The present study is the first one to compare the effects of artistic and trampoline gymnastics training on body composition and selected components of physical fitness; including balance, vertical jump, standing long jump, and flexibility in adult non-gymnasts who started an introductory level of gymnastics. The first main findings were that body weight (1,64% for the AG, 2,98 % for the CG), body mass index (1,55 % for the AG, 2,98 % for the CG), and especially fat percentage (the increasing: 8,85 % for the AG, 18,47 % for the CG) showed a significant increase from pre-test to post-test in the AG and CG groups during the 12-week training. However, in the TG group, fat percentage (13,42±4,73 – 13,51±4,66 % from pre-test to post-test) was not changed significantly during the trampoline training. Additionally, a marked increase did not occur in body weight (76,93±11,05 – 76,98± 12,05 kg from pre-test to post-test) in periods of the trampoline training (Table 4). Aalizadeh, Mohammadzadeh, Khazani, and Dadras (2016) reported that 20-week trampoline training decreased significantly body fat % in 11–14-year-old students and had positive effective results in anaerobic physical fitness. Witassek et al. (2018) reported that after an 8-week mini-trampoline training, body fat percentage was reduced to 5,4% in the study group. There are not enough studies (Aalizadeh et al., 2016; Witassek, Nitzsche, Schulz, 2018) made for the purpose of evaluating body composition changing. The results of study present that the trampoline training may be used to protect body weight and fat percentage without changing them. However, the studies may not be seen to enough for a clear conclusion; because of that, the effects on body composition should be examined separately in future training studies.

In the present study, the scores of the gymnastics groups have statistically increased significantly, according to the Y dynamic balance test, but comparing the scores between the groups, the most remarkable increasing (the range of increasing: 10,38 – 16,76 % in the TG; 5,16 – 8,35 % in the AG) in all direction occurred in the TG. In contrast to these results, in the CG Y balance scores were affected negatively (the range of decreasing: 2,03 – 3,19 % in the CG) (Table 5). The results of the Y balance indicate that trampoline gymnastics training seems to be of a more "increasing" status compared to the artistic gymnastics training. In an examination of the literature, Sadeghi and Baqlaei (2018) conducted a study including the superiority of the underwater trampoline training compared to traditional aquatic training. The study results indicated that the underwater trampoline exercise group improved 65 % on the static balance variable, while the aquatic exercise group improved by 20%. Kidgell, Horvath, Jackson, and Seymour (2007) reported that trampoline exercises were practiced in the standing position, which led to more muscle involvement in the body and develops the balance. Aragão, Karamanidis, Vaz, and Arampatzis (2011) studied the effects of mini-trampoline exercise for dynamic stability on the ability of elderly participants, who regained balance improvement of about 35%. Besides, the subjects who took part in the exercise group showed an improvement in muscle strength of the triceps surae muscles by about 10% after the intervention. Witassek et al. (2018) reported that after the mini trampoline training, the subjects' jumping height performance increased by 7,7 %, and the control group increased by 4,4 %, but not found statistically significant differences between pre and post-test. Atilgan (2013) found that 12 weeks of trampoline training had positive effects on the jump, leg strength, static and dynamic balance of boys who don't do any exercises regularly. de Oliveira, da Silva, Dascal, and Teixeira (2014) reported that 12 weeks of mini-trampoline, floor, and aquatic gymnastics training improved the postural balance of elderly women. Boraczyński et al. (2013) evaluated the effects of a 12 month artistic gymnastics training program on body composition and physical fitness on girls aged 7 years. The participants' static balance test results significantly improved by 36,77 % between the pre and post-test. The results of these studies approve that trampoline training had positive effects on dynamic balance. The findings of the study are in agreement with the previous studies (Boraczyński et al., 2013; Atilgan, 2013; Witassek et al., 2018; Sadeghi & Baqlaei, 2018; Kidgell et al., 2007; Aragão et al., 2011; de Oliveira et al., 2014; Karakollukçu, Aslan, Paoli, Bianco, & Sahin, 2015). As a consequence, taking into account the study and literature's findings, we may suggest that for improving balance, the training programs could include more trampoline exercises to provide more improvement in balance ability.

Table 3
The characteristic of features of groups.

Variables	AG Mean ± SD	TG Mean ± SD	CG Mean ± SD
Age	20,44± 2,03	21,81± 1,68	20,88± 1,67
Height (cm)	173,51± 6,74	177,76± 7,86	172,88± 6,04
Weight (kg)	67,68 ± 5,24	76,93± 11,05	72,16± 7,34
BMI (kg/m^2)	22,53± 1,96	24,32± 2,90	24,16± 2,37
Fat (%)	10,39± 2,91	13,42± 4,73	14,73± 2,54

Table 4
Results of body compositions.

Variables	Groups	Pre-Test Mean ±SD	Post –Test Mean±SD	Δ%	p
Weight (kg)	AG	67,68± 5,24	68,79± 5,30	1,64	0,016
	TG	76,93± 11,05	76,98± 12,05	0,06	0,927
	CG	72,16± 7,34	74,31± 7,47	2,98	0,000
Body Mass Index	AG	22,53±1,96	22,88±1,78	1,55	0,019
	TG	24,32± 2,90	24,28±2,81	-0,16	0,849
	CG	24,16±2,37	24,88±2,40	2,98	0,000
Fat %	AG	10,39± 2,91	11,31± 3,07	8,85	0,007
	TG	13,42±4,73	13,51±4,66	0,67	0,805
	CG	14,73± 2,54	17,45±2,33	18,47	0,000
FFM (kg)	AG	60,56±3,71	60,92±3,79	0,59	0,145
	TG	66,35±8,41	66,26±8,78	-0,14	0,652
	CG	61,42±5,38	61,24±5,23	-0,29	0,224

Note: Δ%: Percent change between pre-test and post-test, AG: Artistic gymnastics group, TG: Trampoline gymnastics group, CG: Control group.
$p \leq 0,05$

Table 5
Results of the dynamic balance test.

	Groups	Pre-Test		Post-Test		Δ%	p
		Mean±SD	Median	Mean±SD	Median		
Y Balance Right Anterior	AG	66,76 ± 4,35	66,50	72,02 ± 5,19	73,33	7,88	0,000
	TG	66,04 ± 3,56	66,35	77,11 ± 2,56	76,90	16,76	0,000
	CG	68,39 ± 2,81	68,73	66,59 ± 3,29	67,15	-2,63	0,000
Y Balance Right Posteromedial	AG	98,82 ± 6,40	99,97	106,19± 4,23	106,24	7,46	0,000
	TG	99,43 ± 5,19	100,48	110,35 ± 4,35	110,50	10,98	0,000
	CG	99,32 ± 5,42	100,82	97,30 ± 6,22	98,57	-2,03	0,001
Y Balance Right Posterolateral	AG	97,72 ± 5,75	97,56	104,60 ± 5,15	103,13	7,04	0,000
	TG	96,07 ± 5,65	95,95	107,62 ± 4,32	108,29	12,02	0,000
	CG	97,09 ± 4,95	98,96	94,86 ± 4,83	96,94	-2,30	0,000
Y Balance Left Anterior	AG	66,12 ± 4,72	65,23	71,64 ± 5,45	73,64	8,35	0,000
	TG	66,00 ± 3,97	65,23	75,46 ± 3,40	75,12	14,33	0,000
	CG	66,52 ± 3,74	65,93	64,40 ± 3,95	64,40	-3,19	0,000
Y Balance Left Posteromedial	AG	101,13 ± 6,53	100,71	106,35 ± 4,64	106,93	5,16	0,000
	TG	97,24 ± 5,58	97,10	107,33 ± 4,92	107,12	10,38	0,000
	CG	97,91 ± 5,21	99,15	95,19 ± 5,85	96,17	-2,78	0,000
Y Balance Left Posterolateral	AG	98,60 ± 7,11	97,98	105,75 ± 4,84	106,24	7,25	0,000
	TG	96,58 ± 5,24	97,08	106,82 ± 3,61	107,11	10,60	0,000
	CG	95,99 ± 5,58	97,93	93,43 ± 6,22	96,04	-2,67	0,000

Note:Δ%: Percent change between pre-test and post-test, AG: Artistic gymnastics group, TG: Trampoline gymnastics group, CG: Control group.
$p \leq 0,05$

Table 6
Results of some selected physical fitness parameters.

	Groups	Pre-Test	Post-Test	Δ%	p
Vertical Jump	AG	48,31±3,40	48,69±3,53	0,79	0,009
	TG	42,38±3,32	44,00±3,16	3,82	0,000
	CG	43,88±4,91	42,81±4,71	-2,44	0,000
Standing Long Jump	AG	229,44±8,82	233,19±8,97	1,63	0,000
	TG	211,56±12,89	221,63±11,90	4,76	0,000
	CG	215,31±13,17	209,44±12,53	-2,73	0,000
Sit and Reach	AG	28,44±4,34	31,88±3,61	12,10	0,000
	TG	27,75±4,42	32,25±3,40	16,22	0,000
	CG	26,75±4,14	23,06±3,89	-13,79	0,000
Trunk Flexibility	AG	41,94±3,77	48,94±5,72	16,69	0,000
	TG	42,31±5,68	49,75±5,85	17,58	0,000
	CG	40,19±4,90	35,00±4,98	-12,91	0,000

Note: Δ%: Percent change between pre-test and post-test, AG: Artistic gymnastics group, TG: Trampoline gymnastics group, CG: Control group. $p \leq 0,05$

In addition, as the balance level increases via gymnastics training, some of the physical fitness components, including vertical jump, standing long jump, flexibility (sit and reach, trunk), are also affected positively via gymnastics training, and that is an another important result of the present study. When comparing the pre and post-test scores in all vertical jump, standing long jump, flexibility, etc., the most noticeable increase was seen in the trampoline training group (Δ%: 3,82 %, 4,76 %, 16,22 %, 17,58 % respectively) (Table 6). In review of literature studies, a gymnastics training was performed during a six-month training three times a week on children (Obreshkov & Simeonova, 2012). As a result, they reported that the ability to jump, flexibility and speed improved considerably in comparison to the tests during the pre and post-test. Karakollukçu et al. (2015) implemented a study for male gymnasts. They reported that 12 weeks of trampoline exercise significantly improved the subjects' standing long jump, vertical jump, 20-meter sprint speed, and anaerobic power. Boraczyński et al. (2013) reported that a 12-month artistic gymnastics training program led to improve the participants' flexibility (sit and reach) results by 43,55 %. Giagazoglou et al. (2013) evaluated the effects of 12 weeks of trampoline training intervention program on some performance parameters in the participants with intellectual disability. The study indicated that trampoline intervention led to significant improvements of participants' flexibility (pre: -13,11±7,27, post: -7,00 ±6,52), long jump (pre: 73,33±30,84, post: 103,44±32,94) vertical jump (pre: 12,89±6,25, post: 19,11±6,45) and balance test performance. Koca, Baykara, Demirel, and Berk (2019) found out that the 15-minutes exercise program on the mini-trampoline was more effective as a heating technique and had more positive effect on muscle elasticity than the 15-minutes walking exercise. As a conclusion, these findings are a contribution to further scientific research in order to reach more accurately clear findings.

CONCLUSIONS

Both the TG and the AG groups' exercises are effective for improving dynamic balance, vertical jump, standing long jump, and flexibility in non-gymnast after 12 weeks of training. But the trampoline exercises are seen to be more efficient on dynamic balance (all directions), jumping performance (vertical and standing long) and flexibility (sit and reach – trunk flexibility). The trampoline exercises may be recommended as an alternative mode of exercise for improving balance and bio-motor abilities, in particular the sports branches that require jumping performance, which may have an extra importance for better results. With respect to the results, the trampoline practices that include both fun and improving performance, may be suggested as a diversity for the training programs.

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SELF-PERCEPTIONS AND SELF-ESTEEM IN ADOLESCENT RHYTHMIC GYMNASTS: IS TRAINING LEVEL A DETERMINANT?

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Original article

Abstract

The purpose of this study was to examine Self-Perceptions and Self-Esteem in adolescent rhythmic gymnasts of different training levels. One hundred female rhythmic gymnasts (32 competitive and 68 recreational level gymnasts), aged 13-15 years, participated in this study. Participants' Self-Perception and Self-esteem were evaluated through the Greek version of Harter's Self-Perception Profile for Adolescents (Harter, 1986;2012; Makri-Mpotsari, 2001) which measures nine specific domains of self-perception (Scholastic Competence, Relations with Peers, Relations with Parents, Mathematics Competence, Athletic Competence, Physical Appearance, Language Competence, Behavioral Conduct, Close Friends) consisting of 5-items each. The inventory also includes a ten-item Global Self-Worth scale that measures Self-Esteem. In addition, gymnasts provided information on their training. Competitive level gymnasts scored higher than recreational in the domain of Relations with Parents (p=0.027, d=0.50) and in Global Self-Worth (p=0.046, d=0.45). No differences were found between groups in other self-perception domains (p=0.068 to 0.611, d=0.41 to 0.10). Engaging in competitive sport may enhance adolescent athletes' Self-Esteem and it is likely that this engagement strengthens the relations of the gymnasts with their parents. Further research is required on the association between training level and Self-Perception domains, and in particular in the case of adolescent female athletes.

Keywords: *self-concept, adolescence, personality traits, assessment, rhythmic gymnastics, relations with parents.*

INTRODUCTION

A large number of studies, over the last two decades have examined the self, across many fields of psychology (e.g. personality psychology, developmental psychology, etc.) and many disciplines (Harter, 2012). The complexity of the self-system has been increasingly evident, with self-perceptions (evaluative distinctions that people make about their competence in various domains of their lives) beginning in childhood (Harter, 1999; 2012). Children have domain-specific perceptions of their adequacy in different fields (e.g. school, family, friends, etc.) and an overall sense of their worth as individuals, labeled *Self-Worth* or *Self-Esteem* (Harter, 2012). Self-Perceptions are specific in context (Fox, 1992) and are formed through interaction with other people and attributions of one's own behavior (Marsh & Shavelson, 1985).

Self-Esteem refers to the personal judgment of an individual's value (Coopersmith, 1967) and is defined as a positive or a negative attitude towards a particular object, the unique self (Rosenberg, 1965). In other words, self-esteem can be defined as the degree to which individuals feel positive about themselves and reflects the emotional dimension of self-perception (Sonstroem & Morgan, 1989). Self-esteem is formatted during middle childhood, when children have developed the ability to compare themselves to their peers (Ruble, Boggiano, Feldman, & Loebl, 1980).

The potential benefit of participating in physical activities and sports for children's self-perceptions and self-esteem has been supported by many studies (Balaguer, Atienza, & Duda, 2012; Fox, 1992; Inchley, Kirby, & Currie, 2011). Sports and physical activity participation contribute not only to the formation of children's personality, their proper perception and self-esteem, but also to their physical and psychological well-being (Biddle, Ciaccioni, Thomas, & Vergeer, 2019; Poitras et al., 2016; Whitehead & Corbin, 1997). According to previous research, children and adolescents with low levels of motor competence demonstrate low levels of perceived physical appearance, athletic competence and global self-worth (Piek, Baynam, & Barrett, 2006). In another study, Kimiecik, Horn and Shurin (1996) found a strong association between the domains of perceived motor competence (i.e. evaluation of physical fitness, perceived physical fitness and goal setting) and participation in physical activity in adolescents, aged 11-15 years. In general, research evidence suggests a positive correlation between participation in sports with components of mental health, and emotional well-being (Nelson & Gordon-Larsen, 2006). Moreover, physical activity and sports are considered effective tools to increase self-esteem (Ekeland, Heian, & Hagen, 2005), apparently because compared to their peers, young athletes show higher levels of self-esteem (Bissinger, Laure, & Ambart, 2006) even if the mechanisms underpinning this fact remain unclear (Duda, 1993). Nevertheless, in some cases, factors uniquely found in competitive sports, and in particular aesthetic sports, like excessive training, heightened competitive demands, extreme dieting and restriction of food intake (Theodorakou & Donti, 2013) in combination with significant others' (e.g. parents, coaches, judges etc.) expectations and judgements might affect young athletes' self-perceptions and lower their self-esteem (Donti et al., 2012). For example, Amac and colleagues (2002) reported that, the self-esteem of young gymnasts (6-13 years old) competing at school level was significantly lower than that of their peers participating at recreational level.

Given the importance of the self in the development of social relationships and adjustments, it is essential for researchers to examine the varying effect of different contexts on adolescents' self-perception (Kokkinos & Hatzinikolaou, 2011). Adolescence is a developmental period where a more complex picture of oneself emerges (Kokkinos & Hatzinikolaou, 2011). Past research has shown that during this period, self-perceptions and self-esteem are related to mental health, depressive mood and anxiety (Bolognini et al., 1996). Lower levels of self-esteem in adolescence are also associated with neuroticism and decreased self-efficacy (Judge, Erez, & Bono, 2002).

Both, competitive and recreational sports contribute to the formation of children's self-perceptions and self-esteem (Whitehead & Corbin, 1997), although they place different demands on adolescents' physical, cognitive and emotional skills, as their practice aims at a whole different purpose (Amac et al., 2002). However, the association between different training and performance levels with adolescents' self-perceptions and self-esteem has not been explicitly studied. Thus, the aim of this study was to examine self-perceptions and self-esteem in adolescent rhythmic gymnasts of different training levels.

METHODS

One hundred adolescent rhythmic gymnasts, aged 13-15 years, were assigned according to their training level as follows: (a) Thirty-two competitive level gymnasts that participated at international and national level competitions, and (b) sixty-eight gymnasts participating at recreational level (i.e. in festivals and contests). All gymnasts completed a questionnaire which included age, weight and height information, as well as training and competition details, such as training experience, number of training sessions/hours per week and number of competitions per year. Participants' Body Mass Index (BMI) was calculated as the ratio of body weight to the squared standing height (kg/m^2).

Competitive level gymnasts were training daily (5 to 6 days per week) for 3-4 hours in each training session and were randomly recruited from 8 different gymnastics clubs. In addition, competitive level gymnasts competed 3-4 times/per year to official qualification, national and international competitions according to the calendar of the Hellenic Gymnastics Federation. Recreational level gymnasts were training 2-3 times a week, for 60-90 minutes in each session, and were recruited from 4 different gymnastics clubs.

Prior to the study, the athletes and their parents were fully informed about the purpose and the procedures of this study. Written parental consent was obtained for each participant and every athlete completed a consent form. The participants filled in the inventory before their training sessions. Procedures were approved by the Institutional Ethics Review Committee and complied with the Code of Ethics of the World Medical Association (Helsinki declaration of 1964, as revised in 2013).

Gymnasts' self-perceptions and self-esteem were measured via the Greek version of Harter's Self-perception Profile for Children (Harter, 1986; 2012; Makri-Botsari, 2001), which is addressed to high school-aged adolescents (aged 13-15 years). The questionnaire was created from Harter (1986), in order to assess nine domain specific Self-Perceptions, consisting of 5-items each, namely: *Scholastic Competence, Relations with Peers, Relations with Parents, Mathematics Competence, Language Competence, Athletic Competence, Physical Appearance, Behavioral Conduct,* and *Close Friends.* The instrument also includes a ten-item *Global Self-Worth* scale which measures Self-Esteem. Each item contains one positive and one negative description of a specific skill in a binary form in order to minimize socially undesirable responses. Respondents are asked to choose which one of the two descriptions (positive or negative) best depicts them. After choosing the description, responders select to what extent the chosen description depicts them by choosing "Really true for me" or "Sort of true for me". Instructions to the participants included a reminder to respond to all items and a statement that there were no right or wrong answers. Participants were well instructed as mentioned above and asked clarifying questions if needed, in order to understand the tool items and to respond properly to the questionnaire. In order to analyse these data, according to Harter (1986; 2012), each item/description is scored on a four-point scale from 1 to 4, where a score of 1 indicates the lowest perceived competence or adequacy, and a score of 4 reflects the highest level of competence or adequacy. Scale scores are calculated as the sum of the scores of items divided by five or ten, accordingly.

The Self-perception Profile for Adolescents is validated for adolescents aged 13–15 years showing strong psychometric properties (Cronbach's α coefficients: 0.70 to 0.90) (Harter, 1986; 2012) and the same was found for Greek population (Cronbach's α coefficients: 0.68 to 0.83) (Makri-Mpotsari, 2001). Cronbach's α coefficients in this study were: 0.83 for *Scholastic Competence*, 0.73 for *Relations with Peers*, 0.79 for *Relations with Parents*, 0.80 for *Mathematics Competence*, 0.90 for *Language Competence*, 0.87 for *Athletic Competence*, 0.78 for *Physical Appearance*, 0.71 for *Behavioral Conduct*, 0.70 for *Close Friends* and 0.85 for *Global Self-Worth*.

Data are presented as means and standard deviations for all variables. Pearson's correlation coefficient (r) was used to detect linear associations among the selected variables. Differences in anthropometric characteristics and in all the examined variables between competitive and recreational level gymnasts were determined using independent samples t-tests. For pairwise comparisons, Cohen (d) effect sizes were calculated and their magnitude was categorized as follows: trivial, <0.2; small, 0.2 to 0.5; small to moderate, 0.5 to 0.8, and large, >0.8 (Cohen, 1988). Statistical significance was accepted at $p<0.05$. All analyses were performed using SPSS (version 20.0, SPSS Inc., Chicago, IL, USA).

RESULTS

The anthropometric characteristics of the participants (mean±standard deviation) are shown in Table 1. No differences were observed between groups in age, training experience and height, however, competitive level gymnasts were lighter and had lower body mass index (Table 1).

Competitive gymnasts scored higher than recreational in the Self-Perception's domains of *Relations with Parents* ($p=0.027$, $d=0.50$) and *Global Self-Worth* ($p=0.046$, $d=0.45$) (Table 2). No differences were observed between the two groups in the rest of the subscales.

Significant correlations were found between Self-Perception's domains and Self-Esteem (Table 3).

Table 1
Anthropometric characteristics of the participants (mean ± standard deviations) (n = 100).

Variable	Recreational level gymnasts (n=68)	Competitive level gymnasts (n=32)	p
Age (years)	13.78±0.83	13.88±0.75	0.580
Training Experience (years)	5.12±2.45	5.71±2.05	0.234
Height (cm)	157.22±7.33	156.47±6.21	0.617
Body Mass (kg)	47.97±7.83	42.90±6.80	0.002
Body Mass Index (kg/m^2)	19.41±3.00	17.45±2.04	0.001

Table 2
Answers of the adolescent rhythmic gymnasts in the Greek version of Self-Perception Profile for Children Questionnaire (means ± standard deviations) (n=100).

Domains of Self-Perception	Recreational level gymnasts (n=68)	Competitive level gymnasts (n=32)	*p*	Cohen's *d*
Scholastic Competence	3.06±0.73	3.33±0.49	0.068	0.41
Relations with Peers	3.06±0.65	2.96±0.70	0.500	0.15
Relations with Parents	3.10±0.64	3.40±0.52	0.027	0.50
Mathematics Competence	2.92±0.99	3.04±0.72	0.531	0.13
Athletic Competence	2.89±0.68	3.09±0.50	0.140	0.32
Physical Appearance	2.65±0.70	2.83±0.66	0.222	0.26
Language Competence	2.80±0.86	2.88±0.73	0.611	0.10
Behavioral Conduct	3.08±0.60	3.22±0.50	0.255	0.25
Close Friends	3.38±0.60	3.54±0.53	0.207	0.28
Global Self-Worth	3.03±0.55	3.26±0.44	0.046	0.45

Table 3
Correlations between the Self-Perception domains in adolescent female gymnasts (n=100).

	1	2	3	4	5	6	7	8	9
1									
2	.292**								
3	.439**	.145							
4	.425**	.038	.329**						
5	.669**	.163	.219*	.388**					
6	.465**	.068	.111	.289**	.542**				
7	.086	-.005	.196	.031	.018	-.179			
8	.406**	.082	.387**	.287**	.276**	.079	.134		
9	.367**	.088	.487**	.537**	.310**	.136	.484**	.330**	
10	.430**	.612**	1	.202*	.380**	.279**	-.085	.084	.180

**p*<0.05, ** *p*<0.01

Note: 1. Global Self-Worth 2. Close Friends 3. Behavioral conduct 4. Language Competence 5. Physical Appearance 6. Athletic Competence 7. Mathematics Competence 8. Relations with Parents 9. Scholastic Competence 10. Relations with Peers.

DISCUSSION

The aim of this study was to examine self-perceptions and self-esteem in adolescent rhythmic gymnasts of different training levels. The main finding of the study was that competitive rhythmic gymnasts scored higher than recreational in the self-perception's domains of *Relations with Parents,* and *Global Self-Worth* with no difference between groups in the rest of the self-perception subscales.

It is well-established that children self-perceptions on their adequacy in different fields are formed through interaction with 'significant others' and attributions of one's own behavior (Burns, Green, & Chase, 1986). The positive association between participation in physical activities or sports and children's self-perceptions and self-esteem has been supported by many studies

(Balaguer, Atienza, & Duda, 2012; Fox, 1992; Inchley, Kirby, & Currie, 2011). However, it is often reported that competitive sports demands, may place excessive physical and psychological load on youth athletes (Theodorakou & Donti, 2013) and this fact, in combination with significant others' expectations and judgements might affect young athletes' self-perceptions (Donti et al., 2012).

This study highlights an interesting finding: competitive adolescent rhythmic gymnasts scored higher than recreational in *Global Self-Worth* or self-esteem. This finding is in line with recent findings also suggesting that both, female and male adolescents who were involved in competitive sports (irrespective of whether they participated in individual or team sports) demonstrated high levels of self-esteem (D'Anna, Rio, & Gomez-Paloma, 2015). Contrary, a previous study found that the self-esteem of young gymnasts (aged 6-13 years) practicing competitive gymnastics was significantly lower than that of girls practicing recreational gymnastics (Amac et al., 2002). However, that study used a sample of child and adolescent gymnasts (6-13 years) and the heterogeneity of the age-range may have affected the findings of the study. A more recent study did not detect any differences in *Global Self-Worth*, in 10-12 years old, competitive and recreational gymnasts (Donti et al., 2012). Another study reported low levels of self-esteem among rhythmic gymnasts due to the pressure to keep low body weight, aesthetics overestimation, and the association with high incidence of eating disorders and body dissatisfaction (Amorim, 2019; Denoma et al., 2009; Krentz & Warchsburguer, 2011). Nevertheless, all previous studies examined child or preadolescent athletes. It is plausible that, as athletes grow and mature, participating in competitive sport along with gymnast's achievements, as well as to whom they compare themselves to, may have a positive impact on the way they value themselves. Along this line, because self-esteem is formed relatively early in the course of development, and remains fairly constant over time, it may be that, a global sense of self-worth may precede, rather than follow domain specific self-representations (Marsh, Craevn, & Debus, 1991). Nevertheless, further research is required on the formation of self-perceptions and self-esteem in different contexts and levels of performance over time in order to understand the psychological parameters underlying elite performance (Gibbons, Lynn, & Stilles, 1997).

The Self-Perception's domain "*Relations with Parents*" refers to the familiarity that gymnasts feel towards their parents. Experts believe that children's emotional, cognitive and behavioral development is affected by parental bonding and relationships (Harter, 1985; Rosenberg, 1986). In general, parental support and understanding have been associated with successful career development among elite young athletes (Wuerth, Lee, & Alferman, 2004) and higher levels of perceived parental support were related to higher levels of adolescent well-being (Kocayöruk, Altıntas, & İçbay, 2015). The results of this study, showed that competitive rhythmic gymnasts scored higher than recreational in the domain of *Relations with Parents* (d=0.50) and the same was found in another study in preadolescent rhythmic gymnasts (aged 11-15 years), which reported that parents were supporting their children-athletes in both, training and competitions (Giannitsopoulou, 2016). Rhythmic gymnastics training and performance on a national level, demands daily training practices of 6 days per week, adherence to strict nutritional demands and a very well organized daily-schedule (Donti, Tsolakis, Bogdanis, 2014; Michopoulou et al., 2011). It seems that, the adolescent competitive gymnasts of this study, felt that their parents supported them and contributed significantly to their participation in daily trainings and competitions. In addition, asking from parents' support is particularly important for adolescents because they have more limited coping strategies than adults (Van Yperen, 1995).

In this study, no difference was found between competitive and recreational rhythmic gymnasts in the self-perception's domains of *Physical Appearance* and the effect size for between group comparisons was small (*d*=0.26). Despite their slim figure and trained bodies (i.e. competitive gymnasts' BMI was 17.45±2.04 kg/m^2 vs. 19.41±3.00 kg/m^2 in recreational) competitive rhythmic gymnasts did not score higher than recreational in the domain of *Physical Appearance*. In addition, competitive gymnasts' BMI in this study was near 17 kg/m^2 a value defining thinness in adolescence (Cole et al., 2007) and indicating gymnasts' attitude towards food. It is known that, competitive rhythmic gymnastics has strict demands on body weight and shape, reinforced by coaches, judges and peers' comments (Theodorakou & Donti, 2013). Along this line, no differences were observed between groups in *Athletic Competence* (*d*=0.32). This result is interesting because some competitive gymnasts were Greek champions of their age category. However, in rhythmic gymnastics performance, every little step, or mistake can make the difference between winning and losing, while at the same time constant improvement of the gymnast's skills is required (Donti, et al., 2016). It seems that the heightened demands of the environment in which gymnasts are exposed and interact, shapes their perceptions.

Collectively, although competitive rhythmic gymnasts would be expected to have higher *Physical Appearance* and *Athletic Competence* compared to recreational gymnasts, this was not found in the present study possibly due to the strict demands on body appearance, and performance of the competitive environment. It is constantly reported that in rhythmic gymnastics, the desire to be leaner to improve performance reinforced by coaches, parents and team-mates pressures for thinness are often confronted by athletes with food restriction (Krentz & Warschburger, 2011). Negative comments from coaches and parents about body weight may increase gymnasts' fear of fatness and body image anxiety (Tan et al., 2016). On the other hand, body appearance in recreational level gymnasts is not judged as they participate in the sport to learn new skills and to spend time with their peers.

A limitation of the study that should be acknowledged is the use of the Greek version of Harter's Self-perception Profile for Children (Harter, 1986; 2012; Makri-Botsari, 2001) which captures general self-perceptions and global self-worth in adolescence and is not specific for youth athletes. However, in this study also participated a large sample of recreational level gymnasts (n=68), and it was thought that an instrument capturing perception of the self for general population would be more appropriate. Another limitation of this instrument is that the *Global Self-Worth* scale contains two possible answers (positive or negative) and does not evaluate any responses in between.

CONCLUSIONS

In conclusion, this study found that rhythmic gymnasts engaging in competitive sports showed higher levels than recreational in *General Self-Worth* (which is the emotional dimension of self-perceptions) and in *Relations with Parents*. It is possible that as athletes grow and mature, the context of competitive sport, along with their achievements, may influence the way they value themselves. However, evidence is limited on if winning at sports leads directly to increases in Self-Esteem (Gibbons, Lynn, & Stilles, 1997). On the other hand, in certain self-perception subscales, some competitive sports' characteristics (the environment athletes participate in or to whom they compare themselves to), may influence the way these gymnasts perceive their *Athletic Competence* and *Physical Appearance.*

Notably, although the perceptions of competitive level gymnasts about their competence in *Physical Appearance* and *Athletic Competence* did not differ from recreational gymnasts, their personal judgement on their overall value (*Global Self-Worth*) was higher (*d*=0.45). This research provides useful information for coaches, parents, judges and sport specialists on the psychological parameters underlying performance and how 'significant others' (parents, coaches, judges, peers etc.) and sport demands may shape gymnasts' perceptions. Therefore, further long-term research is required on the association between performance level and self-perception domains, and in particular in the case of adolescent female athletes, in order to promote understanding of the psychological parameters underlying gymnastics performance.

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"PUPPETS" IN WOMEN'S ARTISTIC GYMNASTICS: THE COACH-GYMNAST RELATIONSHIP FROM PIERRE BOURDIEU'S LENS

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Abstract
In Women's Artistic Gymnastics (WAG), athletes can be coach dependent, becoming submissive and this scenario may reflect subordination, harassment and abuse. This is worrying, because gymnasts are usually children. However, we argue that coach conduct depends on complex interactions. Thus, we analyzed how the coach-gymnast relationship is built. We used Pierre Bourdieu's categories to argue our reflections. We identified that the domination forms in the coach-gymnast relationship are responsible for shaping long-lasting dispositions, triggered by a process marked by the inculcation and embodiment of certain practices. Thus, gymnasts develop a class habitus that reproduces and legitimates the logic of this field. Our appropriation of Bourdieu's lens has shown that the gymnasts are at a disadvantage in relation to the coaches and to the system. Therefore, these structures should not demand early outcomes, but allow gymnasts to decide whether they want to continue in this "game of domination".

Keywords: *Pierre Bourdieu, theory of fields, women's artistic gymnastics, sociology of sport.*

INTRODUCTION

In Women's Artistic Gymnastics (WAG) the main goal is perfection associated with difficulty. As part of this incessant pursuit, the coach-gymnast relationship is the key to being successful in this sport (Arkaev & Suchilin, 2004). So, the intensive training and the need for manual assistance for the safety and learning of new acrobatics skills and connections make this interaction even closer, as the body contact is inherent in gymnastics' training (Barker-Ruchti & Tinning, 2010; Oliveira et al., 2017; Ryan, 1995). In this unique relationship, we argue that the coach manipulates the gymnasts like "puppets", who are submissive to their commands and confident in their actions.

The metaphor that supports our reflections in this theoretical essay is not exhausted in the coaches' spotting in the training routine. An autocratic pattern of coach-athlete relationship prevails in WAG (Barker-Ruchti & Tinning, 2010; Barker-Ruchti & Schubring, 2016; Oliveira et al., 2017). Oliveira (2014) points out that in the sociocultural context of a high-performance training gym there is a hierarchy, in which the coaches have unilateral autonomy and the gymnasts must follow them without arguing. Thus, it is not rare to associate strictness with the coaches' posture and there is evidence that behaviors may become abusive in this context (Barker-Ruchti, 2011; Barker-Ruchti & Tinning, 2010; Frogley et al., 2018; Pinheiro et al., 2014; Stirling & Kerr, 2009). For example, Kerri Strug, a former Olympic gold medalist, highlights that throughout her career she learned to deal with a diverse of coaches' styles and criticisms, as well as dealing with pressure and the fear-based work philosophy (Strug & Lopez, 1998).

Generally, the negative aspects of this dialectical relationship are attributed to the coach who can be seen as the "puppets'" manipulator. On the other hand, we may question: How have coaches been socialized to learn particular behavior patterns? Why these behaviors considered acceptable despite being harmful? What is the role of gymnasts and the context in this relationship? However, in this article, we argue that the coaches' behavior depends on the complex interactions that take place in this scenario, as he/she deals with the expectations of gymnasts, parents, clubs, federations and with his/her own goals.

Therefore, we consider that the symbolic violence exercised by the coaches in the dialectical relationship with the gymnasts is the product of a domination process that happens in WAG's sociocultural context. In this way, we adopt the metaphor "puppets" as a criticism. This word can refer to a person who has no opinion of his/her own and is easily manipulated by others. To break away from this idea, we will clarify that the forms of domination in the coach-gymnast relationship will be responsible for shaping long-lasting dispositions, which are triggered by a process marked by the inculcation and embodiment of certain practices. Thus, we will also analyze the gymnasts' mode of action to understand their role in this context.

From this thesis, we shall analyze how the coach-gymnast relationship is built in WAG's particular context. Methodologically, we will use some categories of Pierre Bourdieu's Reflexive Sociology and Field Theory to argue our reflections and to understand how certain aspects of these interactions have been culturally guiding the behavior of coaches and athletes. And, as a theoretical paper, we will draw off existing published data. Therefore, we hope that our reflections based on the Bourdieu's works, who in some cases appropriated sport as an object of study (Bourdieu, 1978, 1988, 1993), also subsidized the sports field's studies (Cushion & Jones, 2006; Kerr et al., 2016; Leeder & Cushion, 2019), can stimulate the reworking of certain practices, perceived as negative and abusive in WAG.

First, we present the theoretical framework that will support our reflections and discussions. In the next section, we will discuss the context of the study and, later, we will analyze our results in relation to our theoretical framework. We will conclude this essay with a summary of our reflections and suggestions for potential research.

THEORETICAL FRAMEWORK – SOME CATEGORIES OF PIERRE BOURDIEU'S REFLEXIVE SOCIOLOGY AND THE THEORY OF FIELDS

Pierre Bourdieu based his sociological work on the praxiological approach. It dialectically considers both the objective and subjective structures on individual agency. Thus, we can understand the interrelation between structure and agency, which supports the examination of wider forces on the agents' decision-making and action (*práxis*) (Bourdieu, 1998). From this perspective, Pierre Bourdieu drew a relational sociological approach, based on the "Constructivist Structuralism" or "Structuralist Constructivism", which the author characterized as follows:

"By structuralism or structuralist. I mean that there exist, in the social world itself, and not merely in symbolic systems, language, myth, etc., objective structures which are independent of the consciousness and desires of agents and are capable of guiding or constraining their practices or their representations. By constructivism, I mean that there is a social genesis on the one hand of the patterns of perception, thought and action which are constitutive of what I call the habitus, and on the other hand of social structures, and in particular of what I call fields and groups, especially of what are usually called social classes." (Bordieu, 1990, p. 123).

As the fundamental basis for analysis on social subjects, Bourdieu suggested that wider society manifests itself through fields. Therefore, he developed the "Theory of Fields", a sociological praxiological theory that considers the relative autonomy between diverse social spaces. So, a social space can be described as a field of forces, in which objective forces are imposed and irreducible to the agents' intentions or direct interactions between them (Bourdieu, 1993). According to the author, the concept of "Field" refers to a symbolic space, where there are symbolic struggles of positions. These struggles are linked to the social structure of this context, which is marked by the inequality in the distribution of economic, social, symbolic and cultural properties (Bourdieu, 1984). Each field is a relatively autonomous social space, which has a microcosm of its own laws, different from the general laws of society and partially autonomous (Bourdieu, 1993). However, it is still dependent on the impositions of the social space in which it operates and we cannot analyze it independently of the characteristics of its occupants.

For understanding the social structures of the fields we need to pay attention to the properties that guide the disputes inherent within this context. Bourdieu (1986) named them as capitals and stated that their possession and accumulation configure the way to reach and occupy better social positions (Bourdieu, 1998). Bourdieu (1986, p. 47) proposed four types of capital:

"as economic capital, which is immediately and directly convertible into money and may be institutionalized in the form of property rights; as cultural capital, which is convertible, on certain conditions, into economic capital and may be institutionalized in the form of educational qualifications; and as social capital, made up of social obligations ('connections'), which is convertible, in certain conditions, into economic capital and may be institutionalized in the form of a title of nobility."

The author called the fourth type of capital as:

"Symbolic capital, that is to say, capital - in whatever form - insofar as it is represented, i.e., apprehended symbolically, in a relationship of knowledge or, more precisely, of misrecognition and recognition, presupposes the intervention of the habitus, as a socially constituted cognitive capacity." (Bourdieu, 1986, p. 56).

The possession of capital provides to the agent the power of symbolic violence, the authority to regulate the process of distribution and access to capitals within the field (Bourdieu, 1993). This characteristic refers to the *doxa,* the social order accepted and reproduced by the agents within the field (Bourdieu, 1998). The author pointed out that the *doxa* is:

"a particular point of view, the point of view of the dominant, which presents and imposes itself as a universal point of view - the point of view of those who dominate by dominating the state and who have constituted their point of view as universal by constituting the state." (Bourdieu, 1998, p. 57).

In this perspective the dominant agents have an *orthodoxy* way of action, "a right, correct, dominant vision which has more often than not been imposed through struggles against competing visions" (Bourdieu, 1998, p. 56). These competing visions are seen as *heterodoxy*. In this sense, the *heterodoxy* agents who have less capital in the field trend to *heresy* strategies to modify the exercise of power in the field.

Bourdieu (2001) pointed out that this kind of violence can only be applied when there is complicity between the dominant and the dominated agents, that is, they tacitly (mostly unwillingly) accept the symbolic power and contribute to the reproduction of values, limitations and normatization to the impositions from the dominant agents. We emphasize that (re)produced discourses are important mechanisms for imposing a necessary way of doing and acting (Cushion & Jones, 2006; Leeder & Cushion, 2019). Based on these assumptions, we justify the choice of symbolic violence to argue the coach-gymnast relationship. Therefore, we will clarify that this is a relational power relationship and we will understand the actions of the coaches and gymnasts in the WAG's high performance context. For that, we will explain the concept of *habitus*.

Such a concept refers directly to the agency within the field. Bourdieu (1998, p. 8) described *habitus* as a "generative and unifying principle which retranslates the intrinsic and relational characteristics of a position into a unitary lifestyle, that is, a unitary set of choices of persons, goods, practices". The interpretation of this definition would make it possible to affirm that the *habitus* structures the actions of the agents and transforms the field at the same time as it is structured by it. It will also depend on the laws and the paths to the disputes inherent in this space. We emphasize that the fact that they are long-lasting systems allows them to be constantly transformed, rebuilt, but not undone (Bourdieu, 1977; Bourdieu & Wacquant, 1992). Also, we highlight an important part of the *habitus,* which is the *Illusio* (Bourdieu, 2000). The author explained that this concept refers to the *habitus'* manifestation that indicates that it is worth participating in the field, it is worth to "play the game". The *illusio* allows us to understand some investments and behaviors of the agents in the field.

Based on the above arguments, we justify the choice of the Bourdieu's categories to discuss the coach-gymnast relationship in WAG. Assuming the field concept as a methodological category, which depends on the question of each study, we consider high-performance WAG as the field of analysis (Kerr et al., 2016). This sport is a space permeated by power relations, in which positions can be seen as "plus" or "less" dominant, due to the different levels of capital of each agent (Jenkins, 1992). It also has its own social structure and norms, which will be discussed in the next sections.

THE STUDY'S CONTEXT: THE COACH-GYMNAST RELATIONSHIP

The coach-athlete relationship is the key for a successful sports career in high performance. Lyle (2002) points out that this is an essential social interaction and this aspect of the coaching process is unique in athlete development. In the case of the Artistic Gymnastics (AG), Arkaev and Suchilin (2004) state that to achieve success in high performance sports, dedication, trust, commitment and mutual loyalty between coaches and gymnasts are paramount throughout the development of athletes' sports career. From the perspective of motivation theory, coaches should acknowledge and work towards the gymnasts' goals (Nunomura, Okade, & Carrara, 2008; Massimo & Massimo, 2013).

In this way, Oliveira (2014) points out that in WAG the proximity between coaches and gymnasts is accentuated, as there is intense body contact that induces the dependency, the confidence and the surveillance. The author adds that this contact makes coaches refer to gymnasts as "their", that is, as a precious property, while gymnasts trust their own lives in the hands of coaches. Both gymnasts and coaches seem to be aware that there is an interdependence to achieve success in sport

(Oliveira et al., 2017; Ryan, 1995). The authors reveal that athletes and coaches make an agreement, in which the gymnast's development depends on the coach and the coach's reputation depends on the athlete.

On the other hand, the literature points out the imbalance in this relationship, as the high performance gymnasts are too dependent on the coach (Barker-Ruchti & Tinning, 2010; Barker-Ruchti & Schubring, 2016; Oliveira, et al., 2017). Moreover, Oliveira et al. (2017) found that submission to coaches is taught to the athletes, so independent gymnasts could be seen as the most problematic and difficult to work with.

This hierarchy, obedience and discipline on the gymnasts in the relationship with the coaches, refer to the Gymnastics' origins in the eighteenth century, when the sport was practiced for military purposes (Publio, 1998). The fact shows how the current gymnastic sport is deep rooted in the discipline to incessantly repeat exercises to aim perfection and the gymnasts are seen as performing bodies (Barker-Ruchti & Tinning, 2010; Barker-Ruchti, 2011; Oliveira, 2014). Thus, in the WAG's socio-cultural context there still remains an autocratic training model in which the coach has the command voice and the gymnasts must accept the orders without question (Barker-Ruchti & Tinning, 2010; Barker-Ruchti & Schubring, 2016; Oliveira et al., 2017). Lyle (2002, p. 158) points out that this autocratic model is characterized in the sport's context as follows:

"(…) the primacy of coach in decision taken; a dominating, directive approaching in the interpersonal relationship; the transmission of knowledge, teaching and learning assumed to be one way; coach-determined rules, rewards, standards and application; rigidity and lack of personal empathy."

Oliveira et al. (2017) add that the transmission of the culture of the high performance AG by those coaches who were gymnasts also contributes to the maintenance of this model. Thus, some misleading and traditional practices in the gyms persist nowadays, such as: abusive methods for weight control, high training overload, inadequate rest and recovery (Bortoletto & Schiavon, 2016; Caine et al., 2001; Kerr et al., 2006; Stewart et al., 2015).

However, the military roots are far beyond to be the only influence of this model. Another fact that draws attention is the gymnast's age (Barker-Ruchti & Tinning, 2010; Barker-Ruchti & Tinning, 2010; Gervis & Dunn, 2004; Pinheiro et al., 2014; Stirling & Kerr, 2009). To understand this context we need to analyze WAG's evolution.

In this sport, the trend of young gymnasts began in the early 1970s during the Cold War (Barker-Ruchti, 2009; Cervin, 2016). The authors point out that the political context was responsible for changing the sport. Thus, the Soviet government develops the "acrobatization" to innovate and use sporting success in the dispute against to the capitalist countries (Barker-Ruchti, 2009; Cervin, 2016). Thus, by the late of the 1960s, mature women who exhibited graceful movements lost originality to young, childish gymnasts who performed risky and acrobatic gymnastics skills (Barker-Ruchti, 2009; Cervin, 2016; Kerr, 2006). This new way of developing gymnasts' sports career, which involves selection and early specialization, has gained space in international competitions and prompted the capitalist countries to change (Barker-Ruchti, 2009; Cervin, 2016). With the end of the Cold War and the migration of Soviet coaches to other countries, the early trend of WAG spread around the world (Kerr et al., 2017).

So, specialized training usually begins at a young age. Moreover, AG is considered an early specialization sport, in which stages of sports development are accelerated or disregarded (Arkaev & Suchilin, 2004; Nunomura, Carrrara & Tsukamoto, 2010; Smoleuskiy & Gaverdouskiy, 1998). The literature supported this fact and, points out the advantages from the biological point of view. The justification is based on the fact that childhood can be considered the ideal period to start the process of learning complex skills and to develop flexibility and coordination skills, as well as the biomechanical advantages associated with smaller body proportions (Arkaev & Suchilin, 2004; Smoleuskiy & Gaverdouskiy, 1998). Moreover, the children are more subject to adult control, as they tend to be submissive, dependent, obedient and still with less argumentative and decision-making ability (Barker-Ruchti & Tinning, 2010; Barker-Ruchti, 2009, 2011; Oliveira, 2014; Pilotto, 2010).

This aspect brings the coach-gymnast interaction closer (Barker-Ruchti, 2009). Gervis and Dunn (2004) state that this relationship could be considered as the most significant interaction that young athletes would have with an adult. Jesus Carballo Jr. (2000), a two-time world champion in 1995 and 1999, reports that the coach-gymnast relationship is very strong and both form a team with friendship ties. The Gymnast Elena Gomez, world champion in 2002, when talking about her relationship with the coach Jesus Carballo, says he was like a second father. In WAG, young gymnasts spend more time in the sports' context than in their own homes (Gervis & Dunn, 2004; Jacobs et al., 2017; Oliveira, 2014; Schiavon, 2009; Smits et al., 2017). Mainly, those who train in the boarding schools' system (Nunomura & Oliveira, 2012). Thus, because they are young athletes under the command of older coaches and mostly men, this relationship can be confused with the parental relationship (Barker-Ruchti, 2009) primarily observed by the gymnast Elena Gomez. We emphasize that this patriarchal approach also influences the hierarchy, obedience and discipline that lead to asymmetry in this power relationship.

Stirling and Kerr (2009) state that the question of the gymnasts' age and the (older) coaches, gender issues in the case of male coaches in the female team, the status of coaching position, access to financial resources, previous successes and level of knowledge are aspects that would favor the coach in this power relationship. Given the mentioned imbalances, such practices place the gymnasts in a vulnerable position in the relation with the coaches (Pinheiro et al., 2014; Stirling & Kerr, 2009). These studies pointed out that an abusive training context would be constituted, in which certain practices are accepted, reproduced and called "commitment", especially when it involves money, for example: screams, humiliation, intimidation, threats and even minor aggressions are common by the coaches into the training gym (Gervis & Dunn, 2004; Jacobs et al., 2017; Pinheiro et al., 2014; Ryan, 1995; Smits et al., 2017; Stirling & Kerr, 2009); Forcing gymnasts to compete injured is also a form of abuse and often happens in this sport (Gervis & Dunn, 2004; Pinheiro et al., 2014; Ryan, 1995). The dropping out of school activities also highlight this context (Jacobs et al., 2017; Oliveira, 2014; Pinheiro et al., 2014; Ryan, 1995; Smits et al., 2017; Stewart et al., 2015; Stirling & Kerr, 2009).

These facts highlighted in the media in 2018, when the world was shocked by the Larry Nassar's (a former USA gymnastics team doctor) judgment (CNN, 2018). More than 150 surviving gymnasts, as they prefer to be named, have joined forces in their testimony to sentence Nassar to up to 175 years in prison for sexual abuse (CNN, 2018). We point out that some of the American gymnasts blamed their coaches for conniving with Nassar's crimes. In Brazil, more than 40 reports of sexual harassment occurred against the men's gymnastics coach Fernando de Carvalho Lopes, who was banned from the sport (Globoesporte, 2019). Furthermore on the abuse cases, in 2018 the gymnast Sae Miyakawa spoke out against her coach Yuto Hayami, behind the scenes of the Japan's WAG (Japantimes, 2018). The Japanese Gymnastics Association banned Hayami from the national training center and revoked his professional registration for physically assaulting the athlete during trainings for the World Gymnastics Championship, in Doha (2018). The case went public, and Miyakawa explained that the assaults were part of the training process and she still wished to continue training with Hayami. Miyakawa even accused officials of the Japanese Gymnastics Association of power abuse and stated that they wanted to separate her from her coach to put her on another team (Japantimes, 2018).

Despite those cases, recent studies analyzed the phenomenon of career extension in WAG and have identified that with the advent of older high performance gymnasts, the coach-athlete relationship could be changed, more centered on gymnasts and still achieve important results (Barker-Ruchti et al., 2016; Kerr et al., 2015, 2017).

The problems pointed out in this section urge us to think about what need to be changed and after then this context could be improved. We believe the initial step is to understand the relationships and conduct between those involved in this scenario and the gymnastics training's culture that was established at WAG.

BOURDIEU WITHIN THE GYM – SOME NOTES ABOUT THE COACH-GYMNAST RELATIONSHIP

Our interest in this section is to articulate the construction of habitus and symbolic violence in the coach-gymnast power relationship. However, we cannot look at these categories in isolation. Thus, we will start with delimiting the high performance WAG field. In this article we consider high performance WAG as a specific field with particular standards and relatively autonomous (Kerr et al. 2016). However, we do not disregard its general rules that apply to other fields and the sport cultural differences in each country. On the other hand, this field has specific norms, the doxa of WAG's field, derived from the military roots and strong Soviet influence on athletes' sports training since the 1970s (Arkaev & Suchilin, 2004; Smoleuskiy & Gaverdouskiy, 1998). This scenario favored the development of unique characteristics of this sport, as we discussed in the previous section, for example: there is talents selection among 5-7 years old, a system that favors early specialization and early results; young athletes train approximately 30 hours per week there is centralization of sports training in boarding schools; among other aspects (Barker-Ruchti & Tinning, 2010; Barker-Ruchti, 2011; Bortoletto & Schiavon, 2016; Oliveira et al., 2017; Stewart et al., 2015).

Among the general WAG features, we highlight training as an institution permeated by its own rituals and idiosyncratic agreements among its involved (Oliveira, 2014). From this description, we identified that the high performance WAG field doxa directly influences the way individuals interact, relate to and contest symbolic positions. Thus, in this field there will be symbolic struggles over specific capital and for the maintenance of culturally rooted features. Therefore, in this space there will be power relationships between dominant and dominated agents, in which the most dominant positions will use the holding of specific capital, which has value in the field, as a way of exerting power over those in the dominated position.

From this perspective, Stirling and Kerr (2009) revealed some aspects that favor the coaches in the power relationship. The authors speak of asymmetry of power, what we will call here the domination by the coaches through symbolic violence. Thus, we can interpret the notes of Stirling and Kerr (2009) as follows: the fragility of the age of gymnasts and even issues of gender domination (when the male coach works with female/girl gymnasts); the status of the coach's position; the fact that the coach can choose who will make up the team as a means of holding social capital; access to resources; previous successes; and the coach's level of knowledge. These are factors that can be understood as forms of cultural capital. The holding of these capitals puts the coach in a dominant position in the power relationship with the gymnasts.

From this configuration, the habitus of coaches, structured as long-lasting dispositions, are built and made to be perceived as harsh, which are characteristic traits of those who hold power and dominate the field (Barker-Ruchti & Tinning, 2010; Barker-Ruchti, 2011; Pinheiro et al., 2014). In this logic, by considering that the habitus also acts as structuring structures (Bourdieu, 1993, 1998), the coaches also influence the construction of the gymnasts' habitus, which in turn also reinforces the authoritarian habitus of the coaches. Understanding what guides the action of gymnasts and the acceptance of domination will be a key concept to identify the complicity of athletes in symbolic violence exerted by coaches.

The characteristics of the sport would also be responsible for developing lasting dispositions in the athletes and, thus, would structure the “gymnast habitus”. Gymnasts are required to develop perfection in a universe surrounded by risks and difficulty, for this they must adopt orthodox behaviors in the WAG field, which involves hard work, discipline, exhaustive repetition, little rest, resilience and submission to orders (Barker-Ruchti, 2011). By incorporating these norms, gymnasts also learn the domination logic, which both the dominant and the dominated know and reproduce (Bourdieu, 2001). This exercise would only be possible through an inculcation process, in which we visualize the doxa paradox, and the unadjusted can be excluded from the system (Bourdieu, 2001). Therefore, even in the face of abusive situations in the coach-gymnasts relationship, they would obey orders without questioning and naturalize the symbolic violence of coaches (Oliveira, 2014). This embodiment draws attention because it is so subtle that sometimes even the gymnasts do not perceive:

“(...) the girls are all there and get up every day to go there again, why? Because they hate to do that, do you understand? No, it is not. The gymnasts are there because they like it. So it bothers me about this Gymnastics negative general view: it is pressure, it is demanding, it is hard working, it is sacrificing. However, why the gymnasts come back to the gym the other day?” (Costa, 2018, p. 52).

This interview excerpt summarizes this scenario and reveals that the application of the Bourdieu’s categories can show what those who live daily practice could not perceive. Moreover, it reveals that gymnasts do not understand, because in the relationship of domination they cannot understand, it is not worth it for the dominator, it is not part of the “gymnast habitus” to question and doubt his coach. From this perspective, the case of the Japanese Sae Miyakawa also exemplifies the acceptance of gymnasts, including abusive attitudes, such as the physical aggression of the coach, in favor of the development of a sports career. This shows that the application of symbolic violence does not disregard the limits of coercive force, but is subtle and disguised in correct discourses. Stirling and Kerr (2009) mention that fear and even mixed emotions incapacitate gymnasts to oppose the abusive behaviors of coaches. Thus, the gymnasts can see the imposition of symbolic violence as something for their own sake and sometimes dedicate their success to coaches, as we see in this statement: *“(...) thanks to her (her coach) that my gymnastics career worked out.” (Costa, 2018, p. 56).*

Therefore, we believe that another factor that interacts with the “gymnast habitus” is the athletes' expectations. Considering that gymnasts are dominated, we identified that these expectations seem the illusio, “which arises in the relationship between agents possessing the habitus socially required by the field and symbolic systems capable of imposing their demands on those who perceive them and operate them (...)" (Bourdieu, 2000, p. 113). Thus, gymnasts justify resilience to WAG's "negative" scenario and, why not, domination, for the sake of a larger goal, which often leads to participation or expressive results in major competitions such as the Olympic Games (Barker-Ruchti & Schubring, 2016; Costa, 2018; Pinheiro et al., 2014; Schiavon, 2009).

Thus, developing the "gymnast habitus" and learning the logic of domination is essential to raising capital and thereby achieving goals when in an unfavorable position in the field. Barker-Ruchti and Schubring (2016) point out that understanding the games' logic is an important step towards gaining symbolic capital in the field and possibly gaining access to cultural and economic capital. The authors add that maintaining a good relationship with the coach is a way for the gymnast to obtain social capital that in the future could be converted into other types of capital. Kerr et al. (2016) complement that in the coaches' perspective the physical/corporeal capital, that is, the body legitimately accepted in the field, a form of symbolic capital in the sports field, will be essential for the gymnasts to reach the success in the sport.

Thereby, the coaches develop a process of "gymnasts' habitus" construction through symbolic violence, based on discourses that expose the necessary way of acting. This concept is seen as legitimate and orthodox by coaches, and symbolic violence is a mechanism to legitimize it for gymnasts. An important point, is that the 'correct and necessary way of acting' is an arbitrary coaches' perspective in relation to what is considered, within the WAG field, as legitimate and valuable as good. This arbitrary perspective of the field is related to the criteria for distributing of power through the accumulation of capitals, and manifests itself mainly by the cultural capital (Bourdieu, 1984). Therefore, those gymnasts who do not embody this specific habitus, question coaching practices, seek mutual relationship in decision making and want to be more independent are seen as problematic and difficult to work with (Oliveira et al., 2017).

Indeed, the best match for the maintenance of the authoritarian system in this field is a combination of a harsh coach and a submissive and fragile gymnast habitus. However, this combination can lead to problems for these scenario agents. The studies that have identified abusive training in WAG, presented in the previous section, reveal some examples of the imposition of symbolic violence and its regulation by coaches and gymnasts: Shouting, humiliation and intimidation are ways to show gymnasts who commands and are accepted as discourses and actions that expose the right course of action and are necessary to achieve the results; negligence, even injured gymnast will be forced to compete as the absence would disrupt her career, particularly in an internal competitive environment; dropping out of school activities are necessary for young gymnasts to fully dedicate themselves to training; and, access to education could develop the argumentative ability of gymnasts, which would disrupt the logic of the relationship with coaches (Pinheiro et al., 2014; Stewart et al., 2015; Stirling & Kerr, 2009).

We believe that the arguments presented so far helped us to discuss that the WAG field is fertile for the imposition of symbolic violence by the coach. So, the logic of this field is responsible for building a "gymnast habitus", which is accepted, seen as appropriate and legitimated in this context. On the other hand, we emphasize that coaches deal with the expectations of gymnasts, the athletes' families, are charged by clubs, federations and eventually sponsors, as well as addressing his/her own goals in an unstable career. Therefore, we consider that their habitus derives from relationships with various individuals in this field. But, we emphasize that the final decision, traditionally, is up to the coach (Jacobs et al., 2017; Smits et al., 2017).

Thus, this study showed that power relations in the WAG field were structured in an authoritarian and orthodox domination context. However, there is also another perspective and the gymnasts themselves pointed out the good examples of coaches:

"(...) he's a wonderful person (coach) (...) I think he was the best coach I've ever met in my life (...) I like him with passion, he's a guy who taught me gymnastics and started teaching me that I had some value, I think he was a watershed in my life, trying to understand what I was doing there (...) he was the coach I believe everyone should be, he is a guy who motivates athletes, he's a guy who talks to us, he's the guy who can do his best in training (...) I had a very good relationship with him, until today we sometimes trade some message and such. He had a good relationship with my parents too, he made a point of it, he's a rare gem" (Costa, 2018, p. 52).

Thereby, Bourdieu's work has been criticized for not being able to explain these sorts of changes. But, that is beyond the scope of this article and further research would be worthwhile. For example, studies that analyzed the recent and heterodox phenomenon of sports career extension in WAG identified that some parameters in the coach-gymnast relationship would be changing and thus gymnasts would have more voice in decision making (Barker-Ruchti et al., 2016; Kerr et al., 2015, 2017). Such studies allow us to glimpse that certain beliefs are demystified in WAG and with this the coach-gymnasts relationship becomes more balanced and sustainable for the sport.

Therefore, when the health of athletes is at stake, the sports culture should be a subject of debate and changed where necessary. Reflecting and understanding the context as a whole, from both the gymnast and the coach's point of view, is essential to think how the transformation of habitus of the actors of the sport could favor more positive experiences in WAG.

FINAL THOUGHTS

No doubt a deep reflection comes out when we touch issues such as cultural change in the eyes of Sociology of Sport. Using a classical theoretical framework is the opportunity to exercise the use of a great sociological thinker's lens to the reality of the context we are researching. Other lenses may show other perspectives without indicating whether they are positive or negative. Regardless, it is likely that will see a fertile field to explore. The appropriation of Bourdieu's categories allows us to raise problems and show how this situation was developed. Thus, our purpose was to arouse concerns and reflections that could trigger for further research and, perhaps, changes in the WAG's socio-cultural context.

From this perspective, we show throughout the text that the imposition of Symbolic Violence is so subtle that it often appears disguised in discourses accepted as doxa-legitimated truths. Therefore, the complicity of the dominated in this inculcation process is facilitated and the exercise of authoritarian power is seen by them as "natural". Thus, the dominated tacitly accept the limits imposed by the dominant (Bourdieu, 2001). The author pointed out that this acceptance of the "magical frontier between the dominant and the dominated that are triggered by the magic of symbolic power" sometimes happens against the will of the dominated, so they may appear as "bodily emotions" (guilt, anxiety, shyness, humiliation) or "feelings" (respect, admiration), in other words, as part of the habitus (Bourdieu, 2001, p. 38).

Thereby, the data presented showed that gymnasts accept Symbolic Violence and legitimize it throughout their career, as they admire, respect, obey the coach and to trust that the coach will lead them to their goals simply by reproducing the culture from which they are immersed. This is a characteristic of the field to which they belong and want to continue to be part, an effect of the illusio. Therefore, the coach is acknowledged as a significant part of their success. On the other hand, this feeling of respect and to orders against their will, can trigger guilt, anxiety, shyness and humiliation, so gymnasts only reveal certain abuses of coaches after the end of their sports career (Oliveira et al., 2017).

Moreover, we identified that the coaches' favorable position in relation to the gymnasts contributes to the structuring of a specific class habitus. Perhaps the concept of habitus is fundamental to understanding why coaches resist changes in the WAG field (Bortoleto & Schiavon, 2016). The resistance to the changes indicated by the academic field reveals an orthodox habitus of the coaches, who aim to maintain the doxa of the field, as they would remain in a dominant position in the relationship with the gymnasts. On the other hand, we consider that the coach is both domineering (in relation to gymnasts) and dominated (by other structures). Therefore, analyzing how coaches manage other power relationships in the WAG field is essential for a better understanding of these relationships.

Faced with the abuses mentioned earlier, the International Gymnastic Federation (FIG) has implemented measures to prevent incidents of non-accidental violence, harassment and abuse (FIG, 2018). Through these safeguarding procedures, each national federation shall adopt and implement such policies to protect their athletes in order to identify and eradicating unacceptable practices. For example, the Brazilian Gymnastics Confederation (CBG) created the Code of Conduct and Ethics (CBG, 2018). Thus, coaches and stakeholders should police themselves and understand that the abusive practices, such as those ones mentioned in this study must be eradicated in WAG.

We believe that the arguments presented here contributed to prove our initial thesis: gymnasts are not puppets, without own opinion, but they develop a "gymnast habitus" legitimized by Symbolic Violence in the power relationship with the coach, which aims to maintain the doxa of the WAG's field. Therefore, changes in this scenario will require a lot of effort and time, because the habitus does not undo, it transforms itself in the long run, through long lasting dispositions. In this context, gymnasts are at a disadvantage in relation to the coaches and to the system, which include parents, media, sponsors and federations. If these structures do not demand early outcomes, the athletes could be adults when they reach the sport high performance level. Thus, they would decide by themselves whether they want to continue in this "game of domination" or not and with all the consequences.

In this sense, especially the adults involved in WAG have to be aware that their role in sports is to care for and develop communities that help young athletes. This approach would promote holistic athlete development, prevention of sports abuse and even improved sports performance. Thus, the coaches need to learn and recognize their role as educators and the limits of abuse, charge, discipline and punishment. Then, they would recognize or exclude undesirable attitudes, clarify their training methods and stimulate communication with parents and children, etc.

Still, the International Olympic Committee, the FIG and the Gymnastics Federations of each country should make public the cases of abuse in WAG and punish those involved. They could also contribute to enhance interventions at the sport practice. One of these strategies would be empower and oriented the athletes about their rights and duties, and teach that abuse is not a "natural" aspect of the training. We believe that if everyone works together we can develop a more sustainable, healthy and humane WAG.

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THE EFFECT OF AN 8-WEEK ANAEROBIC GYMNASTICS TRAINING ON BDNF, VEGF, AND SOME PHYSIOLOGICAL CHARACTERISTICS IN CHILDREN

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Original article

Abstract

The purpose of the present study was to observe changes in levels of brain-derived neurotrophic factor (BDNF), vascular endothelial growth factor (VEGF), resting metabolic rate (RMR) and maximum oxygen consumption (VO_2max) in the gymnast children after an anaerobic gymnastics training program. Thirty beginner gymnasts aged 8-12 years old were randomly assigned to control (n = 15) and experimental (n = 15) groups. The anaerobic gymnastics training was conducted for 8 weeks, 3 times per a week. Each session lasted 45 minutes: 10 min warm-up, 30 min core exercise, and 5 min cool down. The anthropometric and body composition of subjects were measured and growth factors were measured by using human BDNF and VEGF PicoKine™ ELISA Kit and analysis was performed using sandwich enzyme-linked immunosorbent assay (Morland et al.) before and after the intervention, and VO_2max, maximum heart rate and RMR were measured using a gas analyzer. At the baseline there were not any significant differences between both groups ($p>0.05$). But in the post-test, a significant difference was observed for BDNF($p=0.02$) and VEGF($p=0.018$) values between the two groups. Within-group there was a decrease in the value of the maximum heart rate indicator ($P<0.05$) and VO_2max and BDNF increased significantly after an intervention ($P<0.05$). In conclusion, the results of the present study suggest that anaerobic gymnastic training increases the level of salivary BDNF and VEGF in children. These types of exercises may also improve cardiorespiratory fitness in children.

Keywords: *children, neurotropic factors, growth factors.*

INTRODUCTION

Childhood is the best and the most important period of a lifetime for a lifetime warranty by prevention of diseases such as metabolic problems and improvement of health factors such as cardiorespiratory and growth indexes. Genetic factors, medical conditions, medications, and environmental factors are the most common causes of childhood disorders, which are usually managed through a diet regimen, exercise, and surgical treatment. Individuals with lack of physical activities have a higher burden of vascular and neurological damage than healthy individuals, potentially explaining increased rates of cardiovascular diseases (Languren, Montiel, Julio-Amilpas, & Massieu, 2013). Increasing physical activities through exercise training programs has also been shown to improve vascular, peripheral nerve, and cognitive function through vascular remodeling, angiogenesis, and neurogenesis (Leckie et al., 2014). Therefore, exercise interventions may be especially important for the prevention of complications of health and growth factors problems. Growth factors with angiogenic and neurotrophic properties such as vascular endothelial growth factor (VEGF) and brain-derived neurotrophic factor (BDNF) are implicated in vascular and neurological repair in both animal and human studies (El-Alameey, Ahmed, & Abushady, 2019; Kermani et al., 2005).

BDNF is well known to show an exercise-induced increase in expression and promote neuronal cell formation and angiogenesis. Also, various growth factors, such as VEGF is known to promote the production of new cells and angiogenesis. BDNF is the most abundant in the nerve growth factor family and is related to nerve growth factor, the first neurotrophic factor discovered and acts via protein tyrosine kinase receptor (TrkB) (Soppet et al., 1991). In the periphery, BDNF is found in the plasma, serum, and platelets and it is formed by vascular endothelial cells and by peripheral blood mononuclear cells (Sarchielli, Greco, Stipa, Floridi, & Gallai, 2002). A positive correlation between BDNF levels in the brain and serum was described therefore the peripheral levels of BDNF may reflect the brain levels and vice versa. It should be mentioned however, that some authors challenged the finding by Poduslo and Curran (Poduslo & Curran, 1996) and by Pan et al (Pan, Banks, Fasold, Bluth, & Kastin, 1998).

VEGF is a key cytokine known to increase vascular permeability and vasodilatation. Moreover, there is an evidence that VEGF is involved in the pathogenesis of cardiovascular risk factors, arteriosclerosis, obesity, and metabolism morbidity and mortality (Silha, Krsek, Sucharda, & Murphy, 2005). Angiogenesis is stimulated by VEGF, which also directly enhances neurogenesis and synaptic function; however, the initial molecular signal that leads to increased cerebral VEGF in response to exercise has not been determined (De Rossi et al., 2016).

Exercise at high intensity, causing lactate from active skeletal muscles to accumulate in the blood, and lactate injections have been previously found to increase brain expression of VEGF (Lezi, Lu, Selfridge, Burns, & Swerdlow, 2013), but the mechanism is unknown. Moreover, in wounds, lactate is known to accumulate and stimulate angiogenesis, (Ruan & Kazlauskas, 2013). Lactate, released in situ from polymeric lactic acid microfibers, induces angiogenesis in the brain, again through unidentified mechanisms (Álvarez et al., 2014). Cerebral hypoxia, another condition known to increase lactate levels in the brain, also causes angiogenesis via VEGF (Shweiki, Itin, Soffer, & Keshet, 1992). However, as lactate or exercise does not increase hypoxia-inducible factor 1a (HIF-1a), hypoxia is unlikely to be part of the response (Poduslo & Curran, 1996). The mechanisms behind lactate-induced angiogenesis thus remain to be elucidated (Morland et al., 2017). The mechanisms by which exercise increases VEGF and BDNF are not clearly understood, but Increased density of capillaries due to angiogenesis, the sprouting of new capillaries from pre-existing vessels, is one mechanism (Ding et al., 2006) and Exercise induces cerebral VEGF and angiogenesis via the lactate receptor hydroxycarboxylic acid receptor1 (HCAR1) is another mechanism that is recognized by Cecilie Morland and et all (Morland et al., 2017).

Data from previous studies suggest an exercise intensity dependent effect on blood BDNF and VEGF concentrations. Most of these studies used blood lactate to determine the degree of the exercise intensity, suggesting that exercise with higher blood lactate concentrations results in elevated BDNF and plasma concentrations (Vega et al., 2006). However, it is not clear if lactate per se or other mechanisms are responsible for the described changes in blood BDNF concentrations. To answer this question, Thorsten Schiffer and et al used the lactate clamp method at rest that is an established method to examine physiological and neurological responses of lactate in the human organism. After infusion of sodium-lactate, BDNF and lactate increased significantly and reached baseline values at the end of the experiment. They reported that blood lactate increases during high intensity exercise after the infusion of sodium-lactate but no metabolic acidosis is seen suggesting that the mechanism underlying blood BDNF augmentation is lactate per su (Schiffer et al., 2011). Based on the result of Thorsten Schiffer studies that Lactate infusion at rest increases BDNF blood concentration in humans (Schiffer et al., 2011), and according to the results of Cecilie Morland and et al that exercise induces cerebral VEGF and angiogenesis via the lactate receptor HCAR1 (Morland et al., 2017), this study aimed to investigate the effect of an anaerobic gymnastics training (AGT) on growth factors (BDNF and VEGF), vo2max and resting metabolic rate in children.

METHODS

Thirty 8 to 12_year_old boys who enrolled in an elementary level of gymnastics participated in this study and were randomly divided into an experimental and control groups. Subjects were diagnosed based on the American Council on Exercise lists (Jackson and Pollock equation for three-point subcutaneous fat measurement considering the fat percentage of 6 to 13% as athletic category (normal weight group)) (Jackson & Pollock, 1978; Jackson, Pollock, & Ward, 1980) without concomitant diseases. Exclusion criteria included evidence of any disease, drug therapy, structural abnormality, and prohibition of exercise testing. The study protocol was approved by the Ethics Committee of Ardabil University of Medical Science (IR.ARUMS.REC.1397.290) and Iranian Registry of Clinical Trials (IRCT20190917044807N1). This study was performed under the Declaration of Helsinki (Revised 2008). All subjects and their parents were informed about the study procedure and the possible risks involved, and both parents and subjects signed a written consent form. Baseline characteristics of both experimental and control groups are shown in table 1.

The present study was semi-experimental and its design was pre-test and post-test with a control group. The control group was asked to stop training for eight weeks, and repeated phone calls prevented them from participating in the group's training programs. Depending on the age of the subjects, the subjects were in the pre-pubertal stage. The experimental procedures consisted of a familiarization phase (including 3 sessions for familiarization of participants to the equipment and protocols), followed by pre-testing (24 hours before starting training program), then 8 weeks of anaerobic gymnastics exercise (AGE) (3 days a week), and then post-testing (48 hours after the last session of training program). Each exercise session was guided by a trained instructor, and conducted for 45 minutes in three stages: A 10-minute warm-up, a 30-minute main exercise, and a 5_minutes cool down. During the warm-up, subjects performed fun gymnastics movements and fun animal movements, such as running, rabbit, cat, crab, bear, and kangaroo movements (Fediani, Dewi, Irfannuddin, Saleh, & Dhaini, 2014). AGE including 30-second Continues Jump (30-s CJ), 30-s Vertical Continues Jump on Box (30-s VCJB), Specific Aerobic Gymnast Anaerobic Test (SAGAT) and Running Jump Rolling (RJR) were used for the main part (Čular et al., 2018; Dal Pupo et al., 2014). Of course, we did a pilot study for evaluating the amount of Lactate level before and after doing designed training and showed that level of lactate increase up to 7-8 mmol/L compared to baseline level of 1- 1.6 mmol/L (figure 1).

We used 30-s CJ training, because, according to result and suggestion of previous studies, the continuous jump test seems to be more specific for sports that are acyclic such as gymnastics, basketball, volleyball, etc., all of which involve similar movement patterns and have practical application for coaches and athletes (Dal Pupo et al., 2014).

Since, 30-s VCJB, has a close relationship to the standard laboratory 30-s Wingate test and this training is so common and prevalence in gymnastics physical training, we considered this training to one part of the main exercise. The next training was SAGAT (figure 2). We used this training protocol with a little change in the difficulty of movements according to age, body composition, and fitness level of subjects.

RJR also was selected as one of the exercises performed in each session because of its anaerobic essence and it consisted of jumping over box and front-rolling (Figure 3). RJR test was performed in 2 sets; each set 5 repetitions with a 3-min recovery period between the sets.

Anthropometrical variables including height, weight, waist to hip ratio (WHR), body fat percentage (BF%), body fat weight (BFW), and lean body weight (LBW) were measured before and after eight weeks training. To measure waist and hip circumference, the subjects were asked to stand up straight and breathe out. The smallest circumference between the umbilicus and the xiphoid process was considered as waist and the largest circumference around the buttocks was considered as hip. These circumferences were measured by measure tape.

Three points skinfold test which is a reliable method for estimating body-fat percentage was used in the present study. Harpenden caliper was applied in tight (quadriceps), chest (pectoral), and belly (abdomen)) and Jackson/Pollock 3-Site equation was used to predict BF%. To obtain the best and most consistent measurements, all skin-fold measurements were taken on the right and by the same person. Also, a minimum of two measurements was taken at each location. If the two measurements differed by more than 2 millimeters, a third measurement would be taken. The online body composition calculator then uses the average of the 2-3 measurements to make the calculations. BFW and LBW were calculated by the following formulas (Jackson et al., 1980):

$$BFW = \text{Body weight} \times BF\%,$$
$$LBM = \text{Body weight} - BFW$$

To measure VO2max, Participants were instructed not to feed two hours before the test, abstain from caffeine, and not to perform any strenuous physical exercises 48 hours before the test. Participants were familiarized with the ergometer (automatic ergometer treadmill) a few days before the test. As subjects were children aged 8–12 years old, a modified Balke protocol was used for evaluation of their Vo2max (Washington et al., 1994). Because this continuous protocol is well suited for the unfit, the obese, the very young child, or the chronically ill individual (Washington et al., 1994). After warming up, each subject performed modified Balke protocol, which progressively increases the grade from 2% to more than 10% at 2% increments anyone minutes until the subject could not maintain a constant speed of 3.5 mph and receive to exhaustion (Washington et al., 1994). Subjects continued test until exhaustion and they were verbally encouraged throughout the test. All subjects were assessed on a treadmill in two stages (pre-test and post-test) and data on respiration gas exchange were obtained breath-by-breath using a respiratory gas analyzer (QOSMED, Italy Part2001N.COO627-D2-91). Breath-by-breath data was transformed into 1 s data using KaleidaGraph software. We applied this method for data of VO2, VCO2 and HR in each subject and averages of all subjects' data were used for analyzing.

. The running time and distance were recorded and VO2 and respiratory exchange ratio (García de la Torre et al.) VO2max was considered the maximum value of VO2 attained during the incremental test (Morinder, Larsson, Norgren, & Marcus, 2009). The subject's heart rate was measured by installing a polar on the subjects' chest and recorded every 1 second.

All subjects had 8 hours of sleep, did not perform any exercises for 48 hours before each session, and did not eat or consume any liquids, except water, for 12 h before testing. Each subject was transported by motor vehicle to the testing site to ensure minimal activity before rest metabolic rate (RMR) determination. All RMR measurements were performed between 09:00 and 11:00 hours. RMR was determined by a gas analyzer system by use of the open-circuit technique while the subject was sitting (Consolazio, 1963). After entering the laboratory, subjects rested in a chair for 15 min in an isolated temperature controlled room (21-24 C). After the first 15 min rest, the second 15 minutes started and subjects were fitted with a Hans Rudolf face mask which was connected to the gas analyzer system for the determination of breath by breath oxygen analysis. Analyzers were calibrated before each test according to the specifications of the manufacturer. During the test, the room was darkened, and the noise was kept to a minimum. The subjects were instructed to remain awake, quiet, and motionless before and throughout the entire 15-min period. The average of the last 10 min of the measurement period was used to obtain resting metabolism by the following formula (Gilliat-Wimberly, Manore, Woolf, D SWAN, & Carroll, 2001):

$$\mathrm{RMR} = 3.941\left[\mathrm{VO2}\left(\frac{\mathrm{L}}{\mathrm{min}}\right)\right] + 1.106\left[\mathrm{VCO2}\left(\frac{\mathrm{L}}{\mathrm{min}}\right)\right] = \mathrm{Kcal/min}$$

Saliva samples were collected between 09:00 and 11:00 hours. The parents/guardians and children were requested to adhere as closely as possible to the following standardized saliva collection instructions (Chiappin, Antonelli, Gatti, & Elio, 2007): The children should 1) not eat anything 60 minutes prior to sample collection, 2) not brush their teeth before the sample collection (this may cause the gums to bleed causing blood contamination of the saliva), 3) rinse their mouths with water to remove food residue before the sample collection, and swallow to increase hydration, and 4) wait at least 10 minutes after rinsing before collecting saliva to avoid sample dilution (Chiappin et al., 2007). Saliva samples were collected via unstimulated passive drool over five minutes. The seated children were asked to lean slightly forward and tilt their heads down and accumulate saliva in the floor of the mouth for a minute, and saliva was subsequently swallowed. Then there was a four-minute collection where the children dribbled saliva through a 5 cm plastic straw into a pre-weighed polypropylene cryovial tube (5 ml capacity). Care was taken to allow saliva to dribble into the collecting tubes with minimal orofacial movement. After collection the samples were analyzed in the laboratory (Chiappin et al., 2007).

Human BDNF PicoKine™ ELISA Kit (Catalog No. EK0307; R&D Systems, Austria) and Human VEGF PicoKine™ ELISA Kit (Catalog No. EK0539; R&D Systems, Austria) were used for measurement of BDNF and VEGF respectively. Collected saliva samples were centrifuged for 15 min at 4000 rpm. The evaluation was performed according to the manufacturer's instructions for the use of buffers, diluents, and materials .The analysis of BDNF and VEGF were performed using a sandwich enzyme-linked immunosorbent assay (ELISA). Fluorescence was measured at 450 nm with a microplate reader.

Data are expressed as mean and standard deviations (SD). All analyses were performed using SPSS version 23.0. The Kolmogorov-Smirnov test was used for the normality of distribution and Levin's test was used for the homogeneity of variance. Also, the homogeneity of the regression slope test was used for the test of homogeneity of the regression slope. To compare the mean post-test scores in two groups, analysis of covariance test (ANCOVA) was used. Paired t-tests were used to examine significant differences within groups. A value of $p<0.05$ was regarded as statistically significant.

Table 1
Characteristics of the subjects at baseline.

Variables/Group	Control (*n* = 15) XA±SD	Experimental (n = 15) XA±SD	P-value *
Age (years)	9.60 ± 1.05	9.80 ± 1.47	0.672
Height (cm)	133.37 ± 5.03	133.60 ± 5.36	0.903
Weight (kg)	29.43 ± 3.66	29.40 ± 3.56	0.980

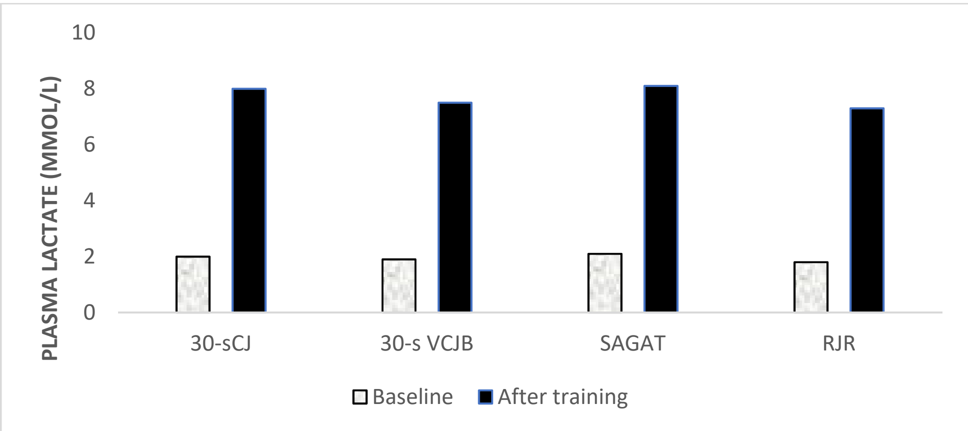

Figure 1. Plasma lactate response to AGE (30-second Continues Jump (30-s CJ), 30-s Vertical Continues Jump on Box (30-s VCJB), Specific Aerobic Gymnast Anaerobic Test (SAGAT) and Running jump rolling (RJR) in a pilot study.

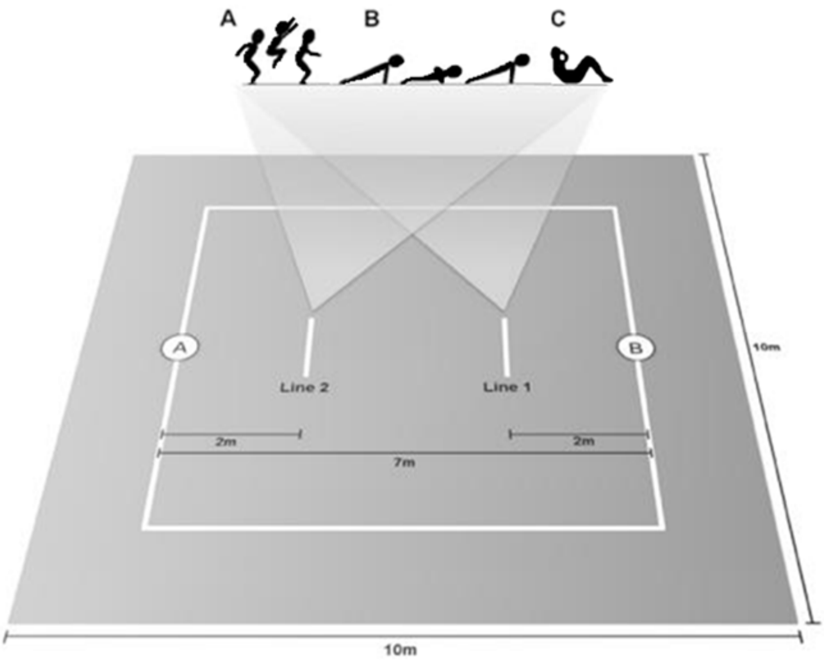

Figure 2. Illustration of SAGAT test: After the start command, the subject taps the floor and runs seven meters to "point B". At this point, the subject taps the floor again and returns two meters towards "point A" (Line 1). At this point the subject performs tuck jumps, push-up, and sit-ups exercises, each one time, and then returns to "point B" and taps the floor. This is the end of the first repetition and the start of the second repetition and subject runs seven meters to "point A", taps the floor, returns two meters towards "point B" (Line 2), performs exercises described above, and then returns to "Point A" and taps the floor that means the end of the second repetition and the start of the third repetition. This pattern continues until a total of 6 repetitions are completed.

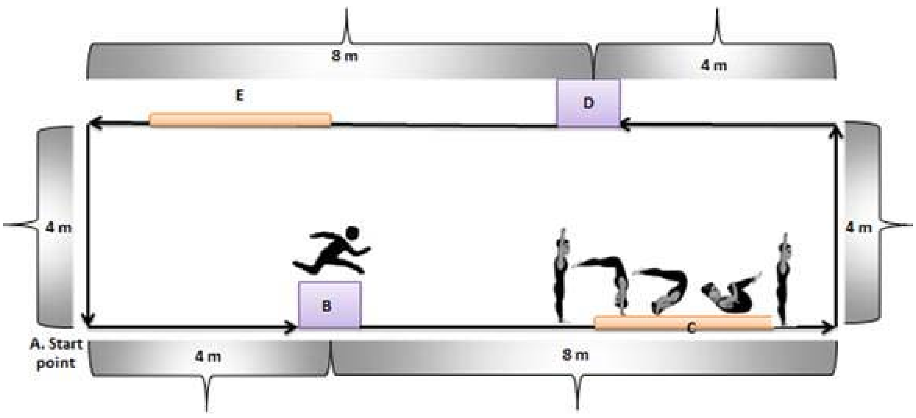

Figure 3. Illustration of RJR test. Each repetition was as follows: after the start command, the subject runs four meters toward "point B" to perform jumping over a box with a height of 50 cm, then continues to running towards "point c" to perform front- rolling. Following rolling, the subject must change the direction and runs fast to reach "point D" for doing jumping over the box, then runs to "point E" for performing front-rolling and at the end runs to start point (point A). After completion of 5 repetitions (first set) subject recovers for three minutes and then starts the second set.

RESULTS

Subject's characteristics including anthropometrical, body composition and physiological factors , and the level of salivary BDNF, and VEGF in experimental and control groups were not significantly different at baseline and are presented at table 2 (p>0.05). Before the test, its defaults were checked. The results of the Kolmogorov-Smirnov test showed that the data distribution was normal (P>0.05). The results of the Leven test were not significant for any of the variables and indicated the homogeneity of variance (P>0.05). Also, the study of homogeneity of regression slope showed that statistical F-ratio is not significant for any of the variables and indicates the assumption of homogeneity of regression slope (P>0.05). To compare the mean post-test scores after controlling the pre-test effect in two groups, analysis of covariance test (ANCOVA) was used. These results have been shown in table 3. According to the results, only in BDNF (p= 0.03) and VEGF (p= 0.03) variables, a significant difference was observed between the two groups.

Table 2

Characteristics of the subjects (anthropometric, body composition, physiological, BDNF, and VEGF) at baseline.

Variable	Groups (n=15 for any group)		P-value*
	Control	Experimental	
Weight (kg)	29.43 ± 3.66	29.40 ± 3.56	0.98
WHR (cm/cm)	0.87 ± 0.02	0.86 ± 0.02	0.58
BF (%)	6.79 ± 1.78	6.74 ± 1.76	0.94
BFW (kg)	2.09 ± 0.81	2.07 ± 0.81	0.94
LBW (kg)	27.80 ± 3.96	27.85 ± 3.98	0.97
VO2max (mL/kg/min)	35.78 ± 4.49	37.63 ± 5.56	0.32
RMR (Kcal/day)	1008.46±145.38	1023.06±187.71	0.81
MHR (beat/ minutes)	185± 18	188 ± 14	0.69
BDNF (pg/ml)	0.061±0.005	0.061±0.003	0.87
VEGF (pg/ml)	1.593±0.401	1.631±0.437	0.80

Note: Data are presented as mean ± standard deviation. WHR= Waist hip ratio, BF (%) = Body far percentage, BFW= Body fat weight, LBW= Lean body weight, VO2max =Maximum oxygen consumption, RMR= Resting metabolic rate, MHR= Maximum heart rate, BDNF= Brain derived nerotrphin factor, VEGF= Vascular endothelial growth factor.

Table 3

Results of analysis of covariance to compare posttest scores of variables in two groups.

Dependent Variables	Mean Differences	95% Confidence Interval for Difference		P-value
		Lower Bound	Upper Bound	
Weight (kg)	-0.202	-0.773	0.370	0.475
WHR (cm)	-0.002	-0.007	0.003	0.466
BF (%)	-0.011	-0.366	0.344	0.951
BFW (kg)	-0.021	-0.214	0.172	0.827
LBW (kg)	0.011	-1/88	1.902	0.991
VO2max (ml/Kg/min)	2.311	-0.235	4.858	0.073
RMR (Kcal/day)	-33.145	-73.50	7.212	0.103
MHR (beat/minutes)	-4.716	-9.451	0.02	0.051
BDNF (pg/ml)	0.008	0.001	0.015	0.02*
VEGF (pg/ml)	0.294	0.054	0.534	0.018*

Note: WHR= Waist hip ratio, BF (%) = Body far percentage, BFW= Body fat weight, LBW= Lean body weight, VO2max =Maximum oxygen consumption, RMR= Resting metabolic rate, MHR= Maximum heart rate, BDNF= Brain derived nerotrphin factor, VEGF= Vascular endothelial growth factor.

Table 4

Pre-training vs. post-training values for anthropometric, body composition, physiological, BDNF, and VEGF variables in the two groups.

Variables		Groups	
		control	Experimental
Weight (kg)	Pre-test	29.43 ± 3.66	29.40 ± 3.56
	Post-test	29.96 ± 3.58	29.73 ± 3.42
	P Value	0.06	0.06
WHR (cm)	Pre-test	0.87 ± 0.021	0.86 ± 0.023
	Post-test	0.87 ± 0.025	0.86 ± 0.022
	P Value	0.17	0.16
BF (%)	Pre-test	6.79 ± 1.78	6.74 ± 1.76
	Post-test	6.88 ± 1.25	6.84 ± 1.21
	P Value	0.66	0.65
BFW (kg)	Pre-test	2.09 ± 0.81	2.07 ± 0.81
	Post-test	2.10 ± 0.58	2.07 ± 0.55
	P Value	0.89	1.00
LBW (kg)	Pre-test	27.80 ± 3.96	27.85 ± 3.98
	Post-test	27.28 ± 3.98	27.34 ± 3.99
	P Value	0.45	0.45
VO_2max (mL/kg/min)	Pre-test	35.78 ± 4.49	37.63 ± 5.56
	Post-test	36.48 ± 4.88	40.14 ± 4.88
	P Value	0.47	0.03†
RMR (kcal/day)	Pre-test	1008.46±145.38	1023.06±187.71
	Post-test	1006.80 ±147.76	984.86 ± 121.91
	P Value	0.23	0.22
MHR (beat/minutes)	Pre-test	185 ± 18	188± 14
	Post-test	184.00 ± 15.07	181± 10
	P Value	0.27	0.04†
BDNF (pg/ml)	Pre-test	0.061±0.005	0.061±0.003
	Post-test	0.062±0.004	0.070±0.013
	P Value	0.33	0.04†
VEGF (pg/ml)	Pre-test	1.593±0.401	1.631±0.437
	Post-test	1.614±0.406	1.928±0.428
	P Value	0.39	0.06

Note. N = 15 in each group. Data Shown are mean ±S.D.

†: significant difference between pre-test and post-test identified by paired t-test

WHR= Waist hip ratio, BF (%) = Body far percentage, BFW= Body fat weight, LBW= Lean body weight, VO2max =Maximum oxygen consumption, RMR= Resting metabolic rate, MHR= Maximum heart rate, BDNF= Brain derived nerotrphin factor, VEGF= Vascular endothelial growth factor.

DISCUSSION

In the present study our results suggest that regular AGE increases the level of salivary BDNF and VEGF, and improves vo2max and maximal heart rate (MHR) in the trained children. The important point for us to the utilization of AGE in this research was the studies in humans that used an infusion of sodium-lactate to determine the level of exercise intensity, suggesting that exercise with increased blood lactate concentrations results in increased BDNF plasma level concentrations. Some studies used the lactate clamp method at rest that is an established method to examine physiological and neurological responses of lactate in the human organism. After the infusion of sodium-lactate, BDNF and lactate increased significantly and reached baseline values at the end of the experiment. They found that the infusion of sodium-lactate provides an increase in blood lactate without metabolic acidosis, which is accompanied during high intensity and lactate exercise (Schiffer et al., 2011). Previous studies have reported that also aerobic, anaerobic, high intensity interval training (HIIT) and resistance exercises increase the expression of growth factors such as BDNF and VEGF and these factors promote production of neurons and have an effect on health, cardiorespiratory indexes, body composition and performance variables (Gillen & Gibala, 2013; Roth, Elfers, Gebhardt, Müller, & Reinehr, 2013), but there is a contradiction in the results (Roth et al., 2013).

Gymnastics training is becoming very popular, fun, and basic exercise among children. Thanks to its short-time, varied, and attractive functional exercises, it has become an interesting alternative for all those who do not like long, low-intensity exercise sessions aimed at improvement in physical performance. Several factors affect the production of BDNF and VEGF such as age, physical activity, body weight, nutritional status, gender, and genetics (Fediani et al., 2014). To reduce bias, authors conducted the equivalency of age, sex, nutritional status, and physical activity levels between two groups by exclusion criteria. The age of less than 8 or more than 12, extreme nutritional status, and a child with a history of champion and professional exercise were excluded. Recent studies showed that an exercise modifies both the synthesis and secretion of BDNF in the brain (Seifert et al., 2010). In humans, these adaptations commonly result in higher circulating BDNF concentrations (Seifert et al., 2010). Others demonstrated higher systemic BDNF concentrations after three months of “Cross-Fit”, a mode of intense exercise that is in line with our research results (Murawska-Cialowicz, Wojna, & Zuwala-Jagiello, 2015). In the current study, we demonstrated that an AGE provided enough stimuli to increase salivary BDNF in healthy children. The higher systemic BDNF concentrations could be the consequence of an increase in BDNF synthesis in the brain or peripheral storage and release system.

Gymnastics is an anaerobic physical activity. During anaerobic exercise, the body including the brain needs greater oxygen and calorie supplies, results in intermittent hypoxia and hypoglycemia. Intermittent hypoxia and hypoglycemia trigger the production of Hypoxia-inducible factor 1-alpha (HIF-1a) and sirtuin proteins. These gene transcription proteins stimulate the production of factors, such as BDNF and Nerve growth factor (NGF), the synthesis of VEGF for improving blood flow, and increase the production of various antioxidants to reduce inflammation (Jones, Lee, Brown, Jarrott, & Beart, 2006; Satoh et al., 2010). Furthermore, in our study the level of VEGF in post-test was significantly different between two experimental and control groups. This suggests that AGE can induce an increase in this factor and increases both skeletal muscle mass and circulation and both processes require the up-regulation of angiogenesis.

The MHR in the progressive modified Balk test was also less than the pre-test in the post-test. The HR is under the control of the autonomic nervous system (Almeida & Araújo, 2003) and although we did not assess parasympathetic activity, vagal activity might increase after 8-weeks of AGE in the experimental group. Vo2max increased significantly after training in the trained group. These changes indicate an improvement in cardiovascular fitness, which meant the heart, handled the workload as a relatively lighter physiological demand. A similar outcome has been reported in previous studies (Gutin et al., 2002).

Multiple possible mechanisms are involved in the effects of exercise in increasing trophic factor expression. For example, BDNF is an important mediator of the beneficial effects of exercise on brain health and plays a vital role in the function of the peripheral organs in both the central metabolic pathway and the modulation of energy metabolism (Pedersen et al., 2009). It has also been observed that increased levels of BDNF after exercise lead to increased oxidation of glucose and triglycerides, resulting in increased body temperature, energy, and oxygen consumption (Huang, Larsen, Ried-Larsen, Møller, & Andersen, 2014). Although there is no evidence in humans regarding the effects of exercise on BDNF receptor expression in peripheral tissues, studies in rodents have demonstrated that exercise increases BDNF receptor expression in skeletal muscle (Ogborn & Gardiner, 2010). Accordingly, other authors suggest that regular exercise increases BDNF sensitivity in peripheral and central organs in humans (Currie, Ramsbottom, Ludlow, Nevill, & Gilder, 2009).

Our study had some limitation such as lack of control over the excitements and other mental factors in participants, as well as their sleep and resting conditions, the small sample size and not using girls as subjects. To explore practical usage and the mechanisms that appear to increase serum BDNF and VEGF in children, it is suggested to the next studies to use a large sample size and girl subjects in their studies.

CONCLUSIONS

In conclusion, the results of the present study suggest that anaerobic gymnastics training increases the level of salivary BDNF and VEGF in children. These types of exercises may also improve cardiorespiratory fitness in children.

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BALLET MOVEMENTS IN RHYTHMIC GYMNASTICS ROUTINES: AN ANALISYS FROM THE LAST TWO CODE OF POINTS (2013-2016 and 2017-2020)

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Original article

Abstract
Ballet is a world-renowned dance and its movements can be seen in athletes' education and training systems from various sports, especially those considered artistic sport, such as rhythmic gymnastics (RG). The competition system of this sport is driven by a Code of Points (CoP) that is established every four years and, although it has some changes during the years, remains in its essence clearly influenced by dance aspects as well as Ballet movements in its performance. Thus, the purpose of this research was to analyze the Ballet movements in RG routines in the 2013-2016 and 2017-2020 Olympic cycles, in order to further understand the relationship between RG and Ballet and compare them in two different RG Code of Points. This was a quantitative research that analyzed 24 RG routines performed at RG World Championship (2013 and 2019) recorded and posted at one of the International Gymnastics Federation's official social media websites. Results show that: a. there was no significant difference between the years ($p \geq 0,05$), but the average of Ballet movements in the four apparatus routines in 2013 was higher than 2019; b. although the difference was not significant, the analysis of the magnitude of the effect size showed a small difference for ball (0.68) and clubs (0.29) and moderate for hoop (0.97) and ribbon (0.74); c. Ballet movements performed during Apparatus Difficulties (AD) and Dynamics Elements of Rotation (R) increased; those performed as connecting elements decreased.

Keywords: *gymnastics, ghoreography, training, ballet movements.*

INTRODUCTION

The relation between Sport and Art are identified in a diversified way, from modern sports to the current most contemporary ones (evidenced by the great spectacularizing of sports activities), situated in its historical and social contexts, in plural possibilities (Melo et al, 2007).

Sports that have this relationship can be considered as "aesthetic sports," precisely due to their aesthetic appeal, determined by their goals and movements (Best, 1980). In some of these sports we identify the presence of elements of Arts, such as classical Ballet's movements in Code of Points of RG (FIG, 2018; FIG, 2014).

In our society, Ballet is not only performed in theaters, but also in the athletes' education from various sports, especially those considered aesthetic sport, such as artistic swimming (Gemma, Wells, 1987; Figura et al., 1993), figure skating (Vieira de Jesus, 2013), artistic gymnastics (Nunomura, Pires & Carrara, 2009) and rhythmic gymnastics (RG) (FIG, 2019, Porpino, 2014; Toledo, 2010; Caçola, 2007).

Gymnastics and Ballet have stories that interweave, and this relationship occurs for different reasons, beginning with the historical aspects of RG, before it became a discipline of competitive gymnastics. Following authors from gymnastics, rhythmic gymnastics compiled the dance and art influences citing Jean Georges Noverre (natural movement and the "art of expressing"); François Delsarte (relationship between postures as the essence of expressive movement); Rudolf von Laban, Isadora Duncan and Elizabeth Duncan (expressiveness and choreography); Emile Jacques Dalcroze (musical and rhythmic characteristics); Rudolf Bode and Henrich Medau (manual apparatus) (Langlade & Langlade, 1970; Bodo-Schimid, 1995; Bobo & Sierra, 1998, Toledo and Antualpa, 2014).

The influence of dance, theater, expression, rhythmic, artistic and aesthetic aspects, in Modern Gymnastics (later RG) can be noted through different theorists related to the large field of the Arts. This influence remained even after RG started being a sport in 1975, when it was named Rhythmic Sportive Gymnastics (RSG). Now called Rhythmic Gymnastics (RG), the discipline is still ruled by a Code of Points made by the International Gymnastic Federation (FIG).

The Code of Points (CoP) is established every four years (after the Olympic Games) and, although it has some changes during the years, remains in its essence clearly influenced by dance aspects, as well as classical Ballet movements, in its performance. There is no doubt that Ballet movements have been inserted in the training and routine of RG gymnasts in order to improve the scores of individual and group exercises (body difficulty - BD and apparatus difficulty - AD), technique and precision of body movements, and artistic components, like expression and rhythm.

Currently, in the 2017-2020 Olympic cycle, gymnasts in individual routines are evaluated in terms of difficulty (D) and execution (E). In Panel D, they are judged on body difficulties (BD) - including jumps, balances, rotations, dance step combinations (S), apparatus difficulties (AD), and dynamic elements with rotation (R). In Panel E, the technical execution is evaluated by the mistakes committed by gymnasts during their performance, as well as their artistic execution related to the choreography (FIG, 2018).

It is interesting to point out that many of the body difficulties elements are closely influenced by typical Ballet movements, even using the same nomenclature. In addition, Ballet movements are used in different moments of the composition, such as connecting elements, dance steps, body difficulties, or composing dynamic elements with rotation.

Due to those requirements of the Code of Points, it is common that RG gymnasts' practice or started practicing Ballet in the early years of their careers (Laffranchi, 2001; Lebre & Araujo, 2006; Ribeiro, 2010). Considered one of the oldest and best organized and systematized training systems (Lebre & Araújo, 2006), Ballet became a guide for training in RG, managing to assist gymnasts in the movements' execution, since it brings the technical details of posture, parts of the body, body articulation and synchronism, all together aiming at perfection.

The relationship between RG and Ballet through body expression and music and body technique must be experienced so that the gymnast can, at the time of her presentation, dialogue with the public, coaches, referees and those who appreciate the performance (Assis, 2019). Ballet in the gymnast's daily life has the function of uniting the line of body movements within the use of apparatus and specific RG body technique, seen in the Body Difficulties (Agostini & Agostini, 2010). However, it is important to emphasize that Ballet can and should be practiced in RG as physical preparation (Laffranchi, 2001), or artistic education, from novice to expert gymnasts' sessions (Ribeiro, 2010). It may include movements using the Ballet bar, as well as center and diagonal exercises (FIG, 2019), varying the complexity.

By observing and analyzing how the highest-level gymnasts are adapting their routines to fit existing the CoP system, coaches can guide gymnasts at all levels to successful outcomes (Ávila-Carvalho, Sousa and Silva & Lebre, 2014).

The hypothesis of this study is that the 2013-2016 cycle, characterized by a limitation in the use of apparatus difficulties (called mastery at this time), allowed greater use of dance step combinations and connections and, consequently, greater frequency of Ballet movements, when compared to the 2017-2020 cycle.

Thus, the purpose of this manuscript is to analyze the Ballet movements in rhythmic gymnastics routines in the last two Code of Points (CoP) cycles (2013-2016, 2017-2020), in order to further understand the relationship between RG and Classical Ballet, and compare them in two different RG Code of Points proposals.

METHODS

This was a quantitative research that used document analysis (Thomas, Nelson & Silverman, 2015), which is restricted to documents, written or not, as a primary source of study. The main documental source was composed by videos of the RG routines performed at the 32nd FIG Rhythmic Gymnastics World Championship (2013/Kiev) and at the 37th FIG Rhythmic Gymnastics World Championship (2019/Baku). The videos were analyzed at the FIG official channel on YouTube®.

Twenty-four routines were considered twelve from each event, three from each apparatus (hoop, ball, ribbon, clubs) from the podium gymnasts. Data collection was carried out in stages.

First, the researchers - one of them being a rhythmic gymnastics referee - identified the Ballet movements in the routines, regardless of the RG components in which they were distributed, i.e., Body Difficulties (BD), dance steps combination (S), Dynamic Elements with Rotation (R), Apparatus Difficulties (AD) or Connections (C).

Then, the identified movements were entered in a Microsoft Excel® spreadsheet, according to the frequency with which they appeared in the compositions. To validate the procedure, two graduated Ballet instructors - with more than ten years of experience teaching Ballet - performed the same process. Both files were compared, and doubts were debated for a final count. It is important to highlight that only the elements with a correct execution were considered.

Later, the names of the elements were revised and standardized according to the Ballet Dictionary (Rosay,1980). Finally, all those involved in the research held a meeting for discussing its findings, in order to conduct data analysis.

Data were organized into tables and arranged by gymnast information (G); ranking (nº); first letter of the apparatus (in English) and year (2013 or 2019).

The table columns were organized to include the gymnasts, their countries, Ballet movements detected, quantity of Ballet movements during each routine of each gymnast, and the variety of movements found. The variety of elements was established by the number of different movements performed, without considering repetitions, while the quantity indicated the total number of movements in the routine, considering the repetitions.

Moreover, the Ballet movements were combined with the RG components of a routine: Body Difficulties (BD), dance steps combination (S), Dynamic Elements with Rotation (R), Apparatus Difficulties (AD) or Connections (C).

For data analysis, the descriptive statistics used were measure of central tendency (mean), measure of dispersion (maximum and minimum values) and frequency. The normality and homoscedasticity tests were used in order to detect the distribution and homogeneity of data. The Wilcoxon test was performed to compare the variables in the years 2013 and 2019. The level of significance was set at 5% ($p<0.05$). The tests were performed using SPSS 22.0 statistical package.

Further, to complement the interpretation of the magnitude of the effect of changes in the Ballet movements, the effect size (ES) and confident limit (CL; 90%) were reported according the procedures proposed in the literature (Batterham & Hopkins, 2006). The ES (corrected by the Hedges formula) was calculated to compare the presence of the elements in the years 2013 and 2019, in the different apparatus. The magnitude of the CL was classified as trivial (<0.2), small (≥ 0,2-0,6), moderate (> 0,6-1,2) and large (> 1,2) (Batterham & Hopkins, 2006). Data were analyzed using Microsoft Excel (Microsoft™; EUA).

RESULTS

Table 1 shows the total number of Ballet movements, identified by gymnast and their routine in each apparatus, in 2013 and 2019.

Regarding the amount of Ballet movements, we present in Table 2, the maximum, minimum and average of Ballet movements identified and the difference in the magnitude of the effect size in the years analyzed.

Despite the variation shown in Table 2, concerning Ballet movements in the routines, it was not possible to identify a significant difference between the apparatus - hoop (H2013/H2019; p = 0,478), ball (B2013/B2019; p = 0,732), clubs (C2013 /C2019; p = 0,821) and ribbon (R2013/R2019; p = 0,888). However, when discussing the magnitude of the effect size, it was notable but small difference for ball (0.68) and clubs (0.29), and a moderate difference for hoop (0.97) and ribbon (0.74).

Table 3 shows the comparison of the frequency of Ballet movements in 2013 and 2019 and in which components of the routine they were present - Body Difficulty (BD), Apparatus Difficulty (AD), dance step combinations (S), Dynamic Elements with Rotation (DER), Connections (C). Only the movements that showed a quantitative difference ≥ to 6 were selected and systematized in descending order.

Table 1
Ballet's movement performed during the RG routines – hoop, ball, clubs, ribbon - 2013 and 2019.

GYMNAST	COUNTRY	BALLET'S MOVEMENT	TOTAL	VAR.
G1-H2013	UKR	*pas de bourrée couru, pirouette attitude, galop, soutenu, grand jeté en tournant*	12	5
G2 –H2013	RUS	*Pirouette passé en dehors, skip, chainés, arabesque penché, passé, retiré, grand battement, grand jeté en tournant, pirouette cou de pied en dehors, pas de chat en tournant, developpé, temps levé, galop, pirouette attitude, tour en l'air*	32	15

G3-H2013	RUS	*skip, chainés, pas de bourrée couru, pirouette passé en dehors, galop, pirouette attitude en dedans, pirouette passé en dedans, pirouette cou de pied en dehors, passé, grand jeté en tournant, soutenu, pas de chat entournat, arabesque, temps levé*	24	15
G1-H2019	RUS	*galop, grand jeté en tournant, skip, arabesque, pas de bourré couru, assemblé battu derriére, fouetté italiano, developpé, grand jeté, arabesque penché, chainés, saut de basque, pas de chat en tournant*	17	13
G2-H2019	ISR	*grand jeté en tournant, arabesque penché, grand jeté, skip, pas de chat en tournant, assemblé battu derriére, chainés*	15	7
G3-H2019	RUS	*chainés, grand jeté en tournant, skip, soutenu, arabesque penché, pas de chat en tournant, assemblé battu derriére, galop*	13	8
G1-B2013	RUS	*arabesque penché, pirouette attitude en dedans, pirouette passé en dedans, grand jeté en tournant, chainés, pas de bourrée couru, piquê arabesque, galop, pas de chat en tournant*	13	9
G2-B2013	RUS	*pas de bourrée couru, enveloppé, temps levé, pirouette passé en dehors, fouetté, galop, passé, soutenu, skip, arabesque penché, pirouette attitude en dedans, tour en l'air, pas de chat en tournant, arabesque*	23	14
G3-B2013	BLR	*soutenu, passé, skip, pas de bourrée couru, piqué arabesque, pirouette en dehors, galop, grand jeté en tournant, chainés, pirouette attitude en dedans, pas de chat en tournant, pirouette passé en dedans*	21	12
G1-B2019	RUS	*passé, grand jeté en tournant, pas de chat en tournant, arabesque penché, enveloppé, skip, galop, saut de basque, assemblé battu derriére, developpé, chainés, attitude*	17	12
G2-B2019	RUS	*grand jeté en tournant, galop, chainés, pas de chat en tournant, arabesque penché, fouetté italiano, enveloppé, pirouette passé en dedans, assemblé battu derriére, saut de basque*	16	10
G3-B2019	ISR	*arabesque penché, passé, galop, grand jeté en tournant, chainés, saut de basque, assemblé battu derriére, grand jeté*	16	8
G1-C2013	RUS	*grand battement, passé, pirouette sur le cou-de-pied en dehors, grand jeté en tournant, chainés, pirouette attitude, arabesque penché, enveloppé, skip, ciseaux, assemblé, grand sissone*	16	12
G2-C2013	RUS	*passé, pas de chat, pirouette passé en dehors, fouetté, skip, tour en l'air, grand jeté, pirouette sur le cou-de-pied en dehors, pirouette en dedans, galop, retiré, battement frappé, pas de bourrée couru, developpé, pirouette attitude en dedans, chainés, arabesque penchée*	31	17
G3-C2013	UKR	*chainés, relevé, galop, grand jeté en tournant, fouetté en second, passé, pas de chat en tournant, developpé, enveloppé*	15	9

G1-C2019	RUS	*skip, grand jeté en tournant, soutenu, passé, developpé, grand écarté, assemblé battu derriére, arabesque penché, saut de basque, pirouette passé en dehors, tour en l'air, pas de chat en tournant*	20	12
G2-C2019	ISR	*passé, chainés, grand jeté en tournant, soutenu, skip, tour en l'air, fouetté italiano, arabesque penché, galop, pirouette passé, grand jeté, pas de chat en tournant*	20	12
G3-C2019	UKR	*grand jeté en tournant, cloche, attitude derriére, pas de bourré couru, attitude devant, pas de chat en tournant, galop, arabesque penché, chainés, pirouette en dedans*	16	10
G1-R2013	RUS	*pas de chat en tournant, arabesque, pas de bourrée couru, passé, failli, galop, chainés, pirouette attitude en dedans, pas de valse entournant, skip, tour en l'air, arabesque penché, saut de basque, grand jeté*	25	15
G2-R2013	UKR	*pirouette en dedans, galop, grand jeté en tournant, passé, pirouette attitude, pirouette arabesque en dehors, chainés*	11	8
G3-R2013	BLR	*cambré derriére, pas de chat en tournant, pirouette en dehors, passé, arabesque, pirouette en dedans, skip, galop, grand jeté en tournant, saut de basque, soutenu, pirouette en attitude, assemblé battu derriére, pas de bourrée couru*	33	14
G1-R2019	RUS	*arabesque penché, soutenu, passé, grand jeté en tournant, pirouette passé en dedans, chainés, assemblé battu derriére, saut de basque, tour en l'air*	18	9
G2-R2019	ISR	*chainés, grand jeté en tournant, assemblé battu derriére, tour en l'air, arabesque penché, fouetté italiano, grand jeté*	11	7
G3-R2019	RUS	*attitude derriére, grand jeté en tournant, soutenu, grand jeté, skip, saut de basque, arabesque penché,grand fouetté en tournant, galop, chainés, passé, pas de chat en tournant, pirouette passé en dedans, temps levé*	20	14

Note: G (gymnast); nº (ranking), first apparatus initial letter (H – hoop); year (2013 or 2019); VAR (variety).

Table 2
Quantity of Ballet Movements per routine

APPARATUS	MAXIMUM		MINIMUM		AVERAGE		MEDIUM AVERAGE		EFFECT SIZE	
	2013	2019	2013	2019	2013	2019	2013	2019	SCORE	CLASS
HOOP	32	17	12	13	22,6	15	11,6	9,3	0,97	Mod.
BALL	23	17	13	16	19	16	11.6	10	0,68	Small
CLUBS	31	20	15	16	20,6	18	12,6	11,3	0,29	Small
RIBBON	33	20	11	11	23	16	12,3	10	0,74	Mod.

Table 3
Comparison of the Ballet's elements frequency between 2013-2019 and its relation to the routine component.

Ballet Movement	Gymnastic elements	Frequency 2013	Routine components 2013	Frequency 2019	Routine components 2019	Quantitative diference
grand jeté en tournant	jump	21	BD	32	BD, AD	11
saut de basque	skip/hop	2	R	12	R	10
assemblé battu derriére	jump	1	C	10	AD, C	9
chainés	rotation	22	R	28	R	6
arabesque penchée	balance	6	BD	12	BD	6
galop	skip/hop	23	C, S	16	C, S	-7
pas de bourée couru	step	13	C, S	4	C, S	-9
arabesque	balance	10	C, S	0	---	-10
skip	skip/hop	24	C,S	13	C, S	-11
pirouette passé en dehors	pivot	14	BD, C, S	2	BD	-12
pirouette attitude	pivot	13	BD	0	---	-13
passé	balance	30	C, S	10	AD, C, S	-20

DISCUSSION

The purpose of this research was to analyze the presence of Ballet movements in Rhythmic Gymnastics routines in the last two CoP Cycles (2013-2016 and 2017-2020). The main finding shows that the year 2013 had a higher number of Ballet movements in the routines than the year 2019.

Although there is no significant difference between the years ($p \geq 0,05$), the average of Ballet movements in the four apparatus routines in 2013 was higher than in 2019 (21,3 against 16,5).

The 2013-2016 CoP cycle was memorable for using masteries, in which the gymnast should perform unusual exercises with the apparatus (FIG, 2014). This rule may have favored more dance compositions and, consequently, was closer to dance origins and to Classical Ballet (and its movements).

There was no significant variation concerning Ballet movements between the years studied (2013;12.0 and 2019;10.1). This result may be related to the style of the gymnast or the choreography itself, which can be created using different music, which leads the gymnasts to execute other types of dance steps to create the artistic aspect of their routines.

It is important to note that even though the results did not show statistical differences in the amount of Ballet movements in 2013 and 2019, it was possible to observe that the largest amount of Ballet movements were performed by Russian and Belarusian gymnasts, while those gymnasts who utilized fewer Ballet movements were Ukrainian and Israeli gymnasts. In addition, it was noticed that although Russian gymnasts did not use classical music, the presence of Ballet movements seemed essential to their routines.

This strong presence of classical Ballet movements, regardless of musical style, can be explained by a cultural reason. Rhythmic Gymnastics training models in Eastern Europe spend a long training period teaching and practicing Ballet movements, as they guarantee basic motor skills, improvement of combinations, and perfect body postural alignment (Róbeva & Rankelova, 1991). Classical Ballet is an intrinsic component of Russian identity. The Russians founded a classical Ballet model that is named "Vaganova," which gained worldwide acclaim and popularity in the 1920s and is intricately connected to the national culture (Amaral, 2011).

Nevertheless, Vieira de Jesus (2013) confirms that Russian athletes' hegemony in artistic sports, such as figure skating and artistic swimming, is related to the social-historical characteristics of their society, which consider Ballet movements the foundation for the high level technical exercises in those kinds of sports and fosters precision and perfect performance of body and body parts, as well as, the relationship between music and expression. Thus, as referenced in the RG athlete development models, the Eastern Europe countries, especially Russia, dictated the composition and style of RG choreographies.

When analyzing the differences between the maximum and minimum amount of Ballet movements performed in 2013 and 2019, we realized that there was a difference between the maximums identified in 2013 and 2019, being the biggest difference in the ribbon routines (33 against 20). Besides no significant statistics difference, the magnitude of the effect size showed a small difference for ball and clubs and a moderate difference for hoop and ribbon.

Such results may demonstrate the influence of the apparatus on the composition: even when the style of the gymnast's routine is not directly related to Classical Ballet, a certain number of Ballet movements are still present, demonstrating how the characteristics of the apparatus can be decisive. On the other hand , if we consider the differences between maximum values, we realize that what may have happened is a decrease in the connections (C) and even in the dance step combinations (S), for the introduction of the most valued exercises.

This decrease, also found in the average quantities, may be related to the changes in the scores from 2013-2016 to 2017-2020 Code of Points (CoP). From 2018, when the Difficulty score became unlimited, there was an increase in the Apparatus Difficulty (AD) exercises, as well as the Dynamic Elements with Rotation (R), leaving less time for the Connections (C) and dance step combinations (S), moments in which Ballet movements appeared quite frequently.

Table 3 acknowledge this aspect. There was an increase in Ballet movements performed during ADs (assemble *battu derriére*) and Rs (*chainés, pas de chat en tournant, saut de basque*) and a decrease in the Cs and Ss (*skip, galop, pas de bourré couru, passé, arabesque*). Exercises such as skip and galop, often used in RG for jumps preparation, decreased from 2013 to 2019 routines from 24 to 13 and 23 to 16, respectively.

The gymnasts may be not be performing them in order to reduce the time of the jumps' preparation. This allows, for example, more time to include other exercises, such as AD's. The AD's had an expressive increase, since in the 2013-2016 Olympic cycle, the mastery (unusual movements with apparatus that in 2017 became Apparatus Difficulty) could only appear five times in the routine. Nowadays, AD's are unlimited, and some gymnasts even do more than 20 of them in a routine. Such a condition is verified by Leandro (2018) when analyzing the evolution of the Apparatus Difficulty in 288 RG routines performed in the World Championship 2013 and 200 RG routines in the World Championship 2017. And the author still states that AD elements were significantly higher from one Olympic cycle to another, due to the increase of the mastery value (22% in 2013 to 46% in 2017).

Regarding Body Difficulties (BD), it was noticed that Ballet movements, such as *pirouettes* (or pivots in the RG CoP), were less frequently performed in 2019 than in 2013. An example of the discrepancy was in the *pirouette attitude*, which appeared 13 times in 2013 and did not appear in 2019. Gymnasts may be choosing pivots in non-classical Ballet movements, such as pivots in the *penché, boucle* or in split with trunk backward, as these add up higher scores than the pivots in the *arabesque, attitude* or *passé* positions. Another aspect to be considered is that in the 2013-2016 Olympic cycle, for every additional rotation in *relevé* the gymnast could double the base value of the pivot. In the 2017-2020 cycle, the additional rotation increases only 0,20, regardless of the pivot's value, which may have discouraged gymnasts from adding it.

We highlight the *grand jeté en tournant*, a jump with a high value movement, which increased its frequency from 21 to 32 times from 2013 to 2019 and was the most frequently performed Ballet movement in the routines. This result agrees with Lebre (2007), who studied the difficulties of the exercises performed by gymnasts in individual routines in the 2007 Portimão World Cup Rhythmic Gymnastics. The author identified a higher number of *grand jeté en tournant,* followed by balance with the horizontal trunk.

Ávila-Carvalho et al (2008) also detected *grand jetés en tournant* as the largest number of executions in the team routines in the same event, most likely related to the value that is given to this exercise in the CoP.

There is a chance that the increase which occurred from one cycle to another is related to the use of jump series. In 2013, it was composed of a maximum of three jumps and now has no limits, being characterized by two or more successive identical jumps/leaps. Many gymnasts have performed a sequence of four *grand jetés en tournant*, in addition to their variation *à boucle* or with back bend of the trunk, that increase the exercise value.

This information suggests the need for further studies to understand the complexity of RG routines and, as addressed by Leandro et al (2015), the factors related to the sport's particularity and the evaluation criteria defined by the authorities, which have an influence (positive and/or negative) on the gymnasts' final scores and on their relationship with the artistic aspects of RG. These aspects have been brought to the scientific field. Toledo & Antualpa (2016) analyzed RG artistic components in the last thirty years of the CoP, identifying that the 2013-2016 cycle was notable for appreciation of the artistic aspects of the routines.

Regardless of being considered Body Difficulties or not, Body Elements are versatile in the CoP, due to their characteristics. Body Elements can appear in different components of the choreography, according to the strategies of composition that tend to value the best movements performed by the gymnast, consequently, achieving the highest score. The diversification of Body Elements is encouraged by CoP, when examples are suggested where pre-acrobatic and rotations (BD's) with 0,10 as base value can be used as components of Rs, BD's and can also be an AD's criteria.

Table 3 demonstrates the versatility of the use of the elements *saut de basque, galop, pas de bourée couru, skip, pirouette passé en dehors* and *passé*. For example, the *saut de basque* is a skip with rotation, characterized as a connecting element, but it can also be used to compose an S or, commonly, to compose elements of rotation of the R's. The *galop*, *pas de bourée couru* and/or *skip* can be presented in different aspects of the routines, such as C and S; the *pirouette passé en dehors* and the *passé* are

BD's that value 0,10 in the CoP, but are also in the composition criteria of AD, R, C or S.

CONCLUSIONS

By analyzing the Ballet movements in the RG routines in the Olympic cycles of 2013-2016 and 2017-2020, we concluded that these elements, being the basis of the body technique of RG, remained present in the routines, but in less frequency. We identified that there was an increase in the use of Ballet elements in the Dynamic Elements with Rotation (*saut de basque, chainés, pas de chat en tournant*), in Apparatus Difficulties (*assemble battu derriére*) and in some Body Difficulties (*grand jeté en tournant, arabesque penché*). In addition, we noticed a decrease in the use of Ballet elements previously used as connection elements (*galop, skip, pas de bourée couru*) and lower value rotation and balance´s BDs (*pirouette passé en dehors, pirouette attitude, passé, arabesque*).

Regardless of changes in the Code of Points over the years, Ballet's movements are timeless and must be worked on in RG, within the specificity of the modality. In addition to providing elements for the correct technical execution of body movements in rhythmic gymnastics, they are components of the difficulties requirements (BDs, Ads, S and Rs) and contribute to the artistic variety of the routine. At this moment, special attention should be paid to movements with body rotation, wich can be included as criteria for validating the Ads and Rs, as well to the higher value BDs, originating in Ballet movements.

The results of this study can help the RG community to understand the real effect in high level routines caused by the changes in the Code of Points, especially, how Ballet movements impacted the routines from one Olympic cycle to another. Additional researches are necessary, expanding the samples, events and levels of RG routines analysis.

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SOKOLSTVO IN UKRAINIAN REGIONS OF THE RUSSIAN EMPIRE: FROM ORIGIN TO DOWNFALL

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Original article

Abstract
The purpose of this study is to advance a better insight into the history of Sokolstvo (Sokol movement) in the Ukraine within the territorial borders of the Russian Empire, and the variety of reasons for its origin and downfall. Slavic origin of Sokolstvo, the activity of supporters of Sokol gymnastics (SG) in the popularization of Sokol idea and, a gradual rapprochement of supporters of the two opposing areas of reforming Russia for further development began ("Slavophiles" and "Westerners") contributed to the emergence and rapid development of the Sokol movement in the Ukrainian regions of Russia. In the 90s of the 19th century, SG began to be cultivated in the Sokol units of gymnastic societies, since 1907 independent institutions began to open. By World War I, Sokol gymnastic societies (SGS) in Ukraine were the largest group. SGS constantly trained instructors, but the majority of SG teachers were foreigners, Czech by nationality. SG was officially introduced into the military training of the army and the curricula of secondary schools and cadet corps. Sokol events were a significant part of the public life of many Ukrainian cities. Representatives of Ukrainian regional societies became members of the Board of the Union of the Russian Sokol, founded in 1910. The crisis of the Sokolstvo began in the years of the World War I due to the growth of xenophobic attitudes. During the years of Soviet power, the Sokol were accused of a bourgeois orientation, recognized as the "hotbed of counter-revolution" and banned in 1923.

Keywords: *Sokol, gymnastics, Russian Empire, Ukraine.*

INTRODUCTION

The conduct of this study and the preparation of the article were caused by the following reasons.

Activities of a gymnastic nature totals more than four thousand-year history. In spite of this long history, according to Russell (2013), gymnastics is currently evolving at an unprecedented pace. On this path, under the influence of political, socio-economic and cultural factors, the state system, the dominant ideology and historical traditions, the history of gymnastics was formed in different countries.

The bright page in the history of gymnastics is *Sokolstvo* (Falconary). In the second half of the 19th and early 20th centuries, the Sokol idea conquered the countries of Europe and immigrated to America (Bábela & Oborný, 2018). *Sokolstvo* expanded in the Ukrainian territories when an independent state did not exist, and its modern regions were part of the Russian and Austro-Hungarian empires. Specifically, historical conditions determined fundamentally different vectors of development of *Sokolstvo* in different regions of modern Ukraine. This study will present the history of the origin and downfall of *Sokolstvo* in the Ukrainian regions of the Russian Empire.

In the historical dimension, the *Sokolstvo* in the Russian Empire and, accordingly, on its Ukrainian lands, did not exist for very long, about 20 years. There are a number of studies of the last three decades devoted to this problem (Gilbert, 2017; Kachulina, 2016; Prikhodko, 1998; Sirotkina, 2017). However, knowledge about the development of *Sokolstvo* in the Ukrainian regions is, first of all, a *"view from the center"*, from the capital of the Russian State. They do not take into account the fact that the Russian Empire at that time was a culturally and estate fragmented state with significant differences in the development of the same cultural phenomena in the regions. To date, case studies on the development of *Sokolstvo* in the regions of Ukraine (Liakh-Porodko, 2010, 2011; Prikhodko, 2011, 2012) are fragmented, and require further research and their systematization.

An important reason for the preparation of this article is the extreme limitation of English-language publications on the history of sports in the countries of the former USSR. Traditionally, such case studies of Slavic scholars are published in Russian and Ukrainian. This limits the ability of a wide English-speaking audience to get acquainted with the results of Ukrainian research, creates a barrier in communication between experts from different countries (Jirásek & Hopsicker, 2010).

Thus, the *purpose* of this study is to contribute to a better insight into the history of *Sokolstvo* in the Ukraine, the variety of reasons for its origin and downfall. The selection criteria for the primary sources corresponded to the subject of research topic of *Sokolstvo*, its features in the Ukrainian regions of the Russian Empire. Data collection was carried out in various historical Archives of Ukraine (Kyiv) and Russia (St. Petersburg). Additionally, articles and dissertations of modern researchers were analyzed.

PRECONDITIONS FOR THE EMERGENCE AND DEVELOPMENT OF THE SOKOLSTVO IN THE UKRAINIAN REGIONS OF THE RUSSIAN EMPIRE

In the Russian Empire, *Sokolstvo* spread later than in other countries. This is explained by the fact that before the beginning of the *"great reforms"* of Tsar Alexander II (60-70s of the 19th century), Russia in all spheres of public life lagged behind Europe for several decades in its development, including the issues of physical education (PE) of the population. In the 19th century, German Turnen Gymnastics and Swedish Gymnastics systems were introduced in Russia. Swedish Gymnastics aroused amateur interest mainly among residents of the capital of Russia. German Turnen Gymnastics also did not take root on Russian soil, and during the period of aggravation of Russian-German relations (70s of the 19th century and later), a flurry of criticism against it especially increased (Oleynik & Grot, 2002; Sirotkina, 2017). The most important barrier for Russians was social reasons, as well as language problems because both social and sporting activities were performed in foreign languages (Grys, 1999).

Russian teachers, progressive public figures, representatives of the military elite of the turn of the 20th century A. Butovsky, P. Lesgaft, V. Ukhov, A. Anokhin et al., tried to create a national gymnastic system (Prikhodko, 1998). However, their inventions did not have wide support in public and, as a rule, were localized in certain regions of the huge Russian state, where they originated. In general, despite the rather active debate in the medical and educational environment and the pressing social need for PE of the Russian population, during this period there was no clear strategy on this issue. Therefore, the appearance of *Sokolstvo* at the end of the 19th century in Russia found fertile ground for distribution both throughout the country and in Ukrainian regions (Kachulina, 2016). According to Alekseev, Gromova, and Silantev (2016), Prikhodko (1998), Sokol gymnastics (SG) gradually began to take a leading position among various gymnastic directions due to its attractiveness, active popularization and state support.

This process was facilitated by such significant factors.

1. *Slavic origin of Sokolstvo.* The idea of uniting the Slavs (Pan-Slavic idea), "skillfully spread by Sokols", corresponded to the foreign policy goals of the Tsar and the Government, contributed to a certain consolidation of Russian society during the growing of the domestic political situation in the country (the first decade of the 20th century) and was extremely popular among secular wealthy youth and found support from wide sections of the bourgeois-democratic public (Oleynik & Grot, 2002, p. 8).

2. *The activity of supporters of SG in the popularization of Sokolstvo*, which promoted in active educational and publishing activities, used symbols of the Pan-Slavic movement, public demonstrations by SG, etc. The democratic organization of classes and membership in society made SG publicly accessible to various sectors of society (Kadilin, 1914; Sirotkina, 2017; Zmuda Palka & Siwek, 2018).

3. *At the turn of the 20th century, a gradual rapprochement of supporters of the two opposing areas of reforming Russia for further development began: "Slavophiles" and "Westerners".* The *Slavophiles* advocated preserving the national identity of the historical path of development of Russia on the basis of Orthodox Christian values and ideals. The *Westerners* were supporters of the development of Russia according to the Western European type. Therefore, *Sokolstvo* in Russia became, as it were, the personification of the results of a consensus of ideologies of *Slavophiles* and *Westerners* in a specific social sphere, specifically in PE. On the one hand, the Slavic origin of gymnastics and *Slavophile* principles are the basis of its ideology. On the other hand, SG was a product of European scientific thought and pedagogical experience.

Besides, at the turn of the 20th century, the idea of "*russification*" of non-Russian peoples living on its territory, in particular Ukrainians prevailed in the national politics of the Russian Empire. At the same time, for various political reasons, relations with Germany began to worsen and anti-German attitudes intensified in society. In the field of PE and sports, this was reflected in the following way: German Turnen Gymnastics became "undesirable" for popularization and preference was given to SG, the most attractive and closes in spirit to Russian society.

SOKOL GYMNASTICS IN THE PUBLIC LIFE OF THE UKRAINIAN REGIONS OF THE RUSSIAN EMPIRE

SG appeared in Russia through Czech mediation − thanks to gymnastics teachers from *Czechia* (the name of the Czech historical lands (Bohemia, Moravia and Silesia), which was widely used in Russian-language primary sources) (Alekseev et al., 2016; Grys, 1999; Kachulina, 2016; Prikhodko, 2017; Sirotkina, 2017). In the 90s of the 19th century in Russia no one knew about the foreigners' affiliation to the Sokol. They were perceived only as experienced gymnastics teachers (Sirotkina, 2017). Therefore, fans of SG as gymnastics from Czech origin carried out activities within the legal framework. They opened units in existing sports and gymnastic organizations, worked as teachers in schools, took part in sports competitions, where they demonstrated all the advantages of SG through their own sports achievements ("Otchet," 1910; "Sokol'stvo," 1910).

At the turn of the 20th century, the first sports and gymnastic organizations began to be founded in Ukrainian regions that actively promoted SG. Some studies indicate that as early as 1870, in *Volyn* (region of Ukraine), the Czech community founded the Sokol society for Czechs (persons from Bohemia, Moravia and Silesia) residing in the region (Kachulina, 2016; Matsukevich, 2011; Sirotkina, 2013, 2017). However, it is believed that *Kievskoe Atleticheskoe Obschestvo* (Kyiv Athletic Society), founded in 1900 in *Kyiv* (the capital of modern Ukraine), stood at the origins of *Sokolstvo* on Ukrainian lands. The initiative group consisting of Czechs, who residing in Kyiv, under the leadership of the founder of the Society, Kyiv citizen *Yevgeny Garnich-Garnitsky* (founder of *Sokolstvo* on Ukrainian lands of Russia), began to purposefully promote SG. In 1905, on the basis of *Kievskoe Atleticheskoe Obschestvo*, an independent institution, the *Gimnasticheskoe Obschestvo "Yug"* (Society "South") was formed, so named by analogy with the *Society "Sever"* (Society "North", founded in 1903), which promoted SG in the capital St. Petersburg ("Ob utverzhdenii," 1905). The Sokol unit of the Kyiv *Gimnasticheskoe Obschestvo "Yug"* was headed by V. Vondrak, led the classes *gymnaziarkh* (gymnastics teacher) F. Brabets ("Gimnasticheskoe obschestvo," 1908). In 1908, the *Kyiv Gimnasticheskoe Obschestvo "Yug"* was renamed the *Sokol* ("Gimnasticheskoe obschestvo," 1910).

Gimnasticheskoye obschestvo "Sokol" v Kieve (Gymnastics Society Sokol in Kyiv) was the largest and most respected Sokol organization in the Ukrainian region, consisting mainly of Czechs (80%). Classes were attended by *"exclusively youth"* and a large number of adolescents. The tradition of the Kyiv Sokol was the holding of the fundraisers, the fees from which were used to finance regular trips to the Sokol *Slets* (rally, gathering or demonstration). The program of charity evenings always included SG, female gymnastics and athletics competitions ("Gimnasticheskoe obschestvo," 1908). By 1913, Kyiv Sokol totaled about 100 permanent members and several dozen *visitors* (no member status). The structure of society included men's, women's and children's gymnastics departments, a football team, wrestling, athletics, lawn tennis units, and a *drama kruzhok* (drama club) ("Gimnasticheskoe obschestvo," 1910).

Sokolstvo quickly managed to gain popularity, despite obstacles from some administrative structures and criticism of supporters of other gymnastic systems. Material support for the *Sokolstvo* was provided by representatives of noblemen, industrialists, *kupechestvo* (merchants) and intelligentsia. Honorary members of Sokol gymnastic societies (SGS) were members of the imperial family, governors, mayors of cities, prosecutors, trustees of educational districts. This testified to the popularity of the *Sokolstvo* among the ruling class and helped in solving the problems of the lack of gyms ("Otchet," 1910; "Otchet," 1913). The main demographic feature of the spread of SG in the Ukrainian region was its coverage exclusively of the urban population from privileged estates: the nobility, *kupechestvo*, and some part of the *meschanstvo* (the lowest category of urban residents). The popularity of *Sokolstvo* among these estates was very high. The peasants and the urban proletariat had absolutely no access to SG.

After the defeat in the Russo-Japanese War (1904-1905) and during revolutionary situation (1905-1907), the *Sokolstvo* was able to suggest and consistently implement the idea of consolidating the nation, improving the body and spirit, so necessary for Russian society at that time (Alekseev et al., 2016). The "completely spoiled relations with Germany and Austria-Hungary" had a significant impact

(Sirotkina, 2017, p.325). After that, the attitude of the Tsar Nicholas II and the Government towards the SG as a gymnastic of foreign origin softened, and in 1907 it received state support and official status (Kachulina, 2016, p.115).

In the first two decades of the 20th century, SGS appeared in Ukrainian cities: Odesa, Kharkiv, Ekaterinoslav (Dnipro), Poltava, Kam'yanets'-Podil's'kyi, Zhytomyr, Chernigyv, Rivne, Lugansk, Kryvyi Rih, Simferopil, Yuzovka (Donetsk), etc. In each Ukrainian *Guberniya* (Province) of the Russian Empire SG and the Sokol movement had their own *gnezda* (organization, representative offices). The Sokol movement in the Ukrainian regions, as a whole in Russia, had a network structure. By 1914, 68 SGS were founded in the country (Liakh-Porodko, 2011). On January 1, 1915, in the Ukrainian region of Russia, there were 206 sports and gymnastic societies, of which SGS constituted the largest group ("Spisok obschestv," 1916).

The activities of SGS as independent public institutions included a wide range of forms of work: gymnastic classes for children and adults, sports competitions, traditional festivals and charity events to attract additional funds for the development of SG. Societies initiated the opening of SG *kruzhok* (unit) in secondary (male and female) schools and universities (Gotlib, 1909a; Liakh-Porodko, 2011; Prikhodko, 2012). The number of people wishing to engage in SG in them reached several dozen people. A feature of the cultural and educational activity of the Ukrainian SGS was the organization of female and children gymnastic units, gala evenings, balls, and out-of-town excursions. The money collected was used for the needs of SGS, and during the World War I − for the needs of the wounded.

In the first decade of the 20th century, SG began to be gradually introduced into the curriculum of Ukrainian schools. The initiators of this were school administrations and heads of board of trustees (Prikhodko, 2012). The unique experience of PE of students on the basis of the SG was gained by the *Yaltinskaya Aleksandrovskaya Gimnaziya* (Yalta Alexander Gymnasium) in Crimea. The director of the Gymnasium, A. Gotalov-Gotlib, believed that SG "was most suitable for the moving Slavic temperament of Russian school youth" and "most fully corresponded to the pedagogical requirements of the Russian school" (Gotlib, 1909a, p. 10). The classical exercises of the SG system were taught in all classes, from 1 to 8, and in the SG *kruzhok*. Especially for exercises, SG costumes were purchased in Prague. The gymnastics teacher was a visiting reputable specialist. The organization of PE based on SG was discussed in the journals *"Russkaya Shkola"* (Russian School) and in the *Časopis "Sokol"* (Gotlib, 1909b).

In Russia, there was a practice of inviting SG teachers from Czech lands, especially to educational institutions for privileged estates and to gymnastic societies. It was believed that the professional level of these specialists was significantly higher than their local colleagues. At the same time, the salaries of Czech teachers were much higher (Grys, 1999; Prikhodko, 2017). In 1910, 32.6 % of the Sokol teachers who taught at educational institutions in Russia practiced in Ukrainian regions (Liakh-Porodko, 2010, p. 149). Later, in connection with the World War I and the 1917 Revolution, the migration processes of foreign teachers in the country took the reversed direction. Many specialists returned to their historical homeland, a significant part joined the *White Movement* (the pro-tsarist, anti-Bolshevik movement) and disappeared from the Ukrainian historical space during the *Civil War* (1917−1921). Only a small part of foreign gymnastics teachers continued their activities in Soviet Ukraine.

In 1912, SG was officially introduced into the program of secondary schools in Russia. Out of 1577 secondary schools in the country, 855 taught SG (Kachulina, 2016). According to Liakh-Porodko (2010, p. 148), SG was taught in male and female gymnasiums, commercial schools, cadet corps in cities as Kyiv, Chernigiv, Kharkiv, Ekaterinoslav, Sumy, Odesa, Zhytomyr, Bila Tserkva, Yalta, Lugansk, etc. Notably, that SG did not practically extend to the primary level of education of the Russian Empire, especially in rural schools.

In the first decade of the 20th century, public exercises SG began to be included in the program of gymnastic and sports events. The Gymnastic Festivals are an inalienable part of the cultural life of the public in many large and small cities throughout the country. They took place in the central squares and hippodromes in the presence of a large number of spectators. Usually, the holiday program included floor exercises and apparatus-work. In Kharkiv, annual *Festivals of Schoolchildren in SG for the Cup of Emperor Nicolas II* were held (Prikhodko, 1998).

The most saturated in the number of Sokol events in the Ukrainian region was 1913 (Prikhodko, 1998). In August, the *First All-Russian Olympiad* was held in Kyiv, the program of which included gymnastics competition and a *Gymnastic Festival of Students of Secondary Schools from Kiev and Chernigov*. The program of the *Festival* was public floor exercise with 275 male students, floor exercises with hoops of female students and team exercises of male students of six gymnasiums on apparatus ("Perepiska," 1913).

At the turn of the 20th century, sports began to emerge and develop in the Russian Empire. The Russian public associated sport primarily with competitive activity. There were heated public debates about the expediency of using the competitive method and competition in the PE of youth. Some members of the Russian Sokol regarded the sports *"with great suspicion, believing ... that the principles of harmonious development and collectivism suffer in sports"* (Sirotkina, 2017, p. 331). Despite this, *Sokolstvo* in Russia and in the regions of Ukraine, in addition to SG, successfully developed such sports as athletics, handball, ice skating and skiing (Windhausen & Tsypkina, 1995). It was a kind of advertising to attract young people to a physically active lifestyle and an opportunity to build relationships with sports societies (Kachulina, 2016). It was from the Sokol that the winners and prize-winners of the first all-Russian sports competitions came out. According to Alekseev et al., (2016)**,** *Sokolsky movement* for Russia is *«the unique phenomenon of national scale», «the impressive samples, when the sport movement, borrowed abroad, becomes nearly the main support of national sport».*

Researchers emphasize that the years 1909−1914 were peak in the activity of the *Sokolstvo* in imperial Russia (Gilbert, 2017; Kachulina, 2016; Liakh-Porodko, 2011; Prikhodko, 1998; Sirotkina, 2013). In 1910, the *Union of the Russian Sokol* (URS) was founded, the chairman of which was elected a member of the *State Duma* (Parliament), Ukrainian *A. S. Gizhitskiy* ("Ustav," 1911). The URS united a fairly consolidated network of regional Sokol organizations and gave the movement a new dynamism. Thanks to the URS, congresses as forums of the PE public with the aim to consolidate the efforts of society in improving the physical development of people were first held in the Russian Empire ("Ustav," 1911, p. 4).

In April 1911, the *First Congress of the URS* took place in Moscow. Fourteen regional Sokol societies delegated their representatives to the Congress, of which five represented Ukrainian *gnezda*: Odesa, Chernigiv, Kyiv, Ekaterinoslav and Poltava. An active participant in the debates of the Congress from Ukraine K. Popel joined the Board of the URS from provincial societies. The main attention of the Congress was directed to the *"Sokol idea as a means of moral, spiritual and physical healing of human and society, the rallying of Slavic peoples around it"* ("Po khodataystvu," 1913, p.13). At the Congress, it was decided to convene the next congress two years later in Kyiv (the capital of modern Ukraine) as "the regional center of Russia, where the Sokol idea had a large number of supporters" ("Po khtaodaystvu," 1913; Liakh-Porodko, 2011).

In 1913, the Second Congress of the URS took place in Kyiv. The journal *"Vestnik Russkogo Sokolstva"* wrote about this:

From all over the Russian land − from St. Petersburg to Odessa, from Volyn to Kavkaz − representatives of Sokol organizations gathered in Kyiv − the first stolnyiy city [capital] of Russia ... Everywhere there is a lively, cheerful mood, joyful revival on all faces, laughter, loud conversations, noisy greetings are heard... those who were at the Congress, those who saw this general upsurge, this readiness to carry their forces to the benefit of the common cause, this amazing energy, which the members of the Congress were full of ... could not help but get the impression that the Sokolstvo in Russia has a great future ... ("Kievskiy s'yezd", 1913, p. 121).

At the Congress, many organizational issues were discussed and debates were held on improving the methodology and organizing the SG classes, competition rules, etc. ("Po khodataystvu,", 1913).

During these years, Sokol regional *Slets* also took place in the Ukrainian regions. In June 1913, the *First Sokol Slet Yugo-Zapadnogo Kraya* (South-Western Territory) was held in Kyiv, where delegates from 22 Sokol societies from all Ukrainian regions gathered ("Obshchestvo ," 1913; "Slet Sokolov," 1913). At the *Slet*, the sketch of the *Sokolsky badge* was presented, the competition rules and the attitude of the *Sokolstvo* to sport were discussed, and exercises for male and female were demonstrated. The program of the event, in addition to traditional meetings, included athletics competitions with the participation of school gymnastics teachers ("Perepiska," 1913, sh. 39).

In 1911, Russia joined the of the *Slavic Sokol Union*, but Ukrainian supporters of the *Sokolstvo* since 1901 (*IV Slet*) have been regular participants in the *All-Slavic Sokol Slets*, which took place both in Prague and Sokol events in other European cities (Gajdoš, Provaznikova, Bednar, & Banjak, 2012; Zmuda Palka & Siwek, 2018). In 1907, the *Kiev Gimnasticheskoe Obschestvo "Yug"* and a group of students aged 16-18 from the *Yaltinskaya Aleksandrovskaya Gimnaziya*, took part in the competitions of the *5th All-Slavic Sokol Slets* in Prague ("Gimnasticheskoe obschestvo," 1908; Gotlib, 1909a; "Russkiye sokola," 1913).

In 1910, the first Sokol gym in Russia, the *Russkaya Sokolnya*, was opened in Kam'yanets'-Podil's'kyi in Ukraine ("Pervaya," 1910/1911). In the same year, the *Sokol journal* was founded in Moscow under the editorship of D. P. Kuzmenko. Since 1913, the Journal became known as the *Russian Sokol*. The format of the Journal, the range of discussion questions, the wealth of illustrations, the guidelines for gymnastics, were largely repeated from the Prague Journal *Sokol*. However, it competed favourably with similar small Russian journals. This made the Journal and SG even more attractive in the eyes of its fans throughout the country and attracted new supporters to the ranks of Russian *Sokolstvo* (Alekseev, et al., 2016; Pikhodko, 1998). Between 1913-1917, the journal *Vestnik Russkogo Sokolstva* was also published in the Russian Empire. During this period, training manuals and books on SG were published by Y. Wagner, B. Gonzatke, A. Gotalov-Gottlib, M. Zusailov, E. Malyi, etc. Textbooks on SG were translated from Czech (Prikhodko, 1998).

In 1910, a new *"Manual on Gymnastics for the Army"* was adopted in Russia and SG was included in the curriculum of military schools and in the physical training of the active Russian Army, where it remained until the 1917 Revolution.

A serious crisis in the development of the *Sokolstvo* in Russia and in its Ukrainian regions was caused by the outbreak of the World War I. Many athletes voluntarily went to the front, driven by a patriotic mood and desire to defend their motherland. The government announced the *"mobilization of sports"* (the Program of government of Russia with the goal of attracting sports organizations to prepare reserves for the army) ("Materialy," 1916). For the SG teachers of Czech nationality and ordinary foreigners from Germany and Austria-Hungary who lived in Russia, this patriotic wave turned into progressive xenophobia (Alekseev, et al., 2016). There was a sharp discussion in SGSs about the possibility of non-Russian subjects taking part in their activities. With the outbreak of War, one of the key tenets of the Sokol collapsed − the idea of creating the union of all brotherly Slavic peoples. The editorial article of *Sokol journal* contained the thesis that *"nothing prevents the Polish, Czech and Croatian Sokols, battled in the Austrian-Hungarian army, from shooting to their Russia "brothers": "There is no Sokol Movement without the Slavic idea"* (Kadilin, 1914, as cited in Alekseev, et al., 2016). By 1916, the URS practically stopped its work due to the self-liquidation of most of the *gnezda* in Russia.

SOKOLSTVO IN THE FIRST YEARS OF SOVIET POWER

In 1918, an initiative group arose to revive the *Sokolstvo* in the Republic of Soviets and convene a *Slet*. By that time, the Sokols had departed from politics, dissociated themselves from the tasks of the Soviet government of *"universal compulsory military training"* and adhered to the principles of Slavophilism. The Sokol units that remained in the USSR developed vigorous activity to popularize SG in educational institutions. SG was also actively developed by proletarian PE organizations.

However, the program and activities of the Sokols did not satisfy the power of the Soviets, which saw them as a *"hotbed of counter-revolution"* (Sirotkina, 2017, p. 333). The *Sokolstvo* was accused of *"bourgeois orientation and anti-Soviet ideology"* (Liakh-Porodko, 2008). The *Central Department of Universal Military Training*, together with the *Komsomol*, began a *great battle* for the *"purification of sports and gymnastic clubs from class-hostile elements,"* such as Sokol (Stolbov & Chudinov, 1962, p. 131). Propaganda of *"anti-sokolstvo"* was carried out on the pages of magazines and newspapers, from the rostrums of party congresses: *"Sokolyatina* (falcon meat) *needs to be burned with a hot iron and the road for Soviet physical culture, which is so necessary for us as air, must be cleaned of this rot"* (Smolin, 1924, as cited in Liakh-Porodko, 2008). In 1923, the activities of the Sokol in the USSR were officially and finally banned. Many of the leaders of the *Sokolstvo* remaining in the USSR were repressed. The communist government persistently uprooted from the history of the USSR all the positive that was founded in tsarist Russia. In the Soviet textbook *"History of Physical Culture"* (1962) for higher education institutions of PE, *Sokolstvo* is mentioned only in a negative context as a counter-revolutionary nationalist reactionary organization whose activity was *"aimed at supporting and glorifying the autocracy and popularizing Western European methods of education"* to the detriment of traditional national exercises and methods (Stolbov et al., p. 113). Such rhetoric persisted until the collapse of the USSR. The Russian *Sokolstvo* continued to exist in emigration, in particular, Yugoslavia, Czechoslovakia, Bulgaria, Latvia, France, USA and China (Kachulina, 2016; Lushin, 2019; Matsukevich, 2011; Sirotkina, 2013).

However, in spite of everything, the *Sokolstvo* left a noticeable mark on the history of Ukraine and other countries of the former USSR. In 1924, *Sokol Slets* were transformed into *Spartakiads of the peoples of the USSR*. Sokol gymnastic terminology, used by the USSR until 1938 (Kachulina, 2016).

CONCLUSION

The *Sokolstvo*, founded by Miroslav Tyrš, is by its nature a model for the education of a physically developed educated person with an active civic position. It reflected the spirit and social needs of his time. The values of the *Sokolstvo* are very close to the mentality of the Ukrainian people and this explains its popularity, the dynamics of the development of a variety of forms of activity in the Ukrainian regions of the Russian Empire. The *Sokolstvo* on the Ukrainian lands of Russia manifested itself, first of all, as a system of PE of the people, which received support from both the advanced part of public and the official authorities. Despite all the prohibitions in the Soviet period, the *Sokolstvo* largely determined the vector and peculiarity of the development of gymnastics in Ukrainian educational institutions for many decades, the popularity of sports such as rhythmic and artistic gymnastics, athletics, football, handball, etc. Ukrainians love to hold mass sporting events. The history of the *Sokolstvo* in Ukraine obviously would not be complete without a detailed study of its development in the Ukrainian regions of the Austro-Hungarian Empire.

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THE PROFILE OF THE ACADEMIC PRODUCTION ON MEN'S ARTISTIC GYMNASTICS FROM THE WEB OF SCIENCE AND SCOPUS

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Original article

Abstract
The objective of this study was to describe the scientific production on men's artistic gymnastics (MAG) in journals indexed on the Scopus and Web of Science platforms. To this end, we searched on both platforms for the keywords "men's artistic gymnastics" and "male artistic gymnastics", with a non-specified date range. After applying the exclusion criteria, 52 scientific articles were found, distributed between 1994 and 2019. The year with the highest number of publications so far is 2018, with emphasis on the period between 2014 and 2018. The authors who contributed the most were Maurice Yeadon and Michael Hiley (both from British universities), Marco Bortoleto (from Brazil), and Ivan Čuk (from Slovenia). There is a predominance of MAG-related articles in the Science of Gymnastics Journal (21%), followed by the Journal of Biomechanics (7%). The articles deal with the biomechanics of gymnastics (34%), the rules of the sport and its judging (19%), the social, historical and political aspects of gymnastics (14%), morphological characteristics of athletes (10%), athletes' health (10%), gymnastics training aspects (8%), and finally, analyses of athletes' age over the years (6%).

Keywords: *scientific production, bibliometric, web of science, scopus*.

INTRODUCTION

Artistic gymnastics has been part of the Olympic Games since its first edition, in 1896, and has officially been in the Olympic programme since 1924, undergoing several changes since then. From this changes, we may highlight the following: the nomenclature change from Olympic gymnastics to artistic gymnastics, the change in the equipment used and its technical requirements, and the inclusion of the modality for women (Atiković, Kalinski, & Smajlović, 2017; Carrara, Amadio, Serrão, Irwin, & Mochizuki, 2016; Oliveira & Bortoleto, 2011; Pajek, 2015; Schiavon & Locci, 2018).

The studies by Silva, Santos-Rocha and Barata (2016) emphasize that there is currently a greater participation of women in artistic gymnastics when compared to men. Such majority is also found when searching for scientific production about the sport. For example, Mkaouer, Hammoudi-Nassib, Amara and Chaabène (2018) claim that while there are several studies on the identification of talents for women's artistic gymnastics (WAG), there are few studies on the same matter regarding the men's sport. By conducting an initial search on the main academic platforms (*Scopus, Web of Science, PubMed, and Google Scholar*), it was possible to identify the scarce literature on men's artistic gymnastics (MAG). In this sense, as a result of the need to analyze the scientific production of specific themes, bibliometric studies are being increasingly used in academic research to assess the advances or lack thereof in a given academic field (Clancy, Herring, & Campbell, 2017; Jamali, Md Zain, Ali

Samsudin, & Ale Ebrahim, 2015; Tsigilis, Grouios, Tsorbatzoudis, & Koidou, 2010). Consequently, with bibliometry, it is possible to detect, classify and categorize the scientific literature on a given subject (Blanca-Torres, Ortega, Nikolaidis, & Torres-Luque, 2019).

Various databases are used in bibliometric research and each one has particular characteristics. However, the most recurring are *PubMed, Google Scholar*, *Web of Science (Clarivate Analytics), and Scopus (Elsevier).* PubMed is the most widely used for biomedical disciplines and life sciences. *Google Scholar* is an easy-to-use tool, but it has some shortcomings, especially the inclusion of non-scientific peer-reviewed content. The last two are the most used bibliographic databases in academic research for almost all disciplines and are used by many universities to establish *educational* rankings(AlRyalat, Malkawi, & Momani, 2019; Harzing & Alakangas, 2016; Mongeon & Paul-Hus, 2016).

This study is part of a broader research that intends to analyze the sports training of male artistic gymnastics athletes. Therefore, as a starting point for the bibliographic survey on MAG, we sought the profile of this academic production in the main databases, which then resulted in the production of this article. It is assumed, then, that from the scientific production profile of a given area it is possible "[...] to analyze the body of literature and research performance easily and efficiently." (AlRyalat et al., 2019, p. 1). Be that as it may, we agree with Sánchez-Pay's statement (2019, p. 14): "Analyzing the scientific production of a particular specialty helps to find research trends as well as the main courses of action."

Thus, this research aims to describe the scientific production on MAG in journals indexed on the *Scopus* and *Web of Science* platforms. The specific objectives are: 1) to indicate the year of publication of the articles; 2) to verify the authors and institutions; 3) to highlight the journals that have published the most on the subject; 4) to thoroughly identify the subjects addressed in the articles.

METHODS

In order to accomplish the proposed objectives, a search was performed in the entire *Web of Science* database, using the descriptors “men’s artistic gymnastics” or “male artistic gymnastics” in the topic of the articles (title, keywords and abstract), without setting a date range. The justification for the choice of these descriptors is based on the understanding that male artistic gymnastics is a sport with its own characteristics. The equipment used in MAG is different from the ones used in the women’s modality, as is the scoring system (Kilijanek & Sanchez, 2020). This search found 52 results.

In order to assure the comprehensiveness of the study, we used the *Scopus (Elsevier) database, which*, together with the *Web of Science*, is considered the most important database due to their breadth (Archambault, Campbell, Gingras, & Larivière, 2009; Jamali et al., 2015). The search with the aforementioned uniterms resulted in 41 articles, including title, abstract and keywords. When comparing searches, 30 results were found in both databases.

No date range was set in the search, since the objective of this research is to outline the profile of academic production regarding the theme, given the temporal implications. Therefore, we selected all articles found up to November 2019, the period in which the data were collected, so this research contemplated articles from 1994 to 2019.

63 results were initially catalogued for this research; however, 11 articles that were not published in full in scientific journals were excluded, namely summaries published in conferences (9) and book chapters (2). Ultimately, 52 articles were analyzed in this paper, and they were cataloged in a spreadsheet containing the

following information: title of the article, name of the publication journal, name of the author(s) and institution, year of publication, abstract, and thematic area of the article.

Data on the journals, such as the hindex (it numerically evaluates the journal's scientific prestige (Minasny, Hartemink, Mcbratney, & Jang, 2013)), country, date range, and journal categories were found on the Scientific Journal Rankings (SJR) platform. In cases where the journal is not indexed in the SJR platform, the h-index field was filled with the acronym "NI" (not included) and the subject area was defined by the authors after reading the scope of each journal. Information regarding the affiliation of the authors was obtained from the *ResearchGate* social network and the *websites* of the affiliated institutions. The theme of the articles was assigned by means of inductive categorization, based on the reading of the titles, keywords and abstracts.

The data analysis presented here was performed in a descriptive way, in four thematic axes: year of publication of the articles, authorship and affiliation, journals, and research subject.

RESULTS

Considering that the *Fédération Internationale de Gymnastique* (FIG) is the oldest sports entity in the world (1881) and that men's artistic gymnastics was the first gymnastics modality in the Olympic program, it is important to highlight the temporality of the 52 scientific articles dealing with the subject (Čuk & Sibanc, 2018), as shown in figure 1.

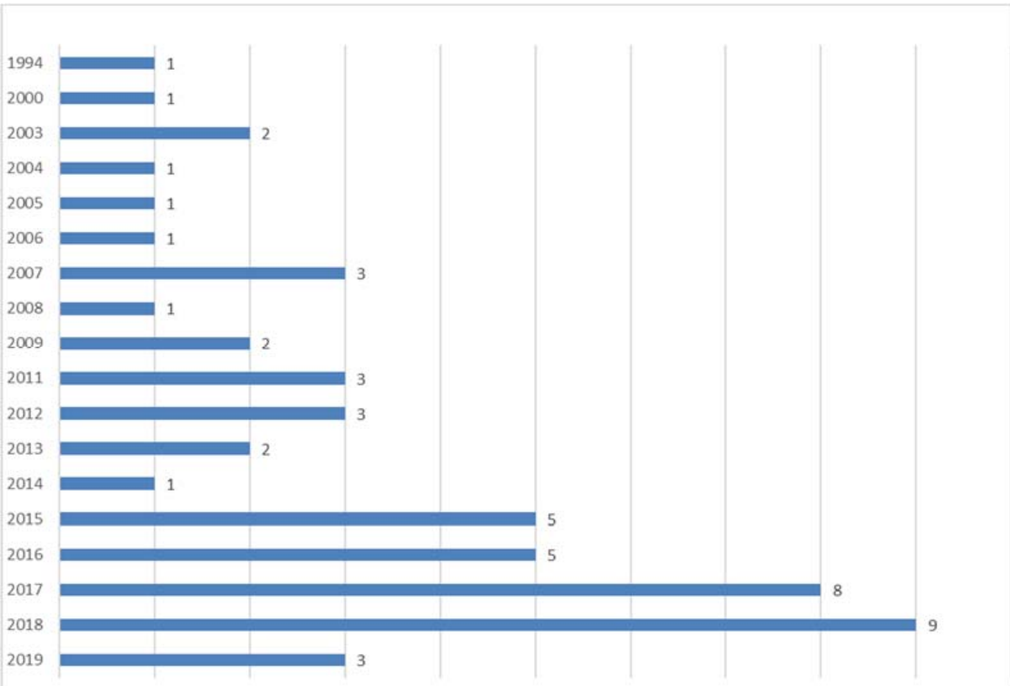

Figure 1. Number of articles per year of publication.

Table 1
Main author and affiliation.

Authors		Institution	Country
Yeadon, Maurice Raymond Fred	8	Loughborough University	United Kingdom
Hiley, Michael	8	Loughborough University	United Kingdom
Bortoleto, Marco Antônio	5	Universidade Estadual de Campinas	Brazil
Čuk, Ivan	5	University of Ljubljana	Slovenia
Atiković, Almir	4	Univerzitet u Tuzli	Bosnia and Herzegovina
Kim, Dong-min	4	Korea National Sport University	South Korea
Irwin, Gareth	3	Cardiff Metropolitan University	United Kingdom
Mkaouer, Bessem	3	Université de la Manouba	Tunisia
Chaabene, Helmi	3	Universität Potsdam	Germany
Amara, Samiha	3	Université de la Manouba	Tunisia
Kalinski, Sunčica Delaš	3	Sveučilište u Splitu	Croatia
Oliveira, Mauricio Santos	3	University of Espírito Santo	Brazil

Table 2
Journals that published the most about MAG.

Journal		Subject Area	H index	Country	Coverage
Science of Gymnastics Journal	11	Health Professions; Medicine; Social Sciences.	7	Slovenia	2012
Journal of Biomechanics	4	Biochemistry, Genetics and Molecular Biology; Engineering; Health Professions; Medicine.	177	Netherlands	1968
Journal of Applied Biomechanics	3	Biochemistry, Genetics and Molecular Biology; Health Professions; Medicine.	50	United States	1995
The Korean Journal of Sport	3	Biochemistry, Genetics and Molecular Biology; Health Professions; Medicine	NI	Korea	1992
The Korean Society of Sports Science	3	Sports Science; Health Professions.	NI	Korea	1991
Motriz. Revista de Educação Física	3	Health Professions; Medicine; Social Sciences.	11	Brazil	2010
Revista Brasileira de Educação Física e Esporte	3	Biochemistry, Genetics and Molecular Biology; Health Professions; Social Sciences.	NI	Brazil	2004
Biology of Sport	2	Health Professions; Medicine.	20	Poland	1996
Human Movement Science	2	Biochemistry, Genetics and Molecular Biology; Health Professions; Medicine; Psychology.	80	Netherlands	1982
Journal of Physical Education and Sport	2	Health Professions.	21	Romania	2011
Sports Biomechanics	2	Health Professions; Medicine.	34	United Kingdom	2002

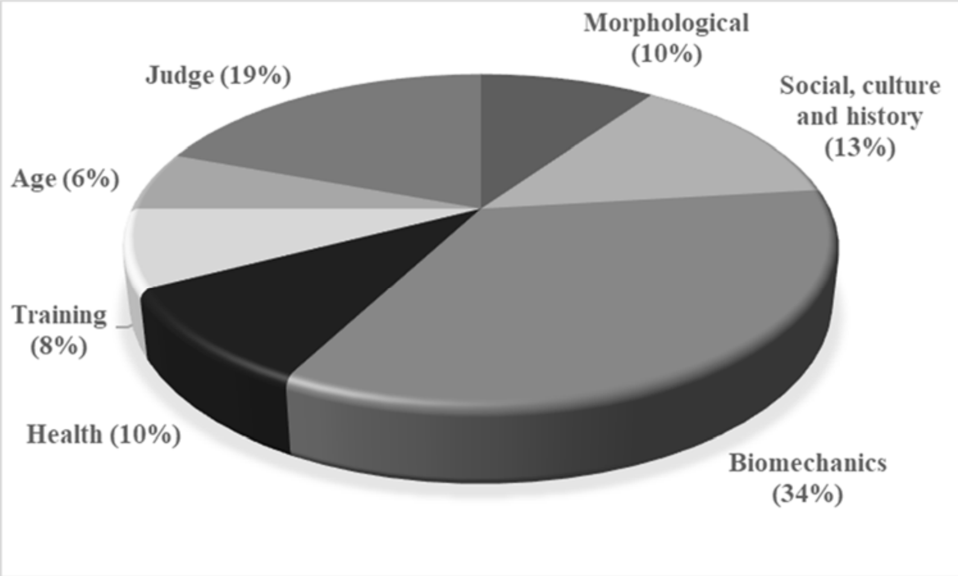

Figure 2. Distribution of articles by subjects.

In the Table 1, we present the authorship of the articles found, considering the name of the author regardless of the order of authorship, the number of articles, the affiliated institution, and the country of origin. For this purpose, authors with three or more occurrences, amongst the 52 articles catalogued for analysis, were presented.

Table 2 presents the journals that published at least two studies on men's artistic gymnastics.

The subjects covered by the articles were classified into seven categories (figure 2): 1) biomechanical aspects of gymnastics (18); 2) scoring code and judging of gymnastics elements (10); 3) social, historical and political aspects of gymnastics (7); 4) athletes' morphological characteristics (5); 5) athletes' health, which includes injuries, pathologies, hydration and nutrition (5); 6) gymnastics training, including metabolic variables, strength training, and training methods (4); 7) analysis of athletes' age over the years (3).

DISCUSSION

Describing the scientific production of a specific area from a bibliometric research can help in understanding its evolution (or lack thereof), as well as point out the trends of publications that cover a certain object of study (Blanca-Torres, et al., 2019). Therefore, we believe that the results presented here may contribute to the specific knowledge of MAG, particularly in order to guide researchers in training (Job, 2006).

Thus, the temporality of the articles found was first verified. Concerning temporality, the oldest article found in this research dates from 1994. However, the *Web of Science* platform features scientific articles since 1945. The *Scopus* database is more recent, with the oldest articles dating from the late 1990s. It is possible that the productions about MAG in the past used the term *men's olympic gymnastics*, a nomenclature that was used in reference to the sport until the 1980s. This change, according to Nunomura, Nista-Piccolo and Eunegi (2004) was made after the inclusion of new gymnastics modalities in the Olympic program - rhythmic gymnastics in 1984 and trampoline gymnastics in 1996 -, thus avoiding confusion since there would be four Olympic gymnastics modalities (men's artistic gymnastics, women's artistic gymnastics, rhythmic gymnastics and trampoline gymnastics).

Also with regard to the temporality of the articles published on male artistic gymnastics, the years 2017 and 2018 stand out as the period with most publications on the sport, approximately 15% (8) and 17% (9), respectively. This substantial increase in production in recent years is possibly the result of the world's overall increase in academic production in line with the expansion of search platforms, as bibliometric research has pointed to the growth, especially in the last decade, of research in different areas of Sport Science (Ciomaga, 2013; Lindahl, Stenling, Lindwall, & Colliandera, 2015; Peset et al., 2013; Prieto, Gómez, & Sampaio, 2015).

Thus, according to the time period of the articles found, scientific production regarding male artistic gymnastics has increased in recent years. This data shows the growing interest in this topic, which might encourage new researchers to look further into it.

Verifying the authorship of scientific articles may help to recognize authors and research groups of a particular area. In this sense, Maurice Raymond Fred Yeadon and Michael Hiley stand out in scientific production on men's artistic gymnastics. The two researchers published eight papers each, each representing approximately over 15% of the total. Together, they published 7 articles, with alternate authorship orders, focusing their research on biomechanical topics. Professor Yeadon is "Emeritus Professor of Computer Simulation in Sport" and one of his projects is entitled "Springboard diving and gymnastics". This project focuses on studies of computerized simulation models of gymnastics movements and ornamental jumps. Yeadon's only research without the collaboration of his colleague Hiley was precisely the one published in 1994, entitled "Twisting techniques used in dismounts from the rings", published in the *Journal of Applied Biomechanics*. This leads to the interpretation that this author is one of the pioneers in studies that link biomechanics and male artistic gymnastics. Hiley, in turn, is the main author of "Optimization of the felge on parallel bars" in partnership with two other authors. As Yeadon, he is a researcher at Loughborough University and holds the position of Senior Lecturer at the institution.

Researchers Marco Antônio Bortoleto and Ivan Čuk stand out with five (9.8%) publications regarding MAG each. Professor Bortoleto teaches at the State University of Campinas (BR) and coordinates research groups about gymnastics and circus, focusing especially on cultural aspects of gymnastics training, circus pedagogy, and promotion and participation in gymnastics for all. His production is concentrated in the socio-cultural dimension of the sport. The article entitled "Public sports policy: The impact of the athlete scholarship program on Brazilian men's artistic", from 2012, is an example of this. Bortoleto is part of the select group of FIG authorities and is also part of the scientific board of the *Science of Gymnastics Journal,* where Čuk is editor in chief. Čuk belongs to the faculty of the University of Ljubljana, Slovenia, where the journal is from, as a member of its Faculty of Sport, where he occupies the position of "Head of Gymnastics and Kinesiology Department". From the articles he has published, it is evidenced that his research subject is likewise the biomechanics of gymnastics.

Still aiming to verify the authorship of articles about MAG, two other researchers were found with four (5.88%) articles each: Almir Atiković and Don-Min Kim. Atiković, who published two studies co-authored with Croatian researcher Sunčica Dela Kalinski, is a researcher from the Faculty of Physical Education and Sport of the Univerzitet u Tuzli, and stands out for his production regarding the age of MAG athletes. In the article entitled "Age trends in artistic gymnastic across world championships and the olympic games from 2003 to 2016", which highlights the linear increase in the age of participants in the Olympic Games and World Championships in artistic gymnastics for men and women, Atiković found the highest age among men in AG when comparing the two groups

(Atiković et al., 2017). It is worth mentioning that this author is also part of the scientific board of the *Science of Gymnastics Journal.*

From the Korea National Sport University, researcher Dong-min Kim stands out for his production on the assessment (referees' scores) of certain MAG equipment in different international competitions. In the results of this research, he is the author who presented the most number of individual research (3). Nevertheless, we did take into consideration the difficulty of reading the articles he has published, as all four of them are in Korean journals that present only the abstract in English.

Other authors were listed with three (5.8%) articles regarding MAG. They are Gareth Irwin - research leader at Cardiff Metropolitan University, United Kingdom, and member of the project "Biomechanics of Gymnastics Rings"; the aforementioned Sunčica Dela Kalinski from the Faculty of Kinesiology, University of Split, Croatia; and the Brazilian researcher Mauricio dos Santos de Oliveira, who is the main author in three articles co-authored with Marco Antônio Bortoleto. This indicates that the studies were conducted by Oliveira with the guidance of Professor Bortoleto.

Bessem Mkaouer, who also appears as the main author of three articles, is Head Professor of the Department of Gymnastics at the Higher Institute of Sport and Physical Education of Ksar Saïd, University of Manouba, Tunisia. In those three articles, researchers Samiha Amara – assistant professor at the same institution – and Helmi Caaabene – guest professor at the Universität Potsdam – occupy different positions of authorship in the same articles. This fact indicates that these articles are the result of the research group from the gymnastics department led by Professor Mkaouer.

The observation of the countries of affiliation of the main authors regarding MAG indicates the predominance of the United Kingdom (three), followed by Brazil (two). The ranking of the countries that have published the most about Sport Science, according to the search carried out on the SJR platform, shows that the United States, the United Kingdom, and Canada occupy the top positions. Accordingly, the study conducted by Jamali et al. (2015) indicated that 39% of the publications on Physics Education on the *Web of Science* between the years 1980-2013 are from the United States, followed by Turkey (17%) and Spain (8%). For this reason, it is noteworthy that no US nor Canadian researcher is among the most productive ones regarding MAG research.

By highlighting the journals that have published the most about a specific area, it is possible to identify the journals that address men's artistic gymnastics. In this sense, the *Science of Gymnastics Journal* stands out. The journal features 11 articles on the modality, approximately 21% of the articles published between 1994 and 2019 on this theme. This fact is certainly not surprising given that it is the only specific international gymnastics journal. The journal is supported by the *Fédération Internationale de Gymnastique* and is edited by the Department of Gymnastics of the University of Ljubljana. The editorial board evidences the representativeness of different countries, namely: Bosnia and Herzegovina, Brazil, Canada, Croatia, Germany, Hungary, Japan, Russia, Spain, United Kingdom and United States of America (SCIENCE OF GYMNASTICS JOURNAL, 2019). It is worth noting that, while the journal in question is completing ten years of existence, its indexation in the SJR platform only occurred in 2012. This may be the reason for it presenting a lower H index than most of the journals categorized. For example, the *Journal of Biomechanics*, the second journal that published the most on MAG, with approximately 7% of the total number of articles (four), has featured articles since 1968, and its H index is 177.

Some consequences are brought up by the fact that there is only one journal that specifically addresses gymnastics, namely: the journal's publications should be frequently followed by researchers who deal with gymnastics; professionals who work directly with gymnasts should be encouraged to access this journal to improve their scientific knowledge about the sport; at least one more journal should address gymnastics, as this would increase the diversity of opinions and approaches on the subject (Franchini, Gutierrez-Garcia, & Izquierdo, 2018).

Following this, there are five journals that have three (5.8%) published articles on MAG each, namely: *Journal of Applied Biomechanics* (United States); *The Korean Journal of Sport* and The Korean Society of Sports Science (Korea); *Motriz. Revista de Educação Física and Revista Brasileira de Educação Física e Esportes (Brazil).* In this sense, it is worth noting that the *Web of Science* platform privileges Anglo-Saxon content and presents greater coverage in the area of science than in arts and humanities (Villarejo, Palao, & Ortega, 2010). Although *Scopus* presents a greater coverage from other countries, in addition to those whose official language is English (Pérez-Gutiérrez, Cobo-Corrales, & Izquierdo-Macón, 2018), the articles found in Korean journals were only identified through the *Web of Scienc*e platform, while the articles in Portuguese were detected by the *Scopus* platform.

Among all the journals found in this research, none is in the top 10 of the scientific journals of Physics Education pointed out by Jamali et al. (2015). This data indicates the need for researchers of male artistic gymnastics to seek publications in the main journals in the Physical Education area, in order to gain prominence within their field.

Table 2 presents the countries of the periodicals that have published the most on MAG. The numerical predominance (55%) of journals from the European continent is highlighted. The second continent with more periodicals is America (27%), but with the representation of only two countries: United States and Brazil. The Asian continent, which stood out for its bibliometric research on judo (Peset et al., 2013), appeared in the third position (18%).

The detailed identification of the subjects addressed in the articles enables the recognition of research trends regarding male artistic gymnastics, as well as the identification of the main authors by subject. In this sense, regarding the Subject Area of the journals, the predominance of the biological area to the detriment of the social area is remarkable. This is not surprising, considering that, in general, there are fewer researchers, and, consequently, fewer publications in the social area of sport. For instance, the research by Corrêa, Corrêa and Rigo (2019) indicates that, in Brazil, there are about 32 graduate programs in Physical Education, with 666 researchers. Among them, approximately 72% are focused on the biodynamics area, 25% in the social area, and another 3% in both.

When observing the distribution by subject, a lack of articles on the pedagogy of sport was identified. Nevertheless, the predominance of articles on biomechanical aspects (34%) was observed, especially regarding the analysis of movements in gymnastics equipment. By presenting the journals that published the most, as well as the authors who produced the most on MAG, it has been possible to identify a larger production on biomechanics.

Prassas, Know and Sands (2006) has already indicated the growth in the number of research on the biomechanics of movement in gymnastics. As an example, Hiley and Yeadon (2016) analyzed the execution of Kovacs - exercises of release and regrasp in the high bar - of nine athletes to help in the execution of the movement, in order to, consequently, avoid falls. For this purpose, the authors used a computer simulation model, and the movement was analyzed before and after the simulation. The success rate of the movement increased from 11% to 93%, indicating an effective technological possibility for the improvement of athletes' performance.

The second subject most addressed in the articles was the judging of gymnastics (19%). In this sense, Carrara and Mochizuki's (2011) research stands out, which verified, from interviews with Brazilian and Portuguese coaches, the influence of new rules (from 2006 on) on the scoring code of the FIG in the training of MAG. The analysis of the content of the interviews indicated an increase in the complexity of the series. This led the coaches to increase the amount and intensity of the trainings, as well as to make adaptations in the physical, technical and tactical preparation.

Social, historical and political aspects of MAG occupy the third position (13%) among publications. Within this group, it was possible to observe different approaches, such as the research by Rohleder and Vogt (2018), which aimed to evidence the challenges for MAG in view of the debate regarding the German sports training system. Čuk and Sibanc (2018) conducted a historical survey of the Olympic medalists from the individual modality since its first edition. The results of the survey also point to the change in the rules of MAG featuring a historical factor, since specialists in certain equipment are increasingly standing out to the detriment of general athletes.

Nonetheless, through the thematic distribution presented, it is possible to notice that the number of articles on MAG under the bias of the Human Sciences is inferior to the ones under the Biological Sciences. This is not surprising considering that previous research on sports already points to this numerical discrepancy. Palazón, Ortega and García-Angulo (2015) indicated that only 2.4% of the academic production regarding indoor soccer, between the years 2005 and 2014, falls into the category they call "sociology of sport", the smallest representation among the nine categories listed by the authors.

It is worth noting that analytical studies that compared the different bibliographic databases indicate that both the *Web of Science* and *Scopus* tend to privilege studies from Biological Sciences(Archambault, et al., 2009; Mongeon & Paul-Hus, 2016).

CONCLUSIONS

By describing the scientific production on MAG in journals indexed on the *Scopus* and *Web of Science* platforms, we concluded that 1) the first article published on the subject dates back to 1994, and the year with the greatest number of publications to date has been 2018, with emphasis on the period between 2015 and 2018; 2) among the authors who produced the most were two British (Maurice Yeadon and Michael Hiley), one Brazilian (Marco Bortoleto), and one Slovene (Ivan Čuk); 3) the numerical predominance of articles on MAG in the *Science of Gymnastics Journal* (21%), followed by the *Journal of Biomechanics* (7%); 4) 34% of the articles are on the biomechanics of gymnastics, 19% on the rules of the modality and judging, 14% on social, historical and political aspects of gymnastics, 10% on the analysis of morphological characteristics of athletes, 10% on the athletes' health, 8% on gymnastics training aspects (including metabolic variables, strength training, and training methods), and 6% are studies that have analyzed the age of athletes over the years.

Nevertheless, it was possible to identify correlations between the investigated variables. By verifying authorship and highlighting the journals that have published the most about MAG, the relationship between the researchers and the journal Science of Gymnastic Journal was identified (Ivan Čuk, Marco Antonio Bortoleto and Almir Atiković). Regarding the subject area of the journals and the identification of the subjects addressed in the articles, biomechanics stood out.

Although it is understood as a limitation of this study the methodological choice of the search platforms and the keywords, the intention was to point out a panorama of the specific academic production on MAG through the methodological requirements mentioned above. Relevant research on this subject is certain to have escaped the filter used in this study, indicating the care authors should take when writing the title, keywords and abstracts of their articles. In addition, it was observed that, when using the *Web of Science* and *Scopus* databases, the content of the Biological Sciences has been privileged to the detriment of the Human Sciences. English-language journals were also favored.

Therefore, it is hoped that this study can provide subsidies for the expansion of knowledge of scientific production on the subject, and encourage researchers to focus on specific themes of MAG. After all, the data presented here may help in choosing which journals to follow and submit future works to, as well as to direct the development of new investigations and locate the main authors and institutions of a particular subject.

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SHORT HISTORICAL NOTES XIX

Anton Gajdoš, Bratislava, Slovakia

Ph.D. Anton Gajdoš born on 1.6.1940 in Dubriniči (today Ukraine) lives most of his life in Bratislava (ex TCH, nowadays SVK). He comes from gymnastics family (his brother Pavel have world championship medals) and he devoted his life to gymnastics. His last achievement is establishment of Narodna encyklopedia športu Slovenska (www.sportency.sk). Among his passion is collecting photos and signatures of gymnasts. As we tend to forget old champions and important gymnasts, judges and coaches, we decided to publish part of his archive under title Short historical notes. All information on these pages is from Anton’s archives and collected through years.

NINA BOCHAROVA (24 September 1924 Suprunovka, Ukraina – 31. August 2020 Roma, Italy)

Nina Bocharova was born in Soviet Union in Ukrainian region of Poltavia. While the great hunger in Ukraina (1932-1933) she remembers she was always hungry and had to steal carrots from collective farm field and eat peels from potatos. No wonder she had only 155 cm of height. According to nowadays gymnasts she was already after WWII model of modern gymnast. During WWII, despite her young age, she took active national duty and transported granates to partisans. In 1944 she moved to liberated Kiev and entered Institute of Physical Education. During her studies she worked at station, where she unloaded cars, what gave her extra strength. In 1948 she graduated with degree of trainer-teacher. She was member of club named Stroitelj (builder) and work under coach Mihail Dmitrev.

Unfortunately Soviet Union did not took part at OG 1948 in London. In 1949 she won USSR championship in all around and repeated it in 1951. Between 1949 and 1951 she was also national champion on beam (1949 and 1951) and on uneven bars (1950, 1951)

Nina Bocharova invented and performed an exercise that no one else in the world has ever performed: a side split on the uneven bars. Since the bars were then of an old design, other athletes had to hold the stands for safety. (photo bellow from https://stuki-druki.com/authors/Bocharova-Nina.php)

It almost happened she could not go to Helsinki OG in 1952. However, she promised not to perform difficult jump on beam and authorities allowed her to join national team.

Reward for her was great. With national team she won, and won also gold medal on beam. In all around she took silver medal behind her teammate Maria Gorokhovskaya. With team she also took silver medal in rhytmics exercise with apparatus.

Her next and last international event was World Championship 1954 in Rome, where despite she was 30 years old, she helped team to win on artistic events and rhythmic event.

After she stopped competing, she was a coach in Moskow and Kiev, where she retired in 1979. She was awarded with state ordens and in 2012 with orden of Ukrainian Olympic Committee. Like many other gymnasts she lived healthy and died in age of 96.

Photo on right: Maria Gorokhovskaja - left - winner at OG 1952 and Nina Botsharova - 2nd place all around

Slovenski izvlečki / Slovene Abstracts

Stewart N. Pritchard, Jillian E. Urban, Logan E. Miller, Laura Lintner & Joel D. Stitzel

KINEMATIKA GIBANJA GLAVE PRI TELOVADKAH

Pretresi pri teleovadbi so slabo raziskani; sedanji dokazi kažejo, da je možna stopnja pretresa možganov višja, kot je bilo prej poročano zaradi premajhnega poročanja med trenerji, športniki in starši. Namen te študije je bil predstaviti metodo za zbiranje podatkov o udarcih glave pri telovadbi in zagotoviti prve meritve izpostavljenosti udarcem glave. Tri orodne telovadke (stare od 11 do 16 let), kategorije poljubnih sestav, so bile opremljene z ustnim merilnikom, ki je meril linearni pospešek, hitrost vrtenja in kotni pospešek glave med opornimi in brezopornimideli prvin med vadbo. Najvišji linearni pospešek, vršna hitrost vrtenja, vršni pospešek vrtenja, trajanje in čas do največjega linearnega pospeška so bili izračunani iz podatkov merilnika. Kinematični podatki so bili časovno usklajeni z videom, nato pa so bili podatki senzorjev razdeljeni v oporne položaje in gibanja, za katere so značilni vrtenje, orodje, vrsta podloge za doskok, vrsta prvine, del prvine, stabilnost pristanka in stik telesa s podlago. Telovadci so bili izpostavljeni 1.394 stikom (41 na telovadko na vadbo), od tega jih je 114 (3,9 na telovadko na vadbo) vsebovalo stik z glavo. Kinematične značilnosti so se razlikovala med vrstami spretnosti, orodji in blazinami za doskok. Mediana trajanja udarcev z dotikom glave (177 ms) je bila daljša od izmerjenih vplivov pri mladinskem in univerzitetnem nogometu. Rezultati te študije pomagajo zagotoviti podlago za prihodnje raziskave, ki bodo morda skušale preučiti izpostavljenost udarcem glave pri telovadbi, da bi bolje informirali o preprečevanju pretresa možganov in vrnitvi v protokole igranja v športu po pretresu možganov.

Ključne besede: izpostavljenost udarcem z glavo, gimnastika, pretres možganov, poškodba glave.

Lucia Selecká, Olga Kyselovičová, Adriana Krnáčová & Anita Lamošová

BIOMEHANIČNE ZNAČILNOSTI RITMIČNEGA SKOKA PREDNOŽNO UPOGNJENO, ZANOŽNO Z ZAKLONOM GLAVE IN TRUPA: ŠTUDIJA PRIMERA

Biomehanski premisleki, ki se kažejo v pravilni ali nepravilni tehniki, zlasti v vseh telovadnih disciplinah, so več kot nedvomni. Skok »jelenček« kot različica prednožno zanožnih skokov je ena temeljnih prvin in ključno gibanje pri razvoju vrhunskih telovadk. Cilj študije je bil analizirati kinematične značilnosti skoka prednožno upognjeno, zanožno z zaklonom glave in trupa pri ritmiki in hkrati ugotoviti eksplozivno moč. V raziskavo je bila vključena članica slovaške vrste. Analizirane so bile kinematične značilnosti skoka. Za zbiranje podatkov je bil uporabljen sistem zajemanja, sestavljen iz 8 infrardečih kamer. Eksplozivno moč spodnjih okončin so diagnosticirali s skakalnim dinamometrom z 2 standardiziranima meritvama: navpični skok v nasprotni smeri brez zamaha rok in 10-sekundni ponavljajoči se navpični skoki z zamahi rok. Poleg tega je bila izmerjena tudi eksplozivna moč med letom. Rezultati v 10-sekundnih ponavljajočih se skokih kažejo najvišjo vrednost telovadnega središča mase 46,4 cm, kontaktni čas 0,195 s in najboljši rezultat v letu 58,3 W.kg^{-1}. Med izvajanjem skoka so zaradi zapletenosti in zahtevnejše skladnosti zgornjih kot spodnjih delov telesa opazili nekoliko drugačne rezultate: najvišja vrednost težiščnega centra mase je bila 40,8 cm, kontaktni čas 0,209 s in izhod v aktivnem faza leta 52,8 W.kg^{-1}.

Ključne besede: ritmika, kinematične značilnosti, eksplozivna moč, 10-sekundni ponavljajoči se skoki, vertikalni skok v nasprotni smeri.

Hounaida Akkari-Ghazouani, Bessem Mkaouer, Samiha Amara & Mokhtar Chtara

KINETIČNE IN KINEMATIČNE ZNAČILNOSTI TREH RITMIČNIH SKOKOV PREDNOŽNO UPOGNJENO, ZANOŽNO BREZ ŽOGE TER METOM ŽOGE PRED ODRIVOM OZ.PRI ODRIVU

Vidna razčlenitev ritmike kaže, da so največje težave pri skokih. Izvajanje skoka z najbolj primerno hitrostjo, velikim razponom in boljšo skladnostjo ter brez napak ni odvisno samo od zmogljivosti ritmičarke, temveč tudi od uporabljenega orodja, izvedenega skoka in uporabljenega zaleta. Cilj je bil preučiti lastnosti moči, hitrosti in gibljivost, ki so se razvile med tremi izvedbenimi skoka prednožno upognjeno z žogo in brez nje. V tej študiji je sodelovalo sedem ritmičark iz državne vrste, starih od 15 do 21 let. Vrstni red treh skokov je bil naslednji: prvi brez orodja, drugi z metom žoge pri zadnjem koraku zaleta in tretji z metom žoge ob odrivu. Osnovne opisne parametre in statistično pomembnost razlik smo določili z uporabo SPSS 20.0, statističnega programa za obdelavo podatkov. Rezultati kažejo pomembne razlike pri $p < 0,05$ pri izvedbenih dejavnikov pri metu žoge, kot so vodoravna in navpična hitrost, kot desnega kolena, sila odriva, vodoravni premik stopala, vrtilna količina središča mase in kotna hitrost desne noge . Nižanje vrednosti spremenljik se razlikuje glede na trenutek metanja žoge. Na koncu lahko trdimo, da met žoge med zaletom povzroči spremembo osnovnih dejavnikov učinkovitosti.

Ključne besede: ritmika, met, lovljenje, žoga.

Thomas Lehmann, Annelie Lorz, Axel Schleichardt, Falk Naundorf, Klaus Knoll, Falko Eckardt, Kerstin Witte

VEČDELNI MODEL ODRIVNE DESKE ZA ORODNO TELOVADBO

Za razvoj in optimizacijo gibanja na je pomembno vedenje o hitrosti odriva in vrtilni količini. Zaradi kratkih stikov na odrivni deski so visokofrekvenčne kinematične metode za določanje hitrosti zelo zamudne. Za določitev sil odriva za izračun določenih parametrov odriva je bil razvit model večdelne odrivne deske. Odrivna deska Gymnova je bila modelirana s pomočjo programske opreme za posnemanje okolja Alaska. Vrednotenje v dinamičnih pogojih je bilo izvedeno s preizkusom padajoče mase, globinskim skokom in premetom naprej. Vrednotenje je bilo izvedeno na parametrih reakcijskih sil podlage (GRF): impulz sile (p) in največja navpična sila (Fmax). Za simulacijo globinskega skoka in premeta naprej je bil kot vhodni parameter v modelu podan dejanski izmerjeni pospešek zgornjega dela deske. Pri primerjavi navpičnega premika stvarne in modelirane vrednosti premika zgornjega dela deske lahko opazimo neskladje 6,1%. Pri preskusu padajoče mase so bile med stvarno ploščo in modelom dosežene razlike za p = 0,4% in Fmax = 28,2%. Za tipične obremenitve za preskok so bili uporabljeni globinski skoki. Ugotovljene so bile razlike do 8,4% za Fmax in 6,8% za p. Nazadnje so bile izmerjene vrednosti pri izvedbi premeta naprej. Raziskane so bile vodoravne in navpične sile. S temeljitim vrednotenjem na več stopnjah je bilo mogoče razviti model odskočne deske, ki je primeren za izračun GRF v dinamičnih pogojih v 2-d. Zato je mogoče izračunati sile, ki delujejo pri odrivu. Parametre odriva je mogoče določiti iz teh sil. Ta ocena tudi kaže, da je treba upoštevati še posebej vodoravne sile.

Ključne besede: orodna telovadba, odrivna deska, modeliranje, premet naprej.

Paula Barreiros Debien, Paulo Márcio de Oliveira, Thiago Ferreira Timoteo, Camila Ferezin, Maurício Gattás Bara Filho & Tim Gabbett

OBSEG VADBE, POČITEK IN POŠKODBE PRI VRHUNSKIH RITMIČARKAH V ČASU TEKMOVALNEGA OBDOBJA: ŠTUDIJA PRIMERA

Tekmovalna obdobja so kritična obdobja, ko imajo vrhunske ritmičarke obsežnejšo vadbo in nezadostno okrevanje. Cilj tega kratkega poročila je opisati posamezne obremenitve, okrevanje in poškodbe pri ritmičarkah v tekmovalnih obdobjih. Šest ritmičark iz brazilske državne vrste je bilo dnevno nadzorovanih v 126-dnevnem obdobju, ki je obsegalo redno vadbo in štiri tekmovanja. Vadbena obremenitev je bila izmerjena z uporabo ocene zaznanega napora (RPE). Ocenili so dnevno obremenitev, dolgotrajno obremenitev in trenutno. Izračunano je bilo razmerje kronične delovne obremenitve (ACWR). Za spremljanje počitka je bila uporabljena lestvica popolne obnovitve kakovosti (TQR), izmerjena pa je bila tudi 3-dnevna tekoča povprečna vrednost (3RA) TQR. Zdravstveno osebje je diagnosticiralo in poročalo o poškodbah, njihova poročila pa so bila nato uporabljena. Uporabljena je bila opisna statistika. Ritmičarke so imele različne dnevne obremenitve, ACWR in vzorce okrevanja ter poškodbe med tekmovalnimi obdobji. Vse so imele hitro povečanje ("konico") obremenitve. Tri ritmičarke so bili več kot 60% časa premalo spočite. Štiri ritmičarke so v času raziskave utrpele pet poškodb (vse poškodbe zaradi prekomerne uporabe spodnjih okončin, dve hudi, dve srednji in ena lažja). Posamezni dejavniki, kot sta starost in dolgoletna poznana obremenitev, določajo kako se vsaka ritmičarka odziva na vadbo in prenaša spremembe obremenitve. Poleg tega se zdi, da poškodbe, ki so jih utrpele med tekmovalnimi obdobji, vplivajo na kratkotrajno in dolgotrajno športno pot ter slabijo vadbo in organizacijo priprav vrste na tekmovanja.

Ključne besede: ritmika, poškodbe, vadba obseg, tekmovanje.

Joana Filipa Pereira de Sousa de Carvalho Barreto, Filipe Luís Martins Casanova, César José Duarte Peixoto

VIDNE ZAZNAVE PRI VRHUNSKIH AKROBATIH PRI SKOKIH Z MALE PROŽNE PONJAVE IN PRESKOKIH MIZE S POMOČJO MALE PROŽNE PONJAVE

Vidni sklop zagotavlja podatke iz okolja in vodi akrobate k izboljšanju zmogljivosti. Vprašanje, kateri viri vidnih podatkov iz okolja prispevajo k uspešnosti, ostaja nejasno. Cilj te študije je razčleniti vidno vedenje, kot zanimivo področje, ki so jih potrdili vrhunski akrobati pri skupinskih akrobatskih sestavah med izvajanjem skokov z male prožne ponjave (MPP) in preskokov mize s pomočjo MPP. Predvidevali smo, da: a) bi akrobati zaustavili pogled na zanimiva območja v okolju, da bi vidno zaznavali ustrezne podatke, b) da bi se v zadnjem delu leta in doskoka pojavile zaustavitve pogleda na območju, ki nas zanima. Trije vrhunski akrobati so opravili tri naloge na MPP in eno na preskoku. Spremenljivke so bile: trajanje zaustavitve pogleda (FD), zanimiva področja (AOI), razmerje med celotnim trajanjem zaustavitve pogleda in celotnim trajanjem naloge (TFD / TD) ter razmerje med celotnim trajanjem zaustavitve pogleda na AOI in celotnim trajanjem zaustavitve pogleda (TFDA / TFD). Rezultati so pokazali, da se je TFD / TD povečeval z zmanjšanjem stopnje zahtevnosti za vse naloge. MPP je bil najbolj pritrjen AOI (razen pri saltu naprej stegnjeno z obrati), medtem ko je bil zid manj krat pritegnil pogled. Na območju zaleta je bilo največ zaustavitev pogleda. Pri nalogi preskoka z MPP so akrobati skrajšali čas zaustavitve pogleda območja zaleta in povečali čas namestitve MPP in mize. Blazina za doskok je bila edina AOI, ki je bila med letom. Rezultati kažejo, da lahko akrobati prilagodijo svojo vidno strategijo stopnji zapletenosti naloge, kar se kaže v rezultatih TFD / TD in TFDA / TFD.

Ključne besede: vidna zaznava, sledilnik oči, skoki, preskoki.

Marjeta Kovač, Vedrana Sember in Maja Pajek

IZVAJANJE UČNEGA NAČRTA TELOVADBE V PRVIH TREH RAZREDIH OSNOVNE ŠOLE V SLOVENIJI

Telovadba je po vsem svetu bistven del učnih načrtov telesne vzgoje, zlasti v prvih letih šolanja. V tem obdobju telesno vzgojo poučujejo razredni učitelji (GT) z nizkimi izkušnjami o poučevanju telovadbe. Namen naše študije je bil ugotoviti, kako so GT upoštevali predpisane vsebine učnega načrta za telovadbo. Vzorec je vključeval 90 GT iz 21 osnovnih šol iz Ljubljane, glavnega mesta Slovenije. Vprašalnik, ki ga izvajamo sami, je bil zasnovan, da bi preučil mnenja GT o nekaterih pomembnih dejavnikih in izvajanju telovadnih vsebin na petstopenjski Likertovi lestvici. Pri obdelavi podatkov so bili uporabljeni enosmerni ANOVA, Tukey post hoc test in Mann-Whitney U test. GT so več časa namenili tistim vsebinam učnega načrta telesne vzgoje, ki so pomembnejše za razvoj otroka in jih je lažje poučevati. Na študijsko leto so porabili le 16,93 pouka telovadbe, telovadb so uvrstili na četrto mesto (od 7) glede na njen pomen za razvoj otrok, telovadba pa se je zdela najbolj zahtevna vsebina za poučevanje. V telovadnih vsebinah so bili najmanjkrat izvedenr prvine, ki so bili omenjene kot najtežje za učenje otrok (akrobatika, vese, opore in preskoki). GT so verjeli, da so metode poučevanja (4,29) manj pomembne za uspešno izvajanje telovadbe kot gibalna učinkovitost otrok (4,73) in samodejavnost (4,57). Rezultati te študije lahko pomagajo pri prihodnji posodobitvi izobraževalnih študijskih programov GT in oblikovanju ustvarjalnega sklopa nenehnega poklicnega razvoja.

Ključne besede: osnovna šola, vzgoja, telovadba, pomen, težave, razredni učitelji.

María Alejandra Ávalos, Ainoa Garde & Lilyan Vega

TEHNOLOGIJA IN SAMOOCENJEVANJE KOT STRATEGIJA ZA SODELOVALNO UČENJE TELOVADBE

Akrobatika je idealna vsebina za delo pri pouku telesne vzgoje zaradi svojih sodelovalnih in vključujočih značilnosti ter številnih koristi, ki jih lahko prinese učencem. Cilj te raziskave je razčleniti dojemanje 81 dijakov srednje šole po izvedbi vadbe akrobatike z uporabo tehnologij in vključitvijo dijakov v postopek ocenjevanja. Za to je bila uporabljena kvalitativna metodologija. Za zbiranje podatkov je bil uporabljen polstrukturiran pogovor, kjer so bila obravnavana vprašanja o koristih in težavah, ki so se pojavile pri učenju prvin, pa tudi o uporabnosti, ki jo mladostniki zaznajo pri uporabi videa med prvin in lastna ocena. Kvalitativni podatki so bili kodirani glede na pripovedno vsebino dijakov in razčlenjeni s programom AQUAD 7. Rezultati kažejo, da dijaki v tej vadbi zaznavajo koristi v smislu užitka in druženja. Kar zadeva težave, so najbolj izstopajoči pomanjkanje časa in posebne zahteve za razvoj tega načina. Poleg tega dijaki pozitivno ocenjuje uporabo videa pri pouku akrobatike in samoocenjevanje, podprto s podpoglavji. Na ta način vadba akrobatike prispeva številne čustveno-družbene koristi, poleg tega pa sklepa, da uporaba videa in vključitev dijakov v ocenjevanje omogočata, da so udeleženci njihovega lastnega učenja in ta način lahko privede do oblikovanja bolj kritičnih in samostojnih ljudi.

Ključne besede: akrobatika, snemanje videa, upravljanje učenja, srednja šola.

Asma Amri-Dardari, Bessem Mkaouer, Sarra H. Nassib, Samiha Amara, Rachid Amri & Fatma Zohra Ben Salah

VPLIV VIDEO MODELINARANJA IN POSNEMANJA NA POUČEVANJE/UČENJE TEMELJNIH PRESKOKOV MIZE

Namen razsikave je bil primerjati učinke različnih strategij poučevanja/učenja (tj. besednih povratnih podatkov, vidnih povratnih podatkov z modeliranjem in vidnim povratnim podatkov s posnemanjem) na izvajanje osnovnih preskokov mize. Sodelovale so tri moške skupine dodiplomskih študentov telesne vzgoje (tj. 135 študentov, razdeljenih v tri skupine po 45). Skupine (tj. tradicionalna, modeliranja in posnemanja) so bile razdeljene pod enakimi pogoji; študenti niso telovadci, imajo enako raven znanja in jih poučuje isti učitelj. Vsi udeleženci so bili preizkušeni, da bi ugotovili začetno raven spretnosti (tj. sklonke). Ta študija zajema 24 vadbenih enot, 21 učenja in tri ocenjevanja, razporejenih v 12 tednih (tj. 2 vadbeni enoti na teden). Razčlenitev videa gibanja (tj. s pomočjo programske opreme Kinovea) je bila uporabljena za ovrednotenje spretnosti / zmogljivosti sklonke. Rezultati kažejo na boljše izboljšanje zmogljivosti v skupini modeliranja v primerjavi s posnemovalno in tradicionalno skupino (ocena sklonke, 11,80 ± 1,22 točke, 10,85 ± 1,50 točke in 9,01 ± 1,30 točke, p <0,01). Poleg tega je analiza delta-odstotka pokazala znatno izboljšanje tehnične učinkovitosti v skupini modeliranja (46,93%) v primerjavi s posnemovalno (27,62%) in tradicionalno (21,64%). Skratka, video povratni podatki s superpozicijo modela so privedle do boljših učnih izboljšav v preskoku v primerjavi s posnemovalno in tradicionalno metodo besednih povratnih podatkov. Predvajanje videa s prekrivanjem modela je omogočila veliko izboljšav pri učenju sklonke.

Ključne besede: vidni povratni podatki, modeliranje, posnemanje, učenje, sklonka, telesna vzgoja.

Burak Gündoğan, Erkan Demirkan, Erbil Murat Aydın & Abdüsselam Turgut

VPLIV RAZLIČNIH TELOVADB NA TELESNO SESTAVO IN SPRETNOSTI PRI ODRASLIH NETEKMOVALNIH TELOVADCIH

Namen te raziskave je bil primerjati učinke vadbe orodnetelovadbe in vadbe na mali prožni ponjavi na sestavo telesa in nekatere razsežnosti telesne pripravljenosti pri odraslih netekmovalcih. Oseminštirideset odraslih je bilo naključno razporejenih v tri skupine: skupina za vadbo na ponjavi (TG) (n = 16), skupina za orodno telovadbo (AG) (n = 16) in nadzorna skupina (CG) (n = 16). Prvi dve skupini sta vadili dvakrat tedensko , skupaj 12 tednov. Nadzorna skupina je dvakrat na teden izvajala le raztezne vaje. Da bi ugotovili učinke vadbe na telesno sestavo, so pred in po študiji vse skupine izvedli Y test dinamičnega ravnotežja, ki je vključeval šest nalog ravnotežja, navpični skok, skok v daljino in dva različna testa gibljivosti. AG in TG sta se znatno izboljšali (p <0,05), ko gre za vse gibalne sposobnosti odraslih netelovadcev po 12 tednih treninga. Toda vaje na prožni ponjavi so lahko bolj učinkovite v primerjavi z vajami orodne telovadbe. Vaje na prožni ponjavi lahko priporočamo kot nadomestni način vadbe za izboljšanje gibalnih sposobnosti.

Ključne besede: orodna telovadba, prožna ponjava, ravnotežje, navpični skok, skok v daljino, gibljivost.

Angeliki Mastrogianni, Maria Psychountaki & Olyvia Donti

SAMOPODOBA IN SAMOSPOŠTOVANJE PRI MLADIH RITMIČARKAH: JE STOPNJA VADBE ODLOČUJOČA?

Namen te raziskave je bil preučiti samopodobo in samospoštovanje mladostniških ritmičark različnih ravni vadbe. V tej raziskavi je sodelovalo sto ritmičark (32 vrhunskih tekmovalnih in 68 občasnih ritmičark), starih 13-15 let. Samopodoba in samospoštovanje udeleženk je bilo ocenjeno z grško različico Harterjevega profila samopodobe mladostnikov (Harter, 1986; Makri-Mpotsari, 2001), ki meri devet posebnih področij samopodobe (šolska pristojnost, odnosi z vrstniki , odnosi s starši, matematična pristojnost, atletska pristojnost, telesna podoba, jezikovna pristojnost, vedenje, tesni prijatelji), sestavljena iz po 5 delov. Popis vključuje tudi desetdelno lestvico Global Self-Worth, ki meri samospoštovanje. Poleg tega so ritmičarke podale podatke o svoji vadbi. Ritmičarke na vrhunski tekmovalni ravni so dosegli višje rezultate kot občasne na področju odnosi s starši ($p = 0{,}027$, $d = 0{,}50$) in pri Global Self-Worth ($p = 0{,}046$, $d = 0{,}45$). Razlik med skupinami v drugih domenah samopodobe ni bilo ($p = 0{,}068$ do $0{,}611$, $d = 0{,}41$ do $0{,}10$). Ukvarjanje s tekmovalnim športom lahko poveča samozavest mladostnic in verjetno ta zveza krepi odnose ritmičark s starši. Potrebne so nadaljnje raziskave povezave med stopnjo vadbe in področji samopodobe, zlasti v primeru mladostnic.

Ključne besede: samopodoba, mladost, osebnostne lastnosti, ocenjevanje, ritmika, odnosi s starši.

Vítor Ricci Costa, Renato Francisco Rodrigues Marques, Mauricio dos Santos Oliveira & Myrian Nunomura

»LUTKE« PRI ŽENSKI ORODNI TELOVADBI: RAZMERJE VADITELJE-TELOVADKA SKOZI OČI PIERRA BOURDIEUJA

V ženski orodni telovadbi (WAG) so telovadke lahko odvisne od vaditelja, postanejo podrejene in ta scenarij lahko odraža podrejenost, nadlegovanje in zlorabe. To je zaskrbljujoče, saj so telovadke običajno otroci. Vendar trdimo, da je ravnanje vaditelja odvisno od zapletenih medsebojnih odnosov. Tako smo razčlenili, kako se gradi odnos vaditelj-telovadka. Za dokazovanje svojih razmišljanj smo uporabili kategorije Pierra Bourdieuja. Ugotovili smo, da so oblike prevlade v odnosu vaditelj-telovadka odgovorne za oblikovanje dolgotrajnih predpogojev, ki jih sproži postopek, zaznamovan z vključevanjem in utelešenjem nekaterih praks. Tako telovadke razvijejo razredno okolje, ki razmnožuje in legitimira logiko tega področja. Naša uporaba Bourdieujevega objektiva je pokazala, da so telovadke v slabšem položaju v primerjavi s vaditelji in okoljem. Zato te strukture ne bi smele zahtevati zgodnjih rezultatov, temveč omogočati telovadkam, da se odločijo, ali želijo nadaljevati v tej "igri prevlade".

Ključne besede: teorija polj, ženska orodna telovadba, sociologija športa.

Vahid Saleh, Roghayyeh Afroundeh, Marefat Siahkouhian & Asadollah Asadi

VPLIV 8 TEDENSKE ANAEOROBNE TELOVADBE NA BDNF, VEGF, IN NEKATERE FIZIOLOŠKE ZNAČILNOSTI OTROK

Namen te raziskave je bil opazovati spremembe ravni možgansko pridobljenega nevrotrofnega dejavnika (BDNF), vaskularnega endotelijskega rastnega faktorja (VEGF), hitrosti presnove v mirovanju (RMR) in največje porabe kisika (VO2max) pri telovadcih, ki so vadili po anaerobnem načrtu telovadbe. Trideset telovadcev začetnikov, starih od 8 do 12 let, je bilo naključno razporejenih v nadzorno (n = 15) in poskusno (n = 15) skupino. Vadba je potekala 8 tednov, 3-krat na teden. Vsaka vadbena enota je trajala 45 minut: 10 minut ogrevanja, 30 minut osnovne vaje in 5 minut ohlajanja. Izmerjene so bile telesne značilnosti in sestava, rastni dejavniki BDNF in VEGF so bili izmerjeni s PicoKine ™ ELISA, razčlenitev pa z uporabo imunsko-imunskega preskusa po Morlandu. Izmerjeni so bile tudi vrednosti pred in po vadbi VO2max, največji srčni utrip in RMR s pomočjo merilca plinov. Na začetku ni bilo pomembnih razlik med obema skupinama (p> 0,05). Toda po vadbi so opazili pomembno razliko pri vrednostih BDNF (p = 0,02) in VEGF (p = 0,018) med obema skupinama. V poskusni skupini se je vrednost največjega srčnega utripa zmanjšala (p <0,05), VO2max in BDNF pa sta se znatno povečala (p <0,05). Rezultati te študije na koncu kažejo, da anaerobni telovadba poveča raven BDNF in VEGF v slini pri otrocih. Te vrste vaj lahko izboljšajo tudi srčno dihalno pripravljenost otrok.

Ključne besede: otroci, nevrotropni dejavniki, rastni dejavniki.

Lorena Nabanete dos Reis Furtado, Eliana de Toledo, Kizzy Fernandes Antualpa & Michele Viviene Carbinatto

BALETNE PRVINE V RITMIČNIH SESTAVAH: RAZČLENITEV ZADNJIH DVEH PRAVILNIKOV SOJENJA (2013-2016 IN 2017-2020)

Balet je svetovno znan ples in njegove prvine je mogoče videti v izobraževanju in vadbi športnikov iz različnih športov, zlasti tistih, ki veljajo za umetniški šport, kot je ritmika. Tekmovalni sistem ritmike poganjajo pravila za ocenjevanje (CoP), ki se vzpostavi vsaka štiri leta in čeprav se med leti spreminja, v svojem bistvu ostaja očitno pod vplivom plesnih vidikov in baletnih gibanj. Namen te raziskave je bil torej razčleniti baletne prvine v ritmičnih sestavah v olimpijskih obdobjih 2013–2016 in 2017–2020, da bi še bolje razumeli odnos med RG in baletom ter jih primerjali z vidika dveh različnih pravilnikov za ocenjevanje. To je bila količinska raziskava, ki je razčlenila 24 ritmičnih sestav, izvedenih na svetovnem prvenstvu v RG (2013 in 2019), zabeleženih in objavljenih na enem od uradnih spletnih mest Mednarodne telovadne zveze. Rezultati kažejo, da med leti ni bilo bistvene razlike (p ≥ 0,05), vendar je bilo povprečje gibanja baletnih prvin v štirih disciplinah leta 2013 višje od leta 2019; in čeprav razlika ni bila pomembna, se je pokazala majhna razliko pri žogi (0,68) in kiji (0,29) in zmerno za obroč (0,97) in trak (0,74); ter povečali se je število baletnih prvin, ki so se izvajali med težavnostjo z orodjem (AD) in dinamičnimi prvinami vrtenja (R); tiste, ki se izvajajo kot povezovalne prvine, se je število znižalo.

Ključne besede: ritmika, koreografija, vadba, balet.

Anna Prikhodko, Olha Kolomiitseva & Vira Prykhodko

SOKOLSTVO V UKRAJINI V ČASU RUSKEGA CESARSTVA: OD USTANOVITVE DO PROPADA

Namen te raziskave je izboljšati vpogled v zgodovino Sokolstva (sokolskega gibanja) v Ukrajini znotraj teritorialnih meja Ruskega cesarstva in različne razloge za njegov nastanek in propad. Slovanski izvor Sokolstva, dejavnost zagovornikov sokolske telovadbe (SG) pri razširjanju sokolske ideje in postopno zbliževanje zagovornikov dveh nasprotnih področij reforme Rusije za nadaljnji razvoj (»slavoljubi« in »zahodnjaki«) so prispevali do pojava in hitrega razvoja gibanja Sokola v ukrajinskih regijah Rusije. V 90-letih 19. stoletja so SG začeli gojiti v sokolskih enotah telovadnih društev, saj so se leta 1907 začele odpirati samostojna društva. Do 1. svetovne vojne so bila društva Sokol (SGS) v Ukrajini največja skupina telovadnih društev. SGS je nenehno izučeval inštruktorje, vendar je bila večina učiteljev SG tujcev, po narodnosti Čehov. SG je bil uradno uveden v vojaško usposabljanje vojske in učne načrte srednjih šol in kadetskega zbora. Sokolski dogodki so bili pomemben del javnega življenja mnogih ukrajinskih mest. Predstavniki ukrajinskih regionalnih društev so postali člani upravnega odbora Zveze ruskega sokola, ustanovljene leta 1910. Kriza Sokolstva se je začela v letih 1. svetovne vojne zaradi naraščanja negativnih stališč do tujcev. V letih sovjetske oblasti so bili pri Sokolu obtoženi meščanske usmeritve, priznani kot "leglo kontrarevolucije" in prepovedani leta 1923.

Ključne besede: Sokol, telovadba, Rusko cesarstvo, Ukrajina.

Pauline Iglesias Vargas & André Mendes Capraro

ZNAČILNOSTI RAZISKOVALNIH ČLANKOV MOŠKE ORODNE TELOVADBE V WOS IN SCOPUS

Cilj te raziskave je bil opisati znanstveno izdelavo člankov o moški orodni telovadbi (MAG) v revijah, indeksiranih v bazah Scopus in Web of Science. V ta namen smo v obeh bazah iskali ključne besede »moška orodna telovadba« z nedoločenim časovnim obdobjem. Po uporabi meril za izključitev je bilo najdenih 52 znanstvenih člankov, razdeljenih med leti 1994 in 2019. Leto z največ doslej objavljenimi objavami je leto 2018, s poudarkom na obdobju med 2014 in 2018. ustvarjalci, ki so največ prispevali, so bili Maurice Yeadon in Michael Hiley (oba z britanskih univerz), Marco Bortoleto (iz Brazilije) in Ivan Čuk (iz Slovenije). V reviji Science of Gymnastics Journal (21%) prevladujejo z moško orodno telovadbo povezani članki, sledi Journal of Biomechanics (7%). Članki obravnavajo biomehaniko telovadbe (34%), pravila telovadbe in njegovo ocenjevanje (19%), družbene, zgodovinske in politične vidike telovadbe (14%), telesne značilnosti telovadcev (10%), zdravje (10%), vidiki vadbe (8%) in na koncu analize starosti telovadcev skozi leta (6%).

Ključne besede: znanstveni članki, bibliometrija, splet.

International Socio-Cultural research group on Women's Artistic Gymnastics
ISCWAG

The future of women's artistic gymnastics: Eight actions to protect gymnasts from abuse

The past weeks have deeply shaken the Olympic sport of women's artistic gymnastics (WAG). Using #gymnastalliance, dozens of current and former gymnasts from several countries have taken to social media to speak out about the emotional/psychological, physical and sexual abuse they have experienced, including body-shaming, bullying and intimidation; racism; dietary control and restriction; overtraining and forced training and competing while injured; medical neglect; and sexual harassment and rape. The statements also demonstrate that the abusive treatment by coaches, officials and WAG organisations was actively covered up in an attempt to save personal status, public image and public relations.

The culture that the gymnasts have described is due to deep-seated ideas that have shaped and continue to shape WAG. One dominant idea is 'sport as commodity', which based on neo-liberal models of high-performance sport governance, have created a 'win at all cost' mentality. The gymnasts' speaking out has painfully exposed how this model of sport creates abusive treatment and short- and long-term suffering.

A second idea is the 'pixie model of WAG'. This model emerged during the 1970s, when increasingly younger and child-like gymnasts began to dominate competitions. This idea assumes that an immature physique and mind are best suited to learn complex gymnastics skills. Puberty is feared as the physical changes this development causes are assumed to reduce perceived performance prerequisites. The career timeframe of the pixie model idea is thus short and believed to demand early specialisation and intense training during childhood. The abusive coaching, dietary restrictions, and refusal/delay of medical treatment reported in research and by gymnasts are symptoms of the strategies currently believed indispensable to achieve the necessary skill learning in the available timeframe.

A third idea that contributes to WAG constituting an abusive culture is that of 'gender and femininity'. Ideals of femininity are fundamental to WAG (e.g., development of the sport; clothing; apparatus; dance-type performance requirements; glamorous image). These ideals also create unequal adult-gymnast relationships (e.g., coach-gymnast; official-gymnast; doctor- gymnast). Research and the gymnasts' speaking out demonstrate that these relations, in many cases, empower coaches and officials and disempower gymnasts into submissiveness and obedience. The gymnasts' long-term silence demonstrates how many gymnasts are not given a voice. This breaches human/child rights and gymnasts say it can take years to (re)gain their voice once they have retired from the sport.

The exposure of the widespread culture of abuse in WAG has resulted in calls for urgent change. This change must be comprehensive, entailing actions at the ideological, structural, managerial and practical levels. Some of the actions are needed immediately; other actions will require long-term efforts.

This manifesto is signed by 21 international scholars who are members of the International Socio-Cultural research group on Women's Artistic Gymnastics (ISCWAG) and researchers associated with ISCWAG. Together, the scholars have during the past decades extensively researched WAG, always with the aim to describe, explain and improve this sport.

We propose eight actions for the future of WAG, all of which aim to empower gymnasts and decentralise the authoritative position coaches, officials, support staff, and other authorities have in WAG.

1. **Independently investigate abuse allegations.** Independent investigations are crucial to overcome conflicts of interest and build trust with victims/survivors and their families, future athletes, and the public.

   Our vision for the future is that investigations: (1) are contracted out to organisations who adopt a survivor-centred approach to their investigation; (2) engage professionals who victims/survivors can relate to (i.e., gender relations are particularly important in this regard); (3) consult gymnasts about what an investigation should entail and how they want to participate in it; (4) allow gymnasts to bring to the investigation individuals who can support them during the process; (5) adopt a no victimisation and shaming policy; and (6) make the results of investigations publicly available.

2. **Acknowledge wrongdoings.** Acknowledging wrongdoing, regardless of the type of poor practices and/or severity of abuses, and how far back in time they reach, represents an important step in being transparent about the past and the reconciliation it may require. Such acknowledgement is also important for the rebuilding of trust between current/former gymnasts and the organisations that were in charge of taking care of them, and ensuring a sound public image. Finally, acknowledging wrongdoing will support gymnast healing.

   Our vision for the future is that WAG organisations: (1) publicly and individually acknowledge and apologise for the abuse that has been reported; (2) provide victims/survivors with appropriate and sustained support (e.g., funded counselling); and (3) are transparent about the actions being taken to manage the disclosures.

3. **Prioritise athlete rights.** The WAG population consists mostly of girl children, who due their age and gender, are vulnerable to abuse and exploitation. As such, their power and agency over the conditions within which they participate are limited if not diminished.

   Our vision for the future is that WAG organisations: (1) critically reflect on the effectiveness of their athlete welfare policies and practices; (2) consider if minimum ages for participating in high-level competitions could be a means to protect gymnasts; (3) consider how a legally binding contract between gymnasts and WAG-organisations could enhance gymnast rights by mandating organisational roles and responsibilities and support services available to gymnasts; (4) integrate gymnasts in all relevant organisational boards by at least a 30% share; (5) actively encourage and support the creation of independent gymnast associations (e.g., gymnast union); (6) implement a permanent independent auditing system that monitors athlete rights, investigates breaches and is able to reprimand with bans and/or de- affiliation; (7) create national and international authorities who register coaches that havebeen found to abuse gymnasts in any form, which safeguarding leads in sport and non-sport organisations can consult when hiring new coaching/medical/other staff, and can penalize clubs that have hired coaches listed in such registers.

4. **Create effective gymnast welfare.** Health and wellbeing support is in many countries either limited or steered by coaches and WAG organisations. Sustained professional care is paramount for performance and welfare.

   Our vision for the future is that WAG organisations: (1) create independent welfare systems that include professional nutrition and psychology support along with what already exists in terms of medical or sport science support and put mechanisms in place that ensure, on the one hand, gymnast confidentiality, and on the other, effective communication between professionals and coaching staff; (2) provide counselling sessions that support gymnasts during their careers and when going through the retirement process; (3) engage athlete welfare officers whose role it is to be available on a day-to-day basis to care for gymnasts (esp. for those living away from home), and are present at all competitions; (4) appropriately integrate parents/caregivers into the training/coaching/competition process; (5) educate gymnasts on what abusive treatment and coaching is and where such behaviours and practices can be reported; (6) create channels through which gymnasts and parents/caregivers can safely report abuse; (7) implement a permanent independent auditing system that monitors athlete welfare, investigates breaches and is able to reprimand with bans and/or de-affiliation; and (8) put in place a mechanism to continuously reflect over policy, practice, and intended and unintended consequences.

5. **Educate coaches, officials, parents and significant others.** Much of today’s coach education focuses on technical aspects. Education for officials, parents and significant others is missing.

   Our vision for the future is that WAG organisations: (1) strategically use the adult gymnast as a role model to renormalize what gymnastics is, who gymnasts can be and what performances they can execute; (2) extend coach education with curriculum focusing on abusive behaviours and practices, child development, training during childhood and youth, and gender ideals; (3) implement education for officials, members of boards of directors, parents and significant others on what abuse is and how to support and protect gymnasts; (4) collaborate with scientists from both the social and natural sciences to create educational curriculum that is evidence-based and state-of-the-art.

6. **Change the representation of gymnasts in the media.** WAG organisations, the media and social media have generally contributed to mystifying the pixie model of WAG. This mystification has contributed to gymnasts being hyper-feminised

and sexualised, a representation that objectifies rather than affords gymnasts agency over their lives.

Our vision for the future is that WAG organisations, journalists, those active on social media, and fans: (1) carefully consider how their reports, blogs, images and posts sustain the pixie model; (2) focus on representations that demystify the pixie model of WAG (e.g., celebrate gymnast agency; cover older gymnasts; focus on different styles of WAG); and (3) continue to critically report on abuse and organisations' failures to protect gymnasts.

7. **Withdraw sponsorship.** Many WAG organisations receive (significant) sponsorship. As with the media, this funding is implicated in sustaining the pixie model of WAG and the ways WAG organisations run their sport.

   Our vision for the future is that sponsors: (1) critically assess how WAG organisations ensure gymnast welfare and protect against abuse when negotiating current and future sponsorship deals; (2) demand that WAG organisations protect gymnasts should sponsorship be considered; (3) suspend and if need be withdraw sponsorship contracts if WAG organisations are found to employ abusive coaches, breach human/child rights policies, and fail to ensure gymnast welfare.

8. **Conduct responsible WAG research.** Sport science research has in many cases accepted the idea that gymnasts should be children and of thin/immature stature and thus, have contributed to the pixie model of WAG becoming institutionalised globally.

   Our vision for the future is that researchers and research funding agencies: (1) carefully consider the implications of the research they conduct/fund, especially in relation to the pixie model; (2) include criteria that demands athlete welfare beyond that of standard ethical guidelines (both as funders and reviewers); and (3) examine and fund research that actively aims to demystify the pixie and win-at-all-cost model of contemporary WAG, and generates knowledge, methods, and tools that provide WAG organisations with the means to change the sport.

We believe that the eight actions we have outlined above will contribute to protecting gymnasts from abuse, which will facilitate their health and wellbeing, and lives post retirement. We are also certain that the actions will improve gymnast performance. This will provide WAG organisations with potential to enhance the sport's image and public relations and realise the promise of sport for the holistic health and wellbeing of children and youth.

Lastly, while this manifesto addresses the future of WAG, ISCWAG research has also covered men's artistic and rhythmic gymnastics, and other artistic sports, including figure skating and synchronised swimming. Based on the insight gained through this research, as well as recent allegations of abuse in these and other gymnastics sports (e.g., acrobatics; trampolining), we believe that the actions proposed here also inform these sports' futures.

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What Happened to Gymnastics?
Personal Reflections

William A Sands, Ph.D., FACSM

Despite a crushing lack of talent, I was a gymnast. Gymnastics was my love and my identity. I grew up by and through gymnastics learning many life lessons from my coach and other coaches of the “old guard.” Before college, gymnastics books were my only coaches – I was lucky to survive. Gymnastics was as much a part of me as breathing. Sadly, things have changed. During the last decade or so, perhaps longer, the gymnastics world has become a toxic, selfish, mean-spirited, greedy, and grotesque place. Except for a handful of experiences, I walked away from gymnastics after the Athens Games. I would like to offer some ideas for those who, like me, still love gymnastics but have also found modern gymnastics a disquieting enigma of the first order.

Months have passed with a nagging emptiness that I could not articulate. I hope that this document adds to the discourse about modern gymnastics. After observing from a distance, I hope you find some useful ideas and that my timing is right.

Why listen to me? In terms of full disclosure, I have placed a brief description of my background at the end.

Maybe it’s always been this way

The organization and implementation of sports governance is simultaneously a job, hobby, and lifelong mission. Sadly, too many people in high positions have used their positions to corrupt the spirit and body of gymnastics, contorting the sport to serve their selfish agendas with little regard for the trail of pain and suffering left behind (10, 20, 39).

> *"Within the current amateur sports system in this country, the important game for too many people is not producing results on the playing field but accumulating and maintaining power in the boardrooms. Large amounts of time, money, and human energy are devoted to this game. It takes so much energy, in fact, that many who play it have all but forgotten (except at election time) that there is a larger goal. The means (control of the national governing body or the USOC) have become an end. Once that control has been achieved, the important task is that of keeping it. Not making improvements.”* (78), p 279.

In the past, while working at the USOC, I often wandered around the training areas to shift focus and remind me of why my job existed. Those who govern and oversee gymnastics must never forget that there is a person in that leotard, wearing those grips, and trying to make it look easy. The athletes have strengths and weaknesses, but they all come with a dream and at least the commitment to start a journey pursuing something bigger than themselves and lasts longer than they do (16). We should find the journey inherently noble and worthy of our admiration and support.

What I've observed in the horrendous damage from the Nassar horror has been a litany of ass-covering, no admissions of guilt, little concern for what happens to gymnastics in the long-term, and lots of finger-pointing. Paying someone a million dollars to "go away" is obscene beyond measure. (https://www.wsj.com/articles/former-u-s-gymnastics-chief-received-1-million-severance-package-1496403590). The only thing worse than this obscenity is that many people who approved the payoff should have known better.

Why did these people become highly ranked and powerfully placed in gymnastics? It is clear that there is/was virtually no formal foundational education nor oversight and training for those responsible for gymnastics. Merely being a gymnast, the ability to hold a handstand, serving an elected or appointed position, or having coached for a little or long time are no longer enough in the international world of modern gymnastics. I believe the days of walking into any organization with global visibility and assuming the role of policymaker through committee membership with little or no formal training are gone or should be gone. Experience has shown that almost no one does any sort of homework regarding the aspects of which they will make policy decisions – until they are sitting at the meeting table. In gymnastics administration, the bar (no pun intended) is much too low. Experience has also shown that people are often misled by arrogance to think that they know all they need to know about an essential topic by merely being alive and marginally or intimately involved in some aspect of the issue. Rarely do people seem to consider anything beyond the advantages that may accrue for their current athlete(s), themselves, or they blindly follow the most assertive personality in the room. We put together groups of people on boards, executive boards, committees, task forces, staff, and others to manage gymnastics when what we need is informed, studied, and experienced leadership (14, 76, 81, 106, 108, 115, 117).

Leadership is not the same as management, and gymnastics needs leadership now more than ever. Managers are a dime-a-dozen; leaders are astonishingly rare. I tremble to recall every reporter, physician, therapist, parent, or intelligent bystander who called a beam a bar or a vault board a ramp. Being exceptional, highly esteemed, and politically connected in other fields are not enough. We need statesmen and stateswomen for and from gymnastics. We had a few of these people in the past; we need them to emerge again (46, 82, 87, 89, 91, 92).

Sadly, recent experience has shown that the moral compass of gymnastics couldn't get anyone to their front door, much less to the high-altitude position of knowledge and wisdom needed to offer gymnastics a new and better way. It is clear that gymnastics demands resurrection, restructuring, and rebuilding. My greatest fear is that despite this incredible opportunity, born of tragedy, we still won't get it right.

> *"But until I entered the world of amateur sports I had never seen so many people being so casually vicious and destructive over so little, and within something that the rest of society perceives as being positive: the Olympic movement."* (78), p 273.

We must move forward. If one is to "fix" gymnastics, where should we start?

Begin with Why, then How, then What

I believe that all enterprises should begin with the question, "Why?" (109). *Why* do gymnastics? *Why* do you coach gymnastics? *Why* is gymnastics valuable? *Why* do you administer and govern gymnastics? *Why* do you judge gymnastics? *Why* do you study gymnastics?

Unfortunately, those of limited experience and outlook tend to narrow their horizons to "What immediately." *What* solves the small, immediate, and local problems. *What* involves the "stuff" of gymnastics practice, the drills, skills, rules, policies, and other moment-to-moment interactions in the gym. *What* gymnasts do is undoubtedly essential, but this is not where leadership should begin. I would guess that 99% of all discourse and time in gymnastics studying and analyzing *what. What* is the third concept of importance for leadership (109)? The second and middle leadership concept is "How?" (109). More on categories two and three later.

*Why*s may vary for each person, situation, and time. *Why*s may be understood but unspoken. Of course, the gymnast's answers to *why* are usually related to fun, challenge, and fame. Coaches might answer the *why* question with these ideas and a host of others. For example, coaches might coach because they enjoy teaching youngsters (22, 88), to make a living (97), to become famous (45, 49), to coach a son or daughter (116), and although perhaps somewhat outdated – to beat the Communists (12, 13, 47). I must confess that growing up during the Cold War raised the importance of beating the Communists for myself and many other coaches from the "old guard." (10, 13, 20, 31, 47, 112). The dreaded Eastern Bloc was a formidable group because they had many excellent athletes, <u>and</u> they cheated (2, 6, 21, 27, 32, 39-42, 48, 62, 70, 73, 75, 83, 112). Communist-style cheating may be upon us again, or perhaps the cheating never stopped (59, 75).

In 1995 I wrote an article *What's Wrong With Women's Gymnastics?* (91). The article seems rather prescient even today. I tried to paint a more accurate picture of women's gymnastics at that time as a response to complaints about media coverage. The folklore of the time considered the media too negative. People forgot that the media's job is/was to report, not promote. The article included a question, "Is gymnastics a veiled form of child abuse?" (91), p 29. At that time, the issue arose from the tragic death of Christy Henrich, resulting from complications caused by an eating disorder. Sadly, this tragedy led to a blizzard of accusations directed at gymnastics coaches in a fearsome example of schadenfreude (43, 65, 74, 118). Some policy changes from these incidents were implemented and are still in effect today. As I reread the article, I remain in agreement with its tenets and believe that gymnastics' self-correction is not only possible but often happens quickly and with little fanfare.

History and generalities aside, *why* should we do gymnastics now? Some years ago, I wrote another article titled *Why Gymnastics* (92). Although the data forming the basis of the report are now out of date, the premises remain sound. Gymnastics builds youngsters and young adults who are highly fit, smart, and confident. Although the qualities listed above are still acquired by and through gymnastics, the rules and governance of gymnastics have created a disquieting cultural shift. Gymnastics has shifted from building champions through tough love to out of proportion emphasis on being “Code smart.” One of my reasons for leaving gymnastics was that I found modern performances ugly and too often scary (67). Difficult skills and the engineering of such skills are admirable, but women gymnasts used to dance on floor exercise and balance beam. Dance teachers/coaches were integral to the overall gymnastics experience and choreography. Floor exercise should not look like tumble, stand and turn, repeat, pant heavily, and then tumble again while the music plays along. Gymnasts are so busy “getting in their difficulty” the performances have lost much of their elegance. Walking heel-toe through the non-tumbling elements appears to be acceptable. Gymnasts, particularly lower level athletes, spend so much time getting “credit” for Code-listed elements that they can hardly move. Governance has not only put the cart before the horse, it appears that someone thinks the cart can pull itself.

Gymnastics should be predominantly a measure of skill, not guts. The rule that gymnasts must “stick” all landings has almost destroyed the flow of floor exercise and presents an increased risk of injury (60, 61, 68, 69, 71, 95, 96, 99, 110). Who decided that sticking was “all important?” One of my favorite floor exercise routines was performed by Franco Menichelli in 1964 (https://www.youtube.com/watch?v=a8CyIJSgUbU) and Maria Filatova in 1979 (https://www.bing.com/videos/search?q=maria+filatova+floor+exercise+fort+worth+1979&&view=detail&mid=A6EA0CBC67D00D078797A6EA0CBC67D00D078797&rvsmid=3BE021320DAE5EFCF2003BE021320DAE5EFCF200&FORM=VDQVAP). They showed how floor exercise could be elegant and exciting with movements that only stopped to emphasize a “hold” part. If, after viewing these routines, your first thought is how easy the skills were, you’re missing my point. The modern rules and lack of a choreographic sense beyond bump-and-grind silliness have trampled elegance and creativity, leaving only “shock value.”

We did gymnastics because it was fun. We did gymnastics because the sport and activity provided enormous challenges with rewards achieved only after years of hard work. Gymnastics training taught the difference between a purchase and an investment. The gymnast knows that all of the training and performance problems will not be fixed like they are in a 30-minute sitcom. I believe that gymnastics tends to make young people “tougher,” more athletically and intellectually agile. Gymnastics training fulfills the dictum of a “sound mind in a sound body” (*mens sana in corpore sano*, Juvenal 55-138ce). Gymnastics coaches, I hope, teach gymnastics to help young people with the life lessons provided in microcosm via sport. Coaches will bring undeniable adult concerns with them to coaching. Coaches will be prideful in their coaching abilities; sometimes, their pride will overrule good judgment. Coaches require oversight and feedback. Coaches will seek fame among other coaches and the limited exposures of the media. Gymnastics coaches could be described as the *Invisibles* (121), or at least the *seldom-visibles*. Coaches, like the gymnasts who preceded them years ago, labor in relative anonymity except for a few members of the Olympic teams and collegiate coaches more recently. However, like the invisibles of Zweig (121), these coaches and their athletes are usually well known and admired among their peers and have established reputations across a variety of geographic areas and coaching levels.

We do gymnastics to win. I am not troubled by admitting that winning is important. Moreover, I hold a visceral objection to the incorporation of participant ribbons, the tenets of self-esteem, and other cons directed at making people comfortable with mediocre performance (7, 19). As a sport scientist, I have repeatedly described the mission of sports science as the application of science in sport to win – *within the rules*. The very nature of competition supports the concept of comparison and determining who and what are best. Establishing worth is inherent in sport and life. Rules are established so that participation is not a free-for-all. Gymnasts are guided by coaches to display their work in competition and be judged, we hope, by impartial evaluators. Unfortunately, athletes, parents, and the general public have trouble with strict adherence to merit, rigor, and honesty when it might hurt someone's feelings. Competition, especially failure, is a powerful method for building young people's resolve.

It is time again for gymnastics to revisit *why*. I can only recommend that despite what most will think obvious, the question is meant to be bigger than personal agendas. *Why* have coaches engaged in sexual abuse? *Why* do judges cheat? *Why* do we use the Code of Points (a rule book) as a coaching text? *Why* are athletes injured, especially the best? *Why* has the TOPs program morphed from a talent identification program to a competitive program for which athletes train for the tests – doesn't that defeat the purpose? *Why* do gymnasts and coaches use the warm-up period as a meet before the meet? Are they trying to win the warm-ups? *Why* would anyone think that NCAA recruiting a youngster in middle school is appropriate? *Why* does gymnastics have so many levels? Do we really need ten levels of Junior Olympic athletes, juniors, seniors, TOPs, Hopes, Excel, and so forth? Are the fundamental skills different from level-to-level, or are there merely different compulsories? Is the hair-splitting of levels necessary for gymnastics or a convenient way to classify athletes to make more money? Should gymnasts be instructed via movement families such as rolling, jumping, landing, swinging, cartwheeling, somersaulting, twisting, and so forth rather than simply learn a compulsory exercise? Gymnastics is much more than a compulsory.

Asking and answering *Why* is vital for beginning the process of building anything. I hope the new decision-makers are exceptional. There seems to be little or no discussion of important topics without a cloud of spin using bromides such as "transparency," "empowerment," "safety," "protection," "morality," and many other terms that do little but obfuscate and provide a warm fuzzy feeling. While there seems to be an abundance of rhetoric, the terms are seldom defined, and worse, there are no apparent plans for selection, implementation, and evaluation of these ideas. Ideas are great but utterly sterile without a means for debate, definition, and discovery along with implementation and evaluation. Within the current chaos, is everything just a counterpunch or are long-term strategies involved. These issues will not be resolved in the office; one person simply cannot know enough. Moreover, there should be regular and systematic discussions and debates from all of those involved.

Let's now turn to the pivotal component for gymnastics once the *why*-question is answered and understood.

How – the Chicken or Egg Question.

Example 1. Rebuilding a sport is not easy. Australia faced similar issues after their embarrassing performance during the 1976 Games in Montreal when Australia didn't win a single medal (9, 104). The Australians seized an opportunity, the result of a tragedy, to take Australia to the highest levels of elite sport via government intervention and funding, creation of excellent national and regional training centers, development of an education and research system that is the envy of the world, and allowed experts to engage their skills in building better athletes (9, 104). The Australians appeared to answer the *why* question by seeking to raise Australia to the highest levels of a respected sporting nation, and they answered the *how* question with targeted spending on everything from coach education, magnificent facilities, well-paid staff, and world-leading expertise and research. Of course, government funding can take sport and athlete preparation to new heights almost overnight. Until the U.S. embraces the reality that athlete development cannot go very far on family-based tuition payments, second and third mortgages, and bake sales. The hand-to-mouth existence of gymnastics will be subjected to pressures from within and without that can derail the best intentions.

> As an aside, those government officials who are concerned with protecting athletes should consider that when coaches are treated like second-class citizens (i.e., little education, unlivable wages, and little or no serious continuing education) and gymnastics schools live hand to mouth – the only coaches that programs can afford are cheap. Perhaps more professional treatment of coaches will result in more ethical and professional behavior. After all, what you pay for is what you get.

There are numerous aspects of the Australian experience and programs that could be used within U.S. gymnastics programs (5, 9, 17, 28, 34, 36, 37, 44, 66, 77, 79, 104, 111, 113, 114). Unfortunately, the Australian model and the Australian Institute of Sport are currently being gutted from within (24). The current dominance of U.S. Women's Gymnastics speaks more to a vast talent pool, huge school sport systems, collegiate scholarships, individual dogged determination, and extraordinary imagination. One might well consider that many of the most recent national teams for women are primarily coached by foreign-born coaches who have trained abroad.

Example 2. Following World War II, Germany was devastated. The country had lost millions of people, infrastructure was in tatters, many of their best and brightest had fled, and most of the country lay shattered by the war. Sport was considered an essential avenue for rebuilding Germany and the morale of Germans. But where to begin (31, 52, 85, 107)?

> *"No country in the world can progress far toward the creation of a top-flight competitive sports system without confronting immediate "chicken and egg" decisions. What comes first, the athletes, the facilities, or the coaches? The profit or long-term investment? The government or the private sector? Many countries in the world have tried to fit these pieces together with a variety of results."* (31), p 56.

> … *"They answered their chicken-and-egg dilemma back in October 1950. The answer was to opt for coaching: trained, professional coaching. Coaches who would go out and find the athletes while getting along with makeshift facilities and equipment until better facilities and equipment could be developed."* (31), p 58. [Emphasis mine]

The GDR elevated coaching to a science and built a system of education that, at the time, was second to none. Of course, enlisting such country-wide engagement of coaching and education was more accessible in a police-state. The drug issues still haunt our understanding of the former GDR (29, 47, 84), but the GDR did a lot more than drugs, and their organization, rigor, and system can provide important lessons.

> *"The elevation of coaching to the level of a science has been an alien idea in America, something that goes against the grain of every suburban volunteer who ever donned a cap and a whistle and set out to impart his self-acquired wisdom to generations of Little Leaguers. It's hard for us to imagine people spending four years in a university, let alone three more in a Ph.D. program, with all their efforts directed toward an education in coaching."* (31), p 58.

Let's take a few lines and investigate what the education of coaches in the former GDR involved. Keep in mind that the information in Table 1 came from coach education practices from at least 40 years ago.

Table 1. Coach education curriculum from the former GDR.

	Typical Curriculum At Leipzig Institute										
					Semester						
	Study Complexes	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**Total**	
					Lessons Per Week						
1	**Fundamentals of Marxism and Leninism**	2	3	4	4	3	3	2	4	300	
2	**Introduction to Logics**	3								66	
3	**Sports Pedagogy**	2	2	2			3	5		104	
4	**Sports Psychology**	4	4					2		120	
5	**Theory & History of Physical Culture**					3				57	
6	**Sports Policy**						2			34	
7	**Leadership in Socialist Physical Culture**						3	3	6	82	
8	**Mathematical and Cybernetical Fundamentals**										
9	**Fundamentals of Natural Science**	6	3	3						222	
10	**Sports Medicine**	1				3	3	2		130	
11	**Biomechanics**				3			2		48	
12	**Theory & Methodology of Training**										
	Specific Sports										
	Basic Training	13	15	9	16	7	6	2		1032	Men
										936	Women
	Special Training	2	2	2	2	4	6	8		270	
13	**General Theory and Methodology of Training**			4	4	3			10	181	
14	**Practicals**			6	6	6	6	6		324	
15	**Training**	5	5	5	5	5	5	5		585	
16	**Foreign Languages**										
	Russian	2	2	1						85	
	2nd Foreign Language				2	2	1			88	
	Introduction in Speaking (pronunciation)	1								22	
	From: Gilbert D. The Miracle Machine. New York, NY: Coward, McCann & Geoghegan, Inc., 1980., page 64.										

Does the curriculum in Table 1 describe the education of only elite coaches – no. Table 1 describes the extent of schooling required for someone majoring in coaching. It should be clear by contrast with how Americans become coaches that the level of professionalism in the U.S. merits some rethinking. If we want our coaches to behave with the utmost professionalism, we need to train, monitor and evaluate them as professionals. Below is a description of the education of volunteer coaches from the former GDR.

Volunteer Coaches

"The certification class I dropped in on in Berlin was the fifth session in a series for prospective Level I swim coaches, and the class included a construction worker, an engineer, several young gym teachers, a musician, an electrical mechanic, and a plumber. The teaching appeared to be excellent.

After completing ten sessions of study and lectures, these would-be coaches would have to pass a written exam before qualifying for their caps and whistles, and even then, they could only work as assistant coaches at the youth level, perhaps the equivalent of Little League baseball in the United States.

After one year of these duties, they would become eligible for the second stage, which involves a forty-hour course taught at a university. It is usually done all in one week, including five eight-hour sessions with another exam at the end. All of the applicant's expenses, including room and board, are picked up by the DTSB. What's more, the time taken for the course must be honored by the employer and cannot be charged off as vacation time. By reaching Level II, the volunteer can be head coach at the Little League level, and then after another year or two has passed he can again move up the line and take a much more advanced forty-hour course leading to the Level III diploma.

With a Level III permit the volunteer coach becomes eligible for postgraduate courses at the university level to allow him or her to keep up with all the latest developments in the science of coaching. Level III coaches work closely with the professional graduates of the Leipzig Institute when it comes to administering the entire sports program. Statistics show that 55.1 percent of all GDR volunteer coaches hold Level I certification, 26.3 percent have reached Level II, and 17.8 percent have reached Level III.

As a result, anyone who goes out for sport at any level is guaranteed to receive instruction from people who have some idea of what they are supposed to be doing. And the volunteers, for their part, have some idea of what to look for in the way of promising youngsters to move along for further testing at the high-performance sports centers." (31), p 51-52.

Keep in mind that this was published in 1980, approximately 38 years ago, at the time of this writing. Of course, coach education in the U.S. has received more attention since then. However, coaching has still not risen to the level of a profession.

The most common answer to every "people problem" we face is "education." Other countries have demonstrated that education can be the foundation and life-blood of sport. However, coach education in the U.S. is poor (31, 55-58, 72, 105). Moreover, describing any problem as a greater need for *education* does nothing actually to solve a problem. Everyone agrees that knowledge is essential, but merely deflecting the problem toward *education* is a smokescreen for doing nothing. Such approaches only give administrators the ability to say they 'checked the box.'

Coaching effectiveness has been a slippery concept, much like school teacher evaluation (18, 25, 30, 35, 86, 119), and suffers from many of the same issues (1, 11, 33, 38, 54-57, 64, 105). Education of whom, about what, what type of curriculum, by whom, and perhaps most important – who gets to decide? The school-based model of lectures, clinics, online videos, and so forth can help, but coach education needs a different and additional approach. I suggest that we look at medical and military models of constant and systematic supervision by *experts* and *confirmed leaders* in the field. Perhaps we could use more *on the job training* with "grand rounds," "fitness reports," and systematically written assessments of the candidates, including pointed feedback. Promotion and graduation are based on the judgment of smart people who know the candidate and the job exceptionally well. If it is true that we face an athlete abuse problem exacerbated by secrecy, then using a much more thorough mentoring approach such as found in military and medical education should expose unbalanced coaches and their hiding places before they can do damage.

Knowledge and knowledge tests are necessary (i.e., the "know that"), the coach also requires expertise in the one-word concept – "know-how" (3, 15, 23, 120). Coach education programs tend to concentrate on "know that" because it's easier to discuss and evaluate. However, the coaching *know-how* that most coaches, especially young coaches, need is sorely neglected. Again, I wrote about the stages of teaching that a coach goes through (88, 90, 94), and we know that athletes and high-performance learners tend to rise through a hierarchy of stages (4, 8, 88). Unfortunately, there is vanishingly little sensitivity to these stages in the information that is provided for coach education in the U.S. Instead, educational experiences for coaches are too often offered by people with little specialized knowledge and training, little long-term experience in coaching at a variety of levels, little specific experience with coaching issues that affect long-term athlete development, and too often with a product or service to sell.

Given that there is no national coach education, numerous self-appointed experts have risen to fill the void. Sadly, this approach merely continues mediocrity and knowledge redundancy. In addition to coach education, secrecy can no longer be tolerated. The strong mentorship approach described above helps ensure that *know-how* is communicated along with moral and ethical experiences because the mentor and mentee must navigate real coaching issues together.

The recent issues of abuse in gymnastics should bring coaching licensure to the forefront as a necessary step to increase the competency and oversight of coaches. *Why* hasn't coach licensure been invoked? Interestingly, one needs a license to cut hair, but a coach only needs to rent a building and hang up a sign to teach gymnastics. Who will have the most significant potential influence on a youngster's life? Licensure, increased depth and breadth of education, close contact with multiple mentors, and constant evaluation and feedback, in my view, are perhaps the only means of maintaining oversight of gymnastics coaches. Everything about gymnastics will need to be exposed to the light of inquiry and evaluation.

> *"Our amateur sports system is an insular world. Americans know far more about how a high school football player becomes a professional in the NFL than they do about how an amateur athlete earns a spot on the U.S. Olympic team. Many within the system would prefer to keep it that way. Over time, this insularity has resulted in a system that is accountable to virtually no one."* (78), p 273-274.

How should be answered with coaches first and foremost. Coaches need to be better, and the training of those in governance should enlist modern methods for professional preparation. Tighter mentorship, much higher regard for coaching knowledge, and abilities via rigorous schooling and continuing education with systematic, regular evaluations should have always been involved in gymnastics. Unfortunately, a crisis was required to point out that gymnastics coaching needs a complete overhaul. Gymnastics is not alone in the need for rebuilding; however, gymnastics is unusual in that the athletes are relatively young and less likely to act independently (i.e., speak out). **Should it be necessary to "empower" athletes to speak out when the problem could have been handled long before the coach was on the floor? Who are the adults in gymnastics? How can we defer to a young athlete's personal nerve to speak out when there are adults involved that should have stopped or redirected the unbalanced coach? While I see such empowerment of children as necessary, it strikes me as cowardly. Again, where are the adults?**

When coaches are highly trained professionals, knowledgeable in all aspects and levels of athlete training, and systematically assessed – *just like other professions* – then I believe the likelihood of coaches abusing athletes will decrease precipitously. The bad coaches won't graduate, and those that do will not be able to hide. Short of such changes, business, as usual, can no longer be tolerated.

What?

Gymnastics is one of the richest of all sports in terms of *what* everyone has to learn. Women have four competitive events and other related activities that require learning hundreds of skills and techniques. Men have six events with a commensurate increase in possible elements. Trampoline, tumbling, foam pits, and various types of conditioning exercises all require special skills and abilities. Coaches learn different teaching progressions and protocols for all of these skills. Many books have been written over decades describing gymnastics skills, how they're taught, how they're spotted, and teaching tips to enhance learning – the *what*.

Judges learn increasingly complex rules that must be applied within a couple of minutes following a competitive exercise. The large number of competitive levels and the different rules used for Junior Olympic athletes, collegiate athletes, and international elite athletes are mind-boggling. Unfortunately, one skill performed at one level may be evaluated differently at another level. Moreover, what sports commonly change their rules fundamentally every few years? Basketball would have to change the height of the rim, dimensions of the court, the value of a jump shot, and what constitutes a foul to compare with the rules changes commonly invoked in gymnastics.

At the *what* level questions, few sports match the complexity of gymnastics. Understanding a cartwheel is vital for a gymnastics coach. The coach should have a mental model of how a cartwheel is performed. The coach's mental performance model is used to determine the level of correspondence the athlete's motions demonstrate when compared to the model. When the athlete's movements deviate from the model, then the coach recognizes whether the deviations are serious enough to warrant changes in teaching language, progression, motion emphases, perceptual focus, age appropriateness, and many others (90). A coach must be highly trained and experienced in the development of motion performance models and how to fashion the "rough-cut" of a gymnast's motions to gradually sculpt these motions into a final performance of science and art.

"What questions" evolve in gymnastics. Skill difficulty is particularly subject to escalation. Difficulty escalation is easily observed by simply watching historical movies and videos of gymnastics (see above). Earlier gymnastics performances can even seem comical when viewed through a modern lens. However, there are many things current gymnasts could gain from watching performances from the past. We are often caught with the impression that gymnastics cannot progress any further, but it always does.

Gymnastics leadership, along with day-to-day coaches at all levels, need to know how progressions work, have the clairvoyance to know which skills and techniques will stand the test of time, and a crystal ball (or skilled performance "scouts") to predict the future and how performance will change and progress. Leadership should systematically visit gyms to observe training, not just competitions. Experience has shown that losing one's perspective on *what* gymnasts do is a dangerous step toward forgetting about the *how* and the *why*.

<u>The complexity of gymnastics demands that governance study and understand the depth and breadth of the issues that arise and will continue to blindside gymnastics.</u> The early Yurchenko vault (26, 50, 51, 53, 63, 80, 93, 101), new vaulting horse (100, 102), roles of stretching (103), and springier apparatus come to mind and can serve as helpful examples (60, 95, 96, 98, 99).

Closing

Coaches, administrators, leaders, athletes, judges, and other interested parties should commit themselves to reevaluate everything about gymnastics. The preceding was an attempt to provide a conceptual scaffolding, template, or model to begin.

Rules can govern your journey. You cannot break the law, defy physics, or put anyone intentionally at undue risk. You cannot use unapproved performance enhancers, you cannot steal, and you cannot deceive or otherwise defraud anyone to make your journey easier. Quick fixes are often seductive but rarely hold up over the long-term. You must acknowledge that the journey will not always be pleasant and that you will suffer from small and large threats and injuries along the way. Make no mistake; you will suffer. Acknowledge the suffering upfront and pledge your commitment to handle the suffering without wavering.

How will you determine your direction of travel after the initial first steps? Your model serves as a continuous reminder of where you want to go. These navigation aids will provide a powerful guide. The guide will help determine *how* to find the best route. Unfortunately, anyone undertaking such an important journey will encounter unexpected threats and barriers. You should use your knowledge and experience to shift seamlessly from *why*, to *how*, to *what*, and back.

Your journey will be punctuated by numerous spur-of-the-moment decisions that are based on what you see in front of your face. However, "*what*" decisions should always be made against the background of *why* and *how*.

I sincerely hope that the new gymnastics leadership is up to the task.

My Background

I was born, raised, and educated in Wisconsin, U.S.A. My involvement in gymnastics spans more than 50 years. I was a gymnast at the University of Wisconsin – Oshkosh. UWO was an NAIA school. We won an NAIA national championship; I was honored with All-American status and the American Athletic Inc. Gymnast of the Year. I served as a coach for about a half-dozen Olympians and World Championship Team members. I owned a gym in a northern Chicago suburb and produced numerous state, regional, and national champions. I coached internationally for the U.S. and served as the assistant coach for the 1979 World Championships.

I went to the University of Utah to attend graduate school in exercise physiology and served as an assistant coach to the University of Utah (many time NCAA National Champions). After my masters and doctorate, I went on to a professorship at Utah, tenure, and adjunct appointments in bioengineering and physical therapy.

Later, my career led me to serve as the Senior Physiologist at the Lake Placid Olympic Training Center, followed by Head of Biomechanics and Engineering and Director of the newly formed Recovery Center at the Colorado Springs Olympic Training Center. More recently, I was director of the Monfort Family Human Performance Laboratory at Colorado Mesa University, Director of Education for the National Strength and Conditioning Association, and professor in Exercise and Sport Science at East Tennessee State University. During my coaching career and after, I served as an officer and chair of the U.S. Elite Coaches Association for Women's Gymnastics (USECA) for over 30 years. I currently serve as a sport scientist at the U.S. Ski and Snowboard Association in Park City, UT.

Writing is one of my passions leading to authoring or co-authoring 13 books, 50 book chapters, over 100 peer-reviewed academic journal articles, and over 250 gymnastics and coaching articles. I've given 95 international presentations and over 200 national presentations.

My wife Linda and I live in Salt Lake City, Utah. Our daughter Hailey is a mental health counselor in Durango, CO.

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