SCIENCE OF GYMNASTICS JOURNAL

vol. 5, num. 3, year 2013

Published by Department of Gymnastics, Faculty of Sport, University of Ljubljana ISSN 1855-7171

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.

Science of Gymnastics Journal is indexed in
EBSCOhost SPORTDiscus, SCOPUS, COBISS (IZUM), SIRC (Canada), OPEN. J-GATE, GET CITED, ELECTRONIC JOURNALS INDEX, SCIRUS, NEW JOUR, GOOGLE SCHOLAR, PRO QUEST and INDEX COPERNICUS.
ScGYM® (ISSN 1855-7171) is an international online journal published three times a year (February, June, October).

Front page design: Sandi Radovan, Slovenia.

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Science of Gymnastics Journal is supported by Foundation for financing sport organisations in Slovenia, Slovenian Book Agency and International Gymnastics Federation.

Fundacija za šport

JAK

F.I.G.

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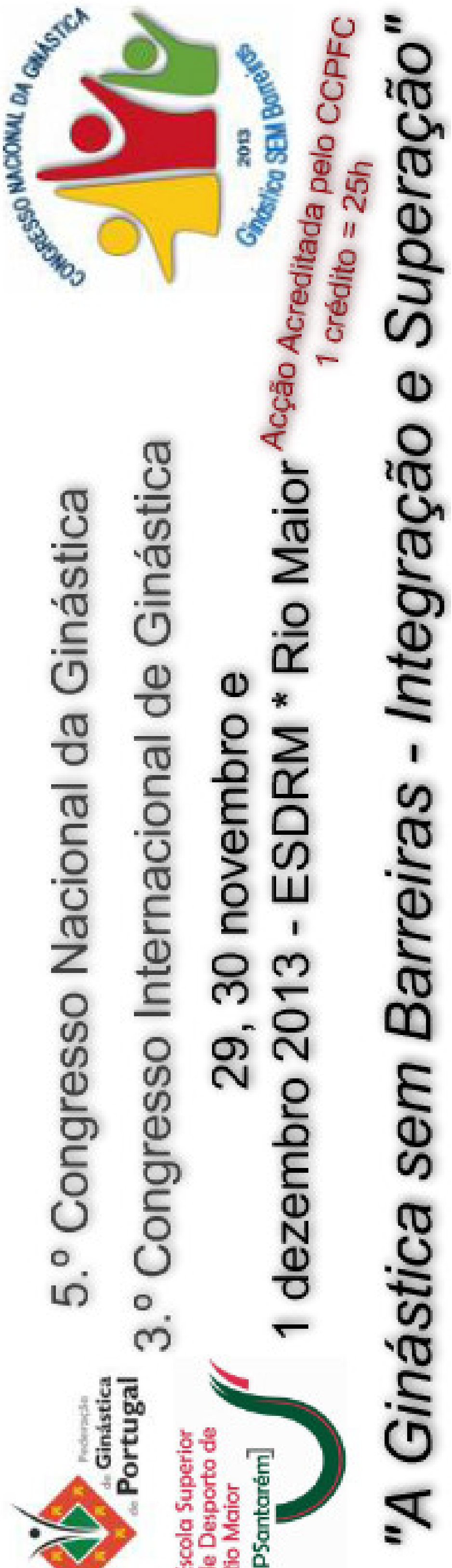

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EDITORIAL

Dear friends,

On October 1st 1863 the first Slovene gymnastics club was established. Our historian Tomaž Pavlin prepared an overview of how Sokol and gymnastics movement developed in Slovenia. I wish we could share historical overviews of all FIG member nations. Up till now, we have published a brief history of the USA, Czech and Slovak gymnastics and I hope that in future there will be more.

It was not only Slovenia that celebrated an important anniversary. FIG celebrated 110 years since the first World Championship (at the time called "International Competition") was organized by the European Gymnastics Union. Another historical moment was when Kohei Uchimura from Japan took the fourth all around title in a row.

For the last issue in 2013 our fellow researchers prepared six articles which brings us to a total of 20 articles for this year. We too are celebrating an anniversary: this is the fifth year of our existence. How time flies! Journal evaluation for Thomson Reuters Impact Factor has been postponed to the beginning of 2015.

Following the first article about the history of gymnastics in Slovenia, the second article comes from Russia. We are glad that Russian gymnastics scientists and experts are sharing their huge knowledge with us. Olga Rumba is sharing her knowledge on rhythmic gymnastics and gives us practical information about the esthetic part of foot work which could apply to all gymnastics sports (including men's artistic gymnastics).

The team from USA and UK under William Sands' leadership prepared an interesting case study on kinematic and kinetic tumbling take-off comparisons of a spring-floor and an Air FloorTM. It shows how important it is to research and evaluate any new tools or apparatus used in gymnast's technical or conditional preparation and to be aware of its positive and negative influences.

The fourth and the fifth article are very similar in content but very different in approach. Both the Spanish team Benjamin Bango, Manuel Silliero-Quintana and Ignacio Grande and the Argentinean author Benjamin Gorosito deal with the swallow on rings and they are both trying to help gymnasts to evaluate their readiness for this element.

The last article is by Czech authors Petr Hedbávný, Jana Sklenaříková, Dušan Hupka and Miriam Kalichová. They present a review article about our most common element – handstand. When kids are doing handstand they instinctively correct their position, but for us it is important to recognize and understand the laws of how to maintain the inverted position.

Just to remind you, if you quote the Journal: its abbreviation in the Web of Knowledge is SCI GYMNASTICS J.

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

Ivan Čuk
Editor-in-Chief

»THE DUTY OF A SOKOL IS TO YET AGAIN STEP INTO THE NATIONAL FRONT LINE«

(SOKOL MOVEMENT IN SLOVENIA - 150TH ANNIVERSARY OF JUŽNI SOKOL)

Tomaž Pavlin

Faculty of Sport, University of Ljubljana, Slovenia

Research article

Abstract

In Middle Europe, gymnastics have roots in the 19th century and since are witnessing the social inovation and institutionalisation of physical activity and exercises to modern exercising systems named by antique original gymnastics. Gymnastics (various exercising systems such as Ling's, Jahn's, Nachtegal's and Tyrš's or sokolism) as physical education soon became a significant political, health-eugenic and military instrument in the shaping of national identities and characters in 19 th century. Among middleeuropean Slavs the gymnastic pioneer was Sokol (Falcon) in Prague in 1862 but at the very same year there was also intention to organise gymnastic society in Ljubljana, Slovenia, independently of Prague's events. Because of the contradictions of authorities first Sokol society on the territory of present-day Slovenia was organised in 1863 and became the central Sokol society among Slovenes. In the years before the WW I. Sokol societies spread around Slovenia and united in Union. With the establishing of Yugoslav state after WW I. Slovene Sokols joined with Serbians and Croatians into Yugoslav Sokol. In the paper we descript Sokols story by focusing on some cruical moments in Sokols history.

Keywords: *Sokol movement, gymnastics, history.*

INTRODUCTION

In Middle Europe, gymnastics have roots in the 19th century and since are witnessing the social inovation and institutionalisation of physical activity and exercises to modern exercising systems named by antique original gymnastics. Among Middle European Slavs the gymnastic pioneer was Sokol (Falcon). Sokol movement based on the principles of the French bourgeois revolution and democracy was open to every member of a nation, man and woman, peasant and citizen, capitalist and worker, free and equal in fraternity to whom freedom and national interest were first. It was important to exercise, as by exercise one strengthens, is healthy and makes progress. Thus, the ideal is virtue, individual, ethical and national, and progress, that magic word of modernism, as to progress was in the circumstances of the middle of the 19th century a must because, as Czhech founder of the Sokol Miroslav Tyrš[1] stressed, in the light of the universal natural survival law, a perpetual struggle for existance and survival exists among nations and societies that have in their life and in culture neglected physical and moral values and thus became effeminate, they succumbed. (Pavlin, 2009d; Kaimakamis &, 2011)

Sokol movement among Slovenes

The organizing or establishing of first Slovene gymnastic society is closely related to the political conditions in the Habsburg Empire. At the end of the 1850s of the 19th century, after dispersals in the foreign affairs and military spheres, poor economy state and after a longer period of the hateful Bach absolutism, the emperor Franz Joseph was forced to promise the time-appropriate changes in the legislation and the constitution. Soon followed the fall of the Minister of the Interior Alexander Bach and the adoption of the October Diploma in 1860 and the February Patent in 1861, both bringing back the constitutional life. The establishing of societies in all areas of national activities – from politics, culture and physical culture, to economy, adequately followed in the Slovene region. The societies also represented the practical side of the then Slovene as well as German nationalism. On the territory of present-day Slovenia, two gym societies, the German Turnverein and the Slovene one were established after constitutional changes in Ljubljana, then the capital of inneraustrian land Carniola and a town where the municipal authority in 1860s was taken over by the Slovenes. Ljubljana took over the position of the leading national, politically-cultural centre among Slovenes. The first Slovene gymnastic society Južni Sokol was organised in 1863 but we have to pointed out that the intention for gymnastic society was brought out already in the summer 1862 to organise utraquistic society. Soon contradictions between Slovenes and Germans spread out and Germans decided to organise Turnverein, while Slovenes because of complications of authoritives organise gymnastic society as much as one year later on 1. October 1863 and named it Južni Sokol (South Falcon). About gymnastics in Južni Sokol already at the end of 1863 referred E.H. Costa (s*tarosta* / president). He pointed the gymnastics, translated in slovene language as *telovadba* / body-exercise (telo/body – vadba/exercise). Gymnastics is "the art" and that the actual education is concerning only about "mind and soul" and it neglect "body" so therefore they were witnessing illnesis, which could be dispatched by going back to the nature and by exercising, as we are dualistic, from body and soul, and if one part got ill both would be ill. He also pointed education of youngs and educational effects of gymnastics and national education through sokol's manifestations. He also advocated gymnastics for peasants because it cultivated the peasant's natural or "raw" strength which could increase the peasant's agility, litheness, improve their walk and posture. Likewise he stressed the importance of the development of women's gymnastics which contributed to the feminisation of physical activities (Costa, 1864; Pavlin, 2009a).

Figure 1. *Dr. Henrik Etbin Costa – the first president of Južni Sokol*

Sokol gymnastics as a specific system of exercise for all-round personal exercising was primarily an activity of urban areas but

[1] Czhech Miroslav Tyrš (1832-1884) was one of the founders of Sokol movement and creator of sokol's ideology.

slowly it did start to make its way into the countryside. With organisational and professional consolidation came gym professional manuals and works. The first gym professional publishing in Slovene *Nauk o telovadbi* (Science of gym) was published as early as 1867 (part I.) and 1869 (part II.) and it was inspired by German professional works. While Czhech societies were professionally uniting around Tyrš's system and it did further developing (Gajdoš, 2012a), the professional bases inspired by Tyrš's system in Slovene Sokol societies introduced Viktor Murnik in the last decade of 19th century. V. Murnik was good gymnast and soon became conductor. He was inspired by Czhech's Sokols profession and studied Tyrš's gymnastics bases. For the Sokol professional development, courses for instructors organized by V. Murnik after 1896 were of big importance. Murnik's work for professional renovation of sokolism in Ljubljana coincided with organisation of several new societies within the Slovene lands – starting in the 1880s - and in historiography is that period marked as era of Sokol renaissance and Murnik as Slovene Tyrš. Major characteristics were organisation of courses for instructors, systematically regular exercising and competitions and adequately uniting around profession, that was gym, introducing woman gymnastics and woman sections. With Sokol renaissance and Murnik's theoretical work Sokol movement brought about a new profession and social activity, which was spreading and developing. Growth of Sokol societies in Slovenia and unique professional bases led to the organisation of national association called Slovene Sokol Union in 1905, which in 1907 joined International gymnastic association (FIG). With this act Slovene Sokols joined the FIG's competions. Murnik's systematical works finally reflected at all sokol festival *(zlet*[2]*)* in Prague 1912 where at the game for Slavic champion surprisingly won the first place Slovene Stane Vidmar and on third place was Karel Fux - the pupil finally attained the teacher. Finally we can not neglect the fact, that Tyrš's system was also adopted by Croats (first society 1874) and Serbs, so Tyrš's Sokolism became the basis of gymnastic work among Slavs. (Zaletel, 1933; Pavlin, 2009a; Stepišnik, 1974) Sokol movement spread also in USA as many of Slovenes in the second half and at the end of 19th century migrated there to find better existence. In free time they established Sokol Societies and contributed to progress of USA gymnastics. (Grossfeld, 2010; Kaimakanis, Dallas, Stefanidis, Panagiotis and Papadopoulos, 2011)

Up to 1914 gymnastics gained importance among the Slovene people and it was on the other hand charged with national emotions since it coincided with tendencies of Slovenes towards national emancipation and political demands for the unification of Slovene lands into a politically autonomous unit of Slovenia within the Austro-Hungarian framework. But we must though stress that various societies or associations, whose purposes were either educational or cultural, social or merely sociable or nationally-defensive and not political (but yet mostly bound to various political conceptions), included gymnastics into their activity. Physical activity served the societies as an "instrument" for "achieving the society's purpose". Similarly in line with the catholic politics of "re-catholisation" at the end of the 19th century, the catholic camp decided to introduce a gymnastics at the beginning of September 1905. Anton Korošec, later a recognized cleric and Slovene and Yugoslav politician but then still an arbitrator for society's entertainment events, advised to organize gymnastic sections within the catholic civil organization, which few years later resulted in an independent catholic gymnastics

[2] Zlet/festival; these were massive manifestations, reunions and promotion of Sokol gymnastics or work – mostly group free exercises, they included also gymnastic match. With festivals started Czhech Sokols (Gajdoš, 2012b) in Slovenia was first in 1888, second in 1904 and third would have to be in 1913, but it was abandoned by authorities.

organization Orel (Eagle). (Pavlin, 2006; Pernišek, 1989)

End of WW I.: new state, new Sokol

The end of World War I signified an ultimate national emancipation and independent political organization of the Austro-Hungarian Slavs. 29th October 1918, the State of Slovenes, Croats and Serbs was announced on the ruins of Austria-Hungary and that was a state of Austro-Hungarian South Slavs. Slovene gymnastic organizations – national-liberal Sokol as well as the catholic Orel – and gymnasts enthusiastically welcomed the new state. Sokol immediately asked "Sokol brothers and sisters" and "all the Sokol units and societies" to instantly start the Sokol activities since "the duty of a Sokol is to yet again step into the national front line" (Pavlin, 2005, p. 100). The most significant duty in first month of peace was to secure the political overthrow by membering the National Guard[3]; they appealed to the members that there should be no Sokol who would not join the guard and help maintain law and order. (Pavlin, 2005; Perovšek, 1996)

The next political step was the union of the State of Slovenes, Croats and Serbs and the Kingdom of Serbia into the Kingdom of Serbs, Croats and Slovenes on 1st December 1918, which was in 1929 renamed to the Kingdom of Yugoslavia. In the first decade, the kingdom went through stirring times. The uniting process namely did not suit all the parties as it was regulated by then effective political rule of conduct "one nation – one state", based on the unitary or centralistic Yugoslav national ideology of an unitarian Yugoslav nation and its three tribes – Serbs, Croats and Slovenes. In the western, catholic part of the state (Croatia and Slovenia), political opposition (in Slovenia especially catholic political camp) advocated that the state had to be reorganized on the national autonomy and were therefore in contradiction with the "Unitarians", the advocates of the integral Yugoslav politics and a unified Yugoslav nation. In Slovenia and Croatia, this meant that the leading national parties either identified with the Catholicism and advocated the national autonomy and rights of the Church in secular, cultural and political life, or with the national liberalism supporting the Yugoslav unitarism. The conflict, which was twofold – on one hand on a state level, on the other hand within the nation – transferred to the cultural domain and therefore to the physical culture domain, since gymnastic societies and their logical development in the 19th century and integration in the national revival of the Slavs in the Habsburg empire, were an important bearer of the national emancipation and neoslavic as well southslavic idea. The cultural conflict between unitarians and autonomists was characteristic for the catholic part of the Yugoslav state and more or less the entire public life was tied into it. (Dolenc, 1996; Pavlin, 2009a; Perovšek, 2005a)

With forming the new state essentially influenced the ideological orientation of the civil society. National and liberal Sokols and on the other hand Catholic Orel faced the question of Yugoslav organization. Sokols were the principal advocates of Yugoslav unitarism and centralistic union. Ideas and plans on south Slavic Sokol union date before World War I. Already in 1913 during the planned all sokol festival of the Slovene Sokol in Ljubljana, south Slavic national sokol asociations intended to link up on a democratic basis into a union. With end of WW I., sokols enrapturedly supported the foundation of the Yugoslav state. In the January 1919 issue of Sokol (official gazette of Slovenian Sokol), Slovene Engelbert Gangl, the later Sokol president, otherwise a teacher, poet and writer, stressed in an article titled *"Victory-freedom"* that the formation of the new state also signified the formation of the new, Yugoslav lifestyle, political as well as cultural, which meant a deviation from the

[3] The National Guard had to secure specially the retreatment of soldiers of Austro-Ungarian army from northeast Italy through Ljubljana and Slovenian countries.

traditional austro-german frame. This represented a new challenge for the Sokol movement and at the same time it was the realization of the south Slavic Sokol ideal. The new state brought the end to the struggle for national emancipation, which was replaced by the "enthusiasm" to the new state and to the new Yugoslav Sokol movement. The path to reach the new Slavic national consciousness led through the Yugoslav state – Gangl stressed and equated the state with the birth child of the Sokol movement. So they have to clench a fist and make every effort to defend since "the Sokols are a fighting organization, revolutionaries who want to build new worlds in the living souls. Foundation – brotherhood, links – unity, aim – freedom!" (Gangl, 1919, p. 4) The euphoria upon the birth of a new country was according to Gangl unfortunately accompanied by grief as well since some of the national territories remained in foreign hands (in Italy, Austria and Hungary – note author). But the grief has to be overcome though, for he stressed at the end, we have a state and victims were not in vain.

At the end of January 1919, the Slovene, Croatian and Serbian Sokols met in Zagreb and decided to join together. In the Declaration it was emphasized that the nation of Serbs, Croats and Slovenes represents one nation and that Sokol societies were, are and have to be national societies. It was also stressed that there is only one Slavicism and it is a part of Mankind. The ideals of Mankind are uniform. Slavic Sokol movement and Sokol movement of Serbs, Croats and Slovenes tended, tend and will tend to fulfill those ideal conceptions. And they had in mind the ideals of democracy originating in enlightened humanism and French revolution. So the national Slovene, Croat and Serb Sokol societies, following the political union, joined together into Yugoslav Sokol Union or shorter Yugoslav Sokol on 29th June 1919 in Novi Sad. The principle of conduct was "one nation, one state, one Sokol", which corresponded with the state centralistic order and the state's idea of the unified Yugoslav nation and three tribes – Slovenes, Croats and Serbs. That meant that former national Slovene, Croatian and Serbian union would dissmised themself, while societies had to transform or joined into new Yugoslav one. The later was delicated especially in the regions of Croatia as, for example, former Croatian and Serbian societies in Croatia had to unite into new Yugoslav one. (Pavlin, 2009b) At the founding assembly they also emphasized that Yugoslav state "is the result of their pre-war efforts and activities". In the view of international gymnastic membership the YS continued the Slovenian and Croatian membership in FIG and replaced former Slovene and Croatian Sokol and in 1924 also started to compete at Olympic Games. (Pavlin, 2009b)

The sit of Yugoslav Sokol (YS) was till 1930 in Ljubljana and during the first decade the Slovenes took over the running of organisation and gymnastics since the former Slovene Sokol organisation was the oldest in the Slavic south and professionally well developed. Because of that, the Slovene gymnasts played an important role in consolidation of the YS organisation and in professional identification on the basis of the Tyrš's sokol gymnastics. As a part of Sokol activities, we must also mention the combining of gymnastics with cultural activities. "*Sokolnica"* or Sokol gymnastic hall was also a national and cultural hall (especially in smaller towns) and it had a broad social meaning. Music, drama and puppeteers' groups all functioned within the Sokol society and Sokol events included gymnastics as well as cultural activities. In central and south Yugoslavia "sokolnica" also functioned as an educational centre, especially if the town or country did not have a school. It helped reduce illiteracy (in 1931, 60% of the Yugoslav population were illiterate, mainly the people in south Yugoslavia) and organised practical lectures on modern farming. (Pavlin, 2009a; Stepišnik, 1974)

As we see, YS related activities with the young state and country. On the other hand, as the advocates and bearers of

Yugoslavism, patriotic nationalism and democracy, they have been politically tied in the liberal unitary camp. However, the national YS unity rather quickly weakened, first in Croatia, where a larger group of members gathered around the umbrella society in Zagreb withdrew from the YS association and re-organized Croatian national Sokol societies within the Croatian Sokol Union. They withdrew at the assembly of YS held in Osijek in 1921 after only two years of unity and southslavic "enthusiasm" (Gangl). After their retreatment YS in the 1921 assembly resolution emphasized the unity of YS association and that the unity represents also the evolution into Yugoslovanism, which requires time. They even more explicitly declared as the bearers of Yugoslovanism and their defenders. Their vision, or we could say their utopia, expected – in the spirit of progress, democracy and social equity regardless of one's race, religion or class –the formation of a specific Yugoslav type of culture "as the means for developing a Slavic culture on the pathway to mankind". They recognized the difficult conditions of living in the country after the war so in this hard time they appointed themselves the role of a guide taking the slogan "Who Sokol, that Yugoslav". (Brozovič, 1930, p. 65-66)

The unity and activity YS presented in 1922 on its first all Sokol festival in Ljubljana. The festival was well participated, also numerously by "brothers and sisters Czhechoslovaks". Within the festival it was included International match or (today) World Championship of FIG. Festival was well organised and it was presentation and promotion of YS and new young state as it was written about it also in foreign newspapers. (Spomenica, 1923)

Yugolsav Sokol and school

YS's important concentration in new state was work on education and within it intention to renew and sokolise the physical education on the level of the state. In the question of school physical education YS already at the assembly meeting 1919 laid down a principle called *Sokol and school* emphasizing the fact that the Sokol and school should be connected reciprocally. They stressed the Sokol movement had had a nation-forming task for over 50 years and in the new state, it should therefore penetrate all national schools, secondary moderns, secondary schools and other schools with its spirit and take over physical education in schools. Sokol teachers should also be physical education teachers and vice versa. The Sokol movement should play a leading professional role in resolving issues concerning physical education as well as within the framework of the authority structures from the lowest to the highest ones at ministry or government level. The YS declaration was taken into account since in January 1920, the Yugoslav government ordered that school gym should be carried out in accordance with the Sokol system. YS also took care of the professional basis and their 1921 assembly made an appeal to the Ministry of Education for organizing courses for gym teachers and for employing gym teachers trained according to Sokol principles in all teacher secondary training schools in the country. They also made an appeal to the authorities for special supervisors for physical education. They also proposed that a department of physical education should be established in at least one faculty of arts – in cooperation with the faculty of medicine; lecturers should be established Sokol experts. The Ministry of Health should award grants to young doctors skilled at physical exercises who could specialize as physiologists and develop the physiology of physical education. However, the demands were too radical (also expensive) for new authorities and in practice, the education of staff was based on YS professional courses (in Ljubljana, a one-month training course for Sokol instructors was organized as early as autumn 1919, similarly in Zagreb; it consisted of 10 lessons every day covering theoretical and practical aspects) which were also recognized in schools as appropriate for teaching physical education. At the end of November 1920, YS met with the Czechoslovak Sokol in Ljubljana to establish the Union of Czechoslovak and Yugoslav Sokol (later Slavic Sokol Union). In a solemn declaration, they stressed the tendency towards the creation of a new and complete type of a Slav who would strive to achieve human completeness and the tendency towards closer contacts among Slavs. Both the Yugoslav and the Czechoslovak Sokols aimed to serve the nations on the basis of the principles of liberty, equality and fraternity. One of the central points of Sokol work was a physical rebirth of a nation and education of young generations, that is why both Sokol organizations demanded that the states should pay attention to these issues and they would help them. They also stressed the fact that among the goals of this Association are the commitment to reforming schools and army according to Sokol principles, an obligatory law on physical education of all citizens and the establishment of a college of physical education either in Czechoslovakia or in the Kingdom of Serbs, Croats and Slovenes. Actually, a six-month Sokol school was organized in Prague in the late 1920s where also Yugoslav Sokols were trained. This training, however, was carried out primarily in a civil society manner. On the basis of Sokols' initiatives, the Yugoslav state got involved in solving the problems regarding professionalism in physical education in the late 1920s. In June 1927, it introduced a one-year course in physical education for physical education teachers in secondary schools. At the same time, YS emphasized that physical education teachers and professionals in the field of civil physical education should study for two years either at university or teacher training short-cycle college until a suitable short-cycle college of physical education was established (Pavlin, 2009b; Pavlin, 2010).

By coming into schools and by introducing Sokol gym and national education, Sokols were – in the catholic part of the country[4] – confronted with the traditional educator, i.e., the Catholic Church, and its intention to use the principles of the catholic Orel in this part of education. This led to an eruption of the cultural fight between the Sokol and Orel movements which had a political liberal and catholic background. At the end of January 1921, after the government order that school gym should be carried out in accordance with the Sokol gym, representatives of the catholic Slovene People's Party and priests from the Ljubljana diocese met to discuss resistance to Sokol education. They made a written protest and required that the order to introduce the Sokol movement into schools should be cancelled. Different catholic societies made written protests addressed to the government in Belgrade, Slovene bishop Jeglič initiated action at bishops' conference level and in February 1922, Slovene and Croatian bishops made a personal protest in Belgrade and demanded that controversial decrees should be revoked. They referred to the Austrian school act which was still valid in Slovenia and which determined religious and moral education while the Sokol education was denied this mission. Catholic gatherings were organized by both the catholic party and the Ljubljana diocese to emphasize political action. In the middle of March 1922, sixty-six gatherings took place to protest against educating the youth in the Sokol spirit.[5] (Dolenc, 1996)

The Sokol status and work in the first decade of Yugoslav state was discusses from January 20th to 27th at special conference organised in Ljubljana, the seat of the YS organisation, with an intention to critically assess the Sokol activity in the first decade in organisational, technical, ideological and educational aspects, review causes that have positively or negatively influenced the development of the Sokol work, and to form on its results guidelines for future work. With the "questionnaire" they very selfcritically established that the Sokol movement only partially managed to

[4] Slovenia, Croatia and part of Bosnia and Herzegovina.

[5] Ljubljana Bishop Jeglič thought at that time that the government would give in and would require only gym in accordance with the Sokol system but would refuse Sokol education.

become the central point of national and cultural movement in the country. The idea of Yugoslavinism, i.e. national and state unity, was more or less bound to the Sokol movement only, while beyond it, it developed in the opposite direction. They also established that the politics often impeded the Sokol development. Sokol members who were active in the politics could generally not perform the Sokol activities since their political job was not in accordance with the Sokol principles, specially national. In regard of profession, they ascertained that the knowledge of the trainers was in general insufficient, that they should be central personalities of the Sokol organisations, and that educational work was unsuccessful due to inadequate inner cooperation of the trainers and educational workers and structures. Consequently, a large part of youth was included in other sports and physical-educational organisations as for example in scouts. They also noticed a decrease of female members and deficiency of female skilled cadres. In regard of inclusion of the Sokol movement in state structures, it was stressed that the relation between the army and the Sokol organisations was otherwise friendly and in spirit of support but cooperation depended on individuals, while military education did not or insufficiently include the Sokol system of education. Also unsatisfactory was cooperation between the Sokol organisations and schools, despite the decrees of the ministry of education and inspite the fact that in the process of giving physical education in schools a Slovene as well as a Yugoslav character, the Sokol movement played the most important professional role. On the contrary, in schools they many times met with a negative attitude not only towards the Sokol movement but also to physical education in general. Somewhat better was the situation in the country where the Sokol movement developed but conditioned by specific circumstances in the state. (Pavlin, 2002)

The 6th January Dictatorship and the Foundation of the Sokol of the Kingdom of Yugoslavia (SKY)

Political chaos ruled in the young Yugoslav state in its first decade as for example in less than ten years ten governments followed, and various political coalitions were from the aspect of principles and polarisation incomprehensible. King Alexander tried to annul traumatic circumstances, which paralysed public life, with the so-called 6th January Dictatorship at the beginning of 1929. He abolished parliamentary political regulation and introduced absolutism to, as he among other explained the citizens in his 6th January "manifest", preserve "national and state unity". With the Law on protection of the state, political parties were prohibited and dissolved, while the existence of political or related societies was linked to special administrative permits. (Perovšek, 2005b) The 6th January decree echoed in the Sokol official gazette Sokolski glasnik. In its approval of the King's action they stressed that the King's act itself was not a solution and that the Sokol members were convinced that "only morality and education can save the nation". Political autonomy was as well just a means to actual national life but could easily be lost "if we as a nation cease to live morally". The latter was the task of the Sokol movement, which in such a manner took part in "building up" the Yugoslav state. (Pavlin, 2002, p. 59)

Because of the traditional links between the political and cultural groups and gymnastic organisations, the dictatorship also influenced the field of gymnastics; sport suffered no consequences. Soon after the King's dictatorship destiny of gym organisations appeared on the agenda of the government sessions. King Alexander accepted in March 1929 YS delegation. He was interested in the activity of the YS and in obstacles that were disturbing their work "for the King, nation and homeland". (Žutić, 1991, p. 43) The YS prepared for the occasion a "memorandum" on physical education with schemes of laws on physical education of youth and on a gymnastic military school (the basis was the January 1929 conference in Ljubljana). In the Memorandum, they suggested a model of sharing competences in physical education between the state and the Sokol organisation. It was pointed out that the state should take care of "physical education of its citizens" as it took care for spiritual education, for "as the human soul and body are inseparably bonded, so natural is the demand for performing physical education in parallel with spiritual education, thus physical education belongs in every school" [...] "Because physical education is not concluded with the school period" and is because of that most necessary from 15 years of age on, "the state should leave it for that period to the Sokol organisations". (Spomenica, 1929)

As Slovene newspaper Jutro reported at the end of November 1929, "a plan was being prepared in Belgrade by which physical education in schools and among the nation was to be organized uniformly, in the spirit and by the principles of the Sokol gymnastics, and to bring the Sokol movement in close connection with the action of the state". (Pavlin, 2002, p. 61) The new Sokol movement, spread among all strata of the Yugoslav society, would have a significant role of the educator of the Yugoslav national and state idea. The planners of the scheme intended to "merge it with the state educational policy", for "only that way it will be possible to convey the Sokol and Yugoslavism to the widest national strata and educate the entire nation in the spirit of national and state unity". (Pavlin, 2002, p. 61) At the beginning of December 1929, the law on the foundation of SKY was adopted. At verification, Jutro pointed out that the foundation for the new organisation was the Sokol idea "on development and strengthening physical culture and a uniform Yugoslav spirit". Such Sokol movement would "become under state control a united national first class militia, a strong factor of national future …, the most significant element of national felicity and progress", and it would be spread among lower classes, workers and peasants, who were "the most efficient national elements". Also stressed was the pre-military significance of "physical culture" for the "Sokol members have always been the healthiest material for the army", therefore massive Sokol membership "will facilitate military education with purpose of state defence". The Sokol recruits would be already trained, only military improvements would be needed, the duration of their service could be shortened. Jutro concluded that statutory founding of a state Sokol organisation was an honouring to the actual Sokol movement, and recognition of past work. (Pavlin, 2002, p. 63) President of the YS E. Gangl immediately greeted the law, reminded of the Memorandum on regulating physical education in the state, and said YS movement was "ready to contribute to their abilities in achieving entirely the great and generous goal of physical and moral education of the whole nation". (Pavlin, 2002, p. 64) By the Law the government and the king wanted to protect the Sokol movement but at the same time wanted to have influence and control over the organization. Essential for further activity of the then gymnastic organisations was article 12, which determined that previous "societies for physical and moral education: YS, Croatian Sokol, Orel and the Serb Sokol, if in three days after the beginning of validity of the law, they would not unite or join the SKY…would be abolished". (Zbornik SSKJ, 1939, pp. 9-12)[6]

While the catholic gymnasts refused to join, the YS joined and transformed into the new Sokol given that the new law was drafted according to its interests. The etatisation of Sokolship and Sokolism reflected in the government's control over the new organisation, the principle of the democratic choice of leadership only applied for the base, while the leaders of the Federation were appointed or later (based on the base's proposal) confirmed by the

[6] The Codex (Zbornik) contained laws, decrees, regulations, and instructions on the organisation and activity of the SKJ.

government. In addition to that regular financing of physical education in direction state-Union, municipality-societies were introduced. In 1932 the Ministry for the Nation's Physical Education was set up and it took over the control and financing of physical education. A larger portion of the budget was given to SKY and the other portion was divided among sports, mountaineers, scouts, shooters and firemen. (Pavlin, 2002)

The seat of SKY was transfered to Belgrade, capital of Yugoslavian state, which in the 1929 renamed into Kingdom of Yugoslavia, similar as Sokol organisation. The first or constitutive session of SKY took place at the end of January 1930. The main point on the agenda was constitution of the SKY and adoption of the statute, which was proposed to the government for ratification. The agenda also contained the question of membership in international organisations, in the FIG and in the Slavic Sokol Union. The entente ally Czechoslovakia was attentively watching over the destiny of the YS. Immediately after the adoption of the Law of SKY, the Czechoslovak Sokol union asked the Yugoslav ambassador in Prague for exhaustive information upon which they could be sure "that in the new Yugoslav Sokol organisation there is nothing fascist, or anything that the Sokol movement could not accept in regard of its democratic and liberal principles". (Pavlin, 2002, p. 66) The Yugoslav ambassador in Prague wrote on the new national organisation to the Czechoslovak Sokol as well as to the Slavic Sokol Union, and expressed a belief that "the Czechoslovakian and the Slavic Sokol Union will be able to evaluate the intentions of the new Sokol organisation in Yugoslavia". He stressed it was necessary "that particulars of gymnastic organisations adapt in every Slavic nation and in every Slavic state to local circumstances". (Pavlin, 2002, pp. 66-67) In Prague, after detailed acquaintance, greetings and approval replaced scepticism and strongly supported SKY in incorporating in FIG and Slavic Sokol Union.

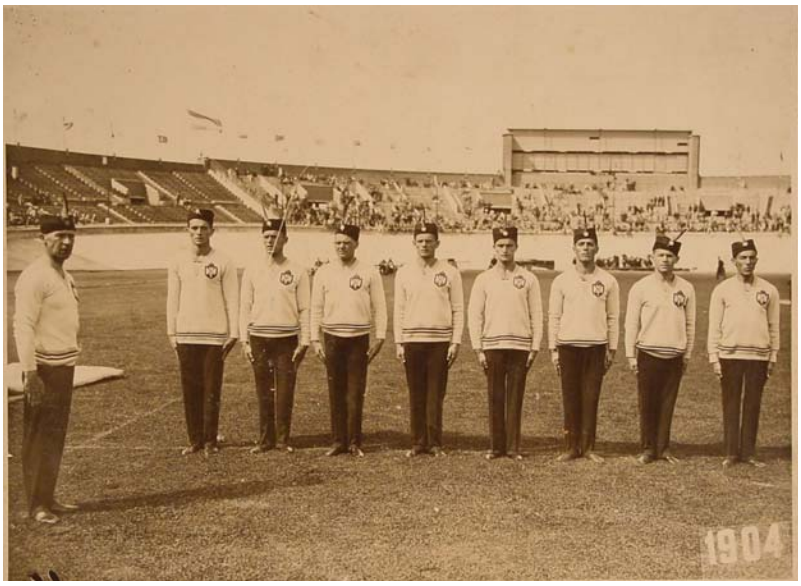

Figure 2. *Yugoslav team at OG 1928, on the left coach dr. Viktor Murnik*

SKY got personal connections with the court because Alexander's heir to the throne Prince Peter was the official leader of Sokol. After King Alexander's assassination in 1934, SKY kept its leading role however, following the political twist in 1935, the government once again gave permission to organise catholic gymnastic societies under new name Slovenski fantje in dekleta (Slovene boys and girls; boys and girls in the sense of young men and women – note author). Up to 1941, the state supported gymnastics and physical education based on gymnastics and in 1934 a law was passed which introduced physical education as an obligatory activity for the young population that finished schooling. In the background, we must take into consideration the Central-European political situation and increasing militarization and totalitarianism, in this case physical education, especially sokolism, was supposed to perform pre-military and patriotic training. In different "decrees" on facilitations for SKY members regarding obligation of serving the military, the minister of army and navy prescribed benefits for members who would, when entering military service, attest five-years continual membership, and successfully conclude the programme of needed preparing. Years the recruit spent in lower age gymnastic categories were also included in the five-year term. (Pavlin, 2009c; Zbornik SSKJ, 1939)

"Golden age"

As pointed in his publication Sokol and Olympian Boris Gregorka, the decade between two world wars was in competitive sence "the golden age". After succeeding the membership in FIG and joining to Olympic movement Yugoslav Sokols competedat all major gymnastic matches with exception of Olympic Games (OG) Los Angeles 1932 and World Championship (WC) Budapest 1934. The reasons for missing the OG 1932 was high expenses, but on the other side in that same Olympic year was also allsokol festival (zlet) in Prague and the head of SKY decided rather to take part with large delegation at Sokol festival. In 1934 they decided to boycott the WC in Budapest because of political reasons. The very first introduction of Yugoslav gymnasts was in 1922 when new YS had its first allsokol festival (zlet) and within it hosted FIG's international match or WC. Among individuals Peter Šumi shared first place, while Stane Vidmar was third and Leon Štukelj eighth. Two years later Yugoslav Sokols appear at Olympics. In Paris OG 1924 surprised the gymnastic world Leon Štukelj winning two golden medals (allround and pole). In 1926 was on schedule WC in Lyon. Among six nations Yugoslavs were second after Czechoslovakia while Peter Šumi became for second time FIG's world champion. At OG 1928 in Amsterdam in gymnastics competed eleven nations and Yugoslavia was third while Leon Štukelj was third in allround and first at rings, Josip Primožič second on parallel bars and Stane Derganc third in vault. The Amsterdam OG were success hard to overgo. Than followed the tragical WC in Luxembourg 1930 as during his appearance on rings tragically fall off young Tone Malej and later died in hospital. Despite of tragedy Yugoslav Sokols finished competition and Josip Primožič became allround world champion. He also won pommel horse, parallel bars and floor exercise. Leon Štukelj, who during the competition injured, was third at horizontal bars. In the thirties new generation was coming but unfortunately it was facing lack of major matches and lost the international contact. Finally they appeared on the scene at OG in Berlin 1936 but the golden age declined and only Leon Štukelj at his last Olympic performance got silver medal on rings.

In Berlin also competed for their first time Yugoslav female Sokols. Last competition before WW II. was FIG's WC in Prague 1938. As it was tense international political situation the participation was truncated. Yugoslav Sokols were in men competition third, among individuals Josip Primožič was third on horizontal bars. In female competition Yugoslav team was second among four national teams.

We have to pointed out that in Yugoslav (Sokol) men national gymnastic teams in "golden age" prevailed Slovenes or gymnasts from Slovene sokol societies. On the major competitions (3 OG and 4 WC) in the period between two world wars competed 26 gymnasts. Among them 4 came outside Slovenian societies, in 1928 Olympic team was one Croatian, in 1936 Olympic team was one Serbian and in WC 1938 team were one Croatian and one

Serbian. More than half of gymnasts competed at least at two tournaments.

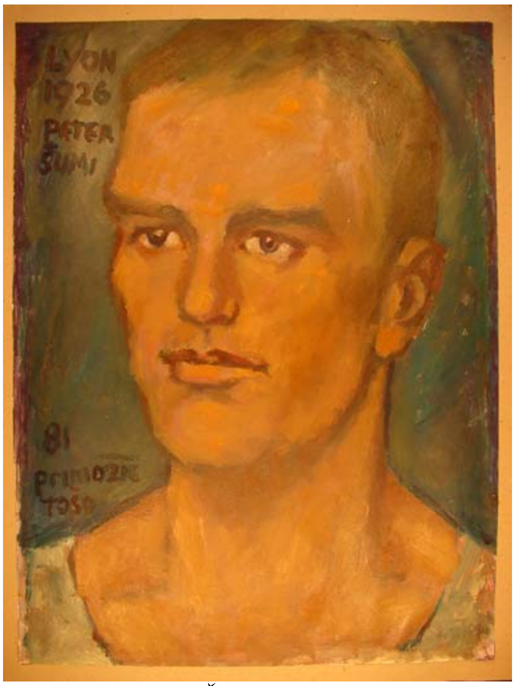

Figure 3. *Peter Šumi (two tims in row all around World Champion). Painted by Jože Primožič the first official apparatus World Champion on Floor, Pommel Horseand Parallel Bars*

The leaders were Leon Štukelj and Josip Primožič at six tournaments, Stane Derganc and Boris Gregorka at four, Mihael Oswald, Janez Porenta, Peter Šumi at three, Slavko Hlastan, Stane Vidmar, Anton Malej, Edvard Antosiewicz, Miroslav Forte, Jože Vadnov and Janez Pristov at two, one appearance had Vlado Simončič, Stane Žilič, Rastko Poljšak, Srečko Sršen, Oton Zupan, Rafael Ban, Konrad Grilec, Miloš Skrbinšek, from Croatian societies Dragutin Ciotti and Stjepan Boltižar, from Serbian societies Josip Kujundžić and Dimitrije Merzlikin. (Gregorka, 1991; Štukelj, 1989)

Unfortunatelly "golden age" followed April sixth attack of Nazi-fascistic bloc on Yugoslavia in 1941, its capitulation, occupation and dismemberment of Slovenia. Sokol was liquidated and their halls took over by occupation authorities or forces. In this situation Sokols in Slovenia supported resistance and were cofounders of National liberal front and partisans while one part of Sokols supported resistance within Yugoslav army leaded by emigrant government and King Peter, former heir and Sokol president, in London. With liberation in 1945 and communistic political takeover, former physical education was transformed into prosovietic "physical-culture". In transformation there was no place for national and liberal Sokol. But its gymnastic heritage and work and methods went on. After the reorganization of physical culture after 1948 (Informbiro confrontation between Soviet Union and Yugoslavia) again was organized an independent gymnastic organization. On the meeting of its Executive board in 1951 it was sugested to name again Sokol, but it was politicaly refused because of Sokol's divison during WW II. It prevailed idea to name the organization Partizan (partisan - fighter for liberation in the WW II.). Another change came in 1963 when was organized Gymnastic Union of Slovenia (on the state level Gymnastic Union of Yugoslavia). In Union was united the competitive gymnastics (sports and rhythmic gymnastics, Gymnastic Union took over also the membership in FIG), while Partizan would have to takeover mass physical activity or recreation. And if we borrow verse of popular song of rock-group Doors, "This is/was Sokol's/ the end, my only friend" (Jim Morrison).

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IMPROVING THE QUALITY OF THE RHYTHMIC FEMALE GYMNASTS' FEET PERFORMANCE BY THE MEANS OF TRADITIONAL CHOREOGRAPHY

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Research article

Abstract

In the article we prove empirically that the feet performance quality is the significant constituent part of the sport skills in gymnastics and among the other components it has influence on gymnasts' success in competitions. Through the survey of the gymnastics specialists we determine the key-points of the female gymnasts' feet performance quality. According to the received data they are the height of rising to half toe position; the capacity to perform for a long time on one foot and maintain its turnout and the height of half toe position; the capacity to balance for a long time in high turnout half toe position; the degree of toe pointing; feet turnout. We explain the chosen check tests that let estimate the performance degree of all the indexes of the female gymnasts' feet performance quality. With determining the most effective exercises of traditional choreography we develop the methods of improving the female gymnasts' feet performance quality. The effectiveness of the developed methods is examined through the educational experiment.

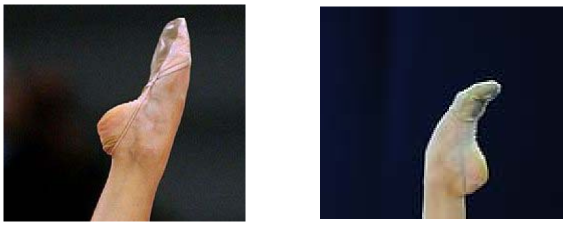
Keywords: *rhythmic gymnastics, motor skills, culture of movements, quality of feet performance, traditional choreography.*

INTRODUCTION

Each sport has a number of demands that, if followed, help a sportsman to achieve high performance. For being successful in rhythmic gymnastics young female gymnasts need to develop flexibility, balance, speed, strength, endurance as well as the artistic components: beauty and elegance of movements, "postural sense", culture of movements, etc. (Karpenko, 2003). To the components of the concept of "culture of movements" many specialists in gymnastics relate quality (accuracy) of feet's performance (Biryuk & Ovchinnikova, 1990; Savelieva, 1997; Borisenko, 2000; Karpenko, Viner & Sivitsiy, 2007; Rumba, 2013, etc).

According to gymnastics specialists the concept "feet performance quality" mainly includes the height of rising to half toe position (heels lifting), the degree of toe pointing, feet turnout (ankle joints flexibility), etc. According to Nesterova, Makarova (2009), female gymnasts' feet work can be represented as main (supporting, impacting, amortizing) and specific (esthetic, manipulation, integral) functions that together have a great impact on female gymnasts' skill level. Figure 1. illustrates gymnastics specialists' notions about higher and lower quality of feet performance.

The height of rising to half toe position



The degree of toe pointing

Figure 1. *The difference between the indexes of female gymnasts feet work quality*

The Code of Points indicates the significancy of this sport skill aspect. Particularly according to the CoP on rhythmic gymnastics for the years 2009-2012 two panels of judges registered the quality of female gymnasts' feet work – Execution (E) jury controlling an execution (technical faults) and Artistic (A) jury controlling the artistic value of a base composition (music and choreography). Execution (E) jury penalized inaccurate feet work: for example, supporting on the heel during the part of rotation or loss of balance when performed in relevè. Artistic jury judged the general effect of female gymnasts' choreographic skills including the feet performance quality. In relation to the degree of complexity, the following penalties were applied: 0.10 point for small errors, 0.20 point for medium errors, 0.30 point and more for large errors. Final score (30.00 points maximum) was a sum of the difficulty score (Difficulty (D) jury), the artistic score (Artistic (A) jury), execution score (Execution (E) jury) – each jury's score is 10.00 points maximum.

Some changes were introduced in the new CoP for the Olympic period (2013-2016). Particularly the final score is a sum of difficulty (D) score and execution (E) score, each of which is given by different panels of judges. E-jury controls now both artistic and technical faults. However, the score for feet performance quality remains practically the same.

Consequently, based on the opinions of the lead specialists and the CoP on rhythmic gymnastics, we can state the fact that the gymnasts' skill largely depends on the feet performance quality. Moreover, the majority of gymnastic coaches tend to enhance this aspect of work-out session with the help of traditional choreography (Botti & Nascimento, 2011). Therefore the hired choreographs are asked first of all to work with the female gymnasts' feet.

At the same time, according to Nesterova & Makarova (2009), the coaches' work on improving the functions of the female gymnasts' feet is determined not only by the aim of rising the executive skills but also by the necessity of flat-foot prevention. Often the main reasons for flat-foot are irrational feet load, lack of prevention and recovery measures, forced physical preparation and overcomplicated competition programs for junior female gymnasts. Furthermore, the majority of female gymnasts questioned by the authors said that incorrect warming-up and lack of systematic control on feet work are the main reasons for ineffective feet performance.

Summarizing the results of theoretical research, it should be admitted that interrelation between feet performance quality and the level of female gymnasts' sport skill hasn't been confirmed empirically; this is why it still remains a widely known specialists' professional opinion. Additionally, the theory and methods of gymnastics still do not include any explicit criteria that would confirm the importance of the "feet performance quality" concept. As a result, we fail to discover scientific methods of improving the female gymnasts' feet performance quality as well as developing more effective ways of forming this sport skill aspect.

All this has led us to start working on the problem of improving female gymnasts' feet performance.

The research hypothesis: it was expected that the feet performance quality is a significant constituent part of the sport skills in gymnastics and has, among other components, influence on gymnasts' success in competitions. By exploring the key-points of female gymnasts' feet performance quality, it will be possible to select a more effective gymnastic routine in traditional choreography and to develop effective methods to improve the feet performance quality.

The research goal: to provide experiment based evidence of methods that can improve the feet performance quality as stipulated by traditional choreography.

The research tasks:

- to explore the key-points of female gymnasts' feet performance quality;
- to empirically confirm the interrelation between feet performance quality and the level of female gymnasts' sport skill;
- to develop effective methods of improving female gymnasts' feet performance quality and to test its effectiveness.

METHODS

The study was conducted in three phases:

1) The first phase comprised the survey of gymnastics coaches in order to summarize their opinions:

- on the influence of feet performance quality on female gymnasts' sport skills;
- on the key-points of female gymnasts' feet performance quality;
- on the effective methods to improve the female gymnasts' feet performance quality.

2) In the second phase we estimated empirically how the feet performance quality influences gymnasts' success in competitions.

3) The third phase included the development of effective methods that improve the female gymnasts' feet performance quality and testing their effectiveness.

In the process of the study the following methods were employed:

- survey;
- testing;
- comparison of opposite examined groups;
- educational experiment;
- methods of mathematical statistics.

Twenty five coaches from different regions of Russia were *surveyed*: from Moscow, St.-Petersburg, Belgorod, Vladimir, Leninogorsk, Omsk, Perm, Petrozavodsk, Pushkin, Samara, Sosnovy Bor, Tyumen, Chita and Elista. The coaches were asked three questions:

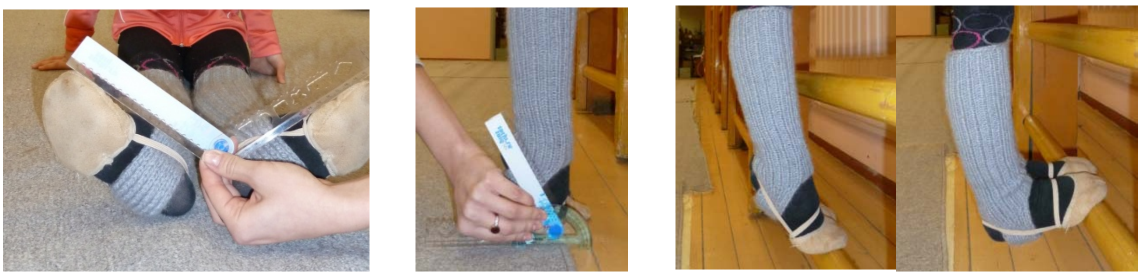
1) Does the quality of female gymnasts' feet performance influence the level of their sport skills? The test offered 5 options: "Yes, it does", "It's likely to influence", "It isn't likely to influence", "No, it doesn't", "Cannot say".

2) What are the main characteristics of estimating the female gymnasts' feet performance quality?

3) What exercises do you find the most effective in improving the female gymnasts' feet performance? The coaches asked to name the most effective exercises.

Testing comprised estimation of feet performance quality of the recruited gymnasts (n=27). It was conducted three times: at the first stage of the study during the comparison of the opposite examined groups; at the third stage of the study during the educational experiment – before and after the experimental work out. In reference to survey answers by coaches, the following check tests were selected:

- to measure the limit angle of feet spreading in the sitting position with the hands behind (in degrees) – feet turnout was estimated (Figure 2a);
- to measure the angle between the floor and the arch of foot in half toe position (in degrees) – the height of half toe position was estimated ((Figure 2b);
- the number of rises to high half toe position from the lower rail of the wall-bar per 30 seconds – calf muscles strength was estimated ((Figure 2c);
- the number of rises of one foot to high half toe position without touching the floor with the other foot and with no time frame – calf muscles of the one foot was estimated;
- how much time a female gymnast needs for a turnout high half toe position on one foot (the second is on passé or in attitude) – the capacity of balancing on one foot to high half toe position was estimated;
- the number of tour lent rotations on one foot without touching the floor with the other foot – the strength of the pivot foot, feet turnout, balance function were estimated.



a b c

Figure 2. *Feet position in different tests.*

Joints flexibility was estimated by the goniometry method with the help of special compasses – *goniometer*. (Figure 3).

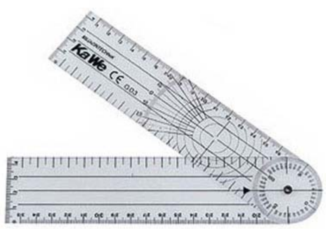


Figure 3. *The tool for measuring joint flexibility – goniometer.*

To eliminate doubt we conducted *the comparison of opposite examined groups* in two ways:

1) On the basis of performance results at the last five competitions. The points that every recruited female gymnast got at the last five competitions for the compositions were added up. In reference to the received data all recruited female gymnasts were ranged in accordance to the success rate. The first six recruited female gymnasts were put in a “strong group”, the other ones were combined into a “weak group”. Then we compared the level of quality of their performances in order to find differences.

2) On the basis of arranging results according to the pair-wise comparison method by Alexander Gorelov. All the recruited female gymnasts were compared pair-wise: the stronger female gymnast got 1 point and the weaker got zero points. For being equal each female gymnast got 0.5 point. Then the points were added up (Table 1). On the basis of these results all female gymnasts were ranked by their sport skills. On the ranking list the first six participants

made the “strong group” and the other six comprised the “weak group”. Then we compared the recruited gymnasts’ quality level of feet performance in order to find significant differences.

Table 1.*The formula for the recruited female gymnasts ranking according to the pair-wise comparison*

	Gymnast 1	Gymnast 2	….	Gymnast n	Point total	Ranking place
Gymnast 1	╬	1		0		
Gymnast 2	0	╬		0		
….	….	….	….	….	….	….
Gymnast n	1	1		╬		

The *educational experiment* aimed to estimate the effectiveness of our method that helps improve the quality of female gymnasts’ feet performance with the help of traditional choreography. For the experiment we recruited 27 female gymnasts of equal qualification aged 8-10 years, attending one and the same training program with one and the same coach. The duration of the experimental period was four months, at a frequency of three lessons per week, each lesson 90 min. The parents of the female gymnasts gave written consent prior to this study. The methods were in agreement with ethical standards of the Declaration of Helsinki. Before and after the experiment we ran check tests with the female gymnasts in order to assess the feet performance quality.

The methods of mathematical statistics included the following standard measures: arithmetic mean calculation (M); standard error of the mean finding (m); confidence estimation of differences with the help of Student’s t-test (p); base data checking for normalcy of distribution concerning the Pearson's chi-squared test. The statistical analysis of the experimental information was done by the statistical package Statgraphics Plus for Windows and the program Microsoft Excel.

RESULTS AND DISCUSSION

The results of *the gymnastics coaches’ survey* show that 84 per cent believe that the quality of female gymnasts’ feet performance influences the general level of their sport skills. Moreover, another 16 per cent answered “It’s likely to influence”. That means that in fact all surveyed coaches find this index as an important constituent part of being successful in rhythmic gymnastics competitions.

The following most significant characteristics distinguishing the quality of female gymnasts’ feet performance were pointed out by the respondents: the height of rising to half toe position (88%); the capacity to perform for a long time on one foot and maintain its turnout and the height of half toe position (84%); the capacity to balance for a long time in high turnout half toe position (80%); the degree of toe pointing (72%); and feet turnout (64%).

All respondents (100%) see exercises from traditional choreography as the most effective for improving the quality of feet performance; 60% prefer special exercises from rhythmic gymnastics; 28% favour special groove machines. A large majority of the surveyed maintains that regular choreographic activity is necessary for developing this aspect of female gymnasts’ executive skills. The data collected in response to this question corresponds to the data published in the book “Rhythmic Gymnastics” edited by Professor Ludmila Karpenko (2003).

Generally, the survey results confirmed our initial hypothesis that the feet performance quality is a significant component in gymnastics executive skills that may be developed effectively by the means of traditional choreography.

In Table 2 are the figures gained during the *experimental study revealing the influence of the female gymnasts’ feet performance quality on the general level of* *their sport skills*. It's important to note that determining the opposite examined groups in two ways we got practically the same results. That confirms the rightness and objectivity of the pair-wise comparison method for determining the opposite groups.

Table 2. *The estimation of feet performance quality of gymnasts in "strong" (n=6) and "weak" (n=6) groups*

№	Index	«Strong» groups M±m	«Weak» groups M±m	P (t-test)
1	Feet turnout (angle of feet spreading, in degrees)	166.8±2.8	143.9±3.2	p<0.05
2	Height of half toe position (angle between the floor and the arch of foot in half toe position, in degrees)	59.5±1.0	52.5±0.8	p<0.05
3	Rises to high half toe position from the lower rail of the wall-bar (the amount of times per 30 seconds)	48.3±1.3	41.3±2.2	p<0.05
4	Rise to half toe position on right foot (the amount of times)	29.5±2.1	16.0±2.8	p<0.05
5	Rise to half toe position on left foot (the amount of times)	28.3±1.3	17.6±2.5	p<0.05
6	Balance on left foot in passe (sec)	16.7±2.1	5.9±1.0	p<0.05
7	Balance on right foot in attitude (sec)	23.8±1.6	10.0±2.4	p<0.05
8	Tour lent rotations on right foot (the amount of times)	6.7±0.5	3.7±0.3	p<0.05

Our data produced the following facts. The limit angle of feet spreading in the sitting position with hands behind the gymnast in the "strong" group was 166.83^0 and in the "weak" group 143.92^0 ($p<0.05$). The angle between the floor and the arch of foot in half toe position was 59.50^0 in the "strong" group and 52.58^0 ($p<0,05$) in the "weak". The gymnasts in the "strong" group have stronger calf muscles than those in the "weak" group. The "strong" group gymnasts can rise 48.33 times to high half toe position from the low bar per 30 seconds; the number of rises in the "weak" group was 41.33 ($p<0.05$). The number of rises on the right foot to high half toe position without touching the floor with the other foot and with no time frame in the "strong" group was 29.50, on the left foot 28.33. In the "weak" group the figures were 16.0 and 17.67 respectively. The differences are statistically significant ($p<0.05$).

As female gymnasts prefer to perform front horizontal lever with the right leg we assessed the ability to balance on the right foot in half toe position through a more difficult lever in attitude (Figure 4). The left leg was assessed when the right was on passé (Figure 5). Interesting that it was the right foot on which the female gymnasts managed to balance on half toe position longer despite the more difficult task for the right leg. The results of gymnasts in the "strong" group were positively better than in the "weak" group ($p<0.05$): the right foot – 23.88 and 10.05; the left – 16.77 and 5.90 seconds respectively.

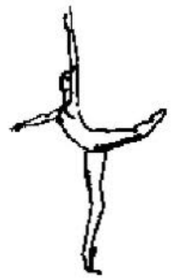


Figure 4. *Attitude*

Figure 5. *Passé*

Most gymnastics and choreography specialists believe that tour lent rotation is one of the most difficult elements. Its qualitative performing depends on a pivot foot strength, feet turnout and balance function. Tour lent (French: slow rotation) is a slow rotation of 360^0 (or more) on one foot with the working leg opened for any position of 90^0 (or higher). Again the results differ considerably: the “strong” group 6.75 rotations; the “weak” group 3.75 rotations. The differences are statistically valid ($p<0.05$).

We can see that all selected indexes indicate that female gymnasts with higher sports skill level have better feet performance quality. This proves that among other things the feet performance quality helps being successful in gymnastics. Moreover, it confirms that coaches who pay attention to the development of their junior female gymnasts’ feet turnout, the height of half toe position, the calf muscles strength, etc., are right.

When developing experimental methods to improve female gymnasts’ feet performance quality we considered traditional choreography exercises.

Traditional choreography is a unique set of movements providing the all-round body development: strength of feet, arms and back, joints and muscles flexibility, steadiness (aplomb), coordination, culture of movements (Vaganova, 1980). According to Karpenko (2003), random exercises from traditional choreography are not effective. For this reason, traditional choreography classes were included in training process in Russia long ago. Usually traditional choreography lessons for women comprise four parts: 1) bar exercises; 2) floor exercises; 3) jumping; 4) training in ballet shoes. Such a structure of the lesson is typical for choreographic academies and dance companies. For better results, ballet dancers have this training practice every day (Kostrovitskaya, Pisarev, 1976; Vaganova, 1980). Still, for a variety of reasons the situation in gymnastic is different.

According to coaches, the duration of a traditional choreography lesson is 90 minutes, followed by the main training. Hence, as a rule, it consists of two parts: bar and floor exercises or bar exercises and jumping or floor exercises and jumping. We discovered that only one coach from Omsk includes training in ballet shoes in the lesson process. Ballet shoes are one of the most effective ways of the ballet dancers’ feet training and prevent flat-foot (Figure 6).

Figure 6. *Women ballet shoes (pointe) providing ballet dancers’ feet training*

In regards to the frequency of traditional choreography lessons, only the representatives of the elite Olympic rhythmic gymnastics team have daily two-hour trainings. Two or three 1.5-hour lessons per week is the norm for middle-ranking female gymnasts attending children's and youth sports schools or children's sport clubs (Karpenko, 2007).

Due to the lack of lessons (two or three lessons per week), coaches fail to develop the quality of middle-ranking female gymnasts' feet performance.

In order to settle this problem new traditional choreography methods aiming to improve the feet performance quality have been developed. For this purpose:

- we firstly determine the most effective traditional choreography exercises in relation to feet training and increase their number of them in the lesson structure;
- secondly, we start regular trainings in ballet shoes.

These exercises include:

- releve – (French: raise) – rise to half toe position. It helps to develop calf muscles strength, foot strength, turnout and steadiness. It can be performed at a leisurely or at a quick (mounts to half toe position) pace on two feet (in every position) or one.
- plie – (French: flexion) – squatting. It develops feet strength, hip and ankle joints turnout, ligaments' flexibility, Achilles tendon. There are several kinds of plie: demi plie (French: half flexion) – half squatting and grand plie (French: full flexion) – complete squatting. In addition to plie half toe position is also productive;
- battement tendu (French: beating) – a strained leg movement from one position to another. It improves ankle and hip joints, leg strength and stretch – knees, feet, feet balls, toes.

The proportion of these exercises in the lesson process have been increased:

1) By taking as bases releve and plie, we composed two 10-minutes combinations that can be performed alternatively facing the bar and on the floor:

Combination №1 comprises different kinds of releve performed in every position on one foot changing the speed of movements from two times 4/4 to 1/8 (from 8 times to 1);

Combination №2 consistes of releve combinations, all kinds of plie including plie on half toe position. Speed also varies from two times 4/4 to 1/8 (from 8 times to 1).

2) We increased the number of battement tendu compulsive combinations from one or two to three with the duration of 32 times 2/4 each of them (64 times):

Combination №1 includes a set of battement tendu together with plie and releve and is performed at a leisurely pace facing the bar;

Combination №2 was developed on the basis of Combination №1 by adding more difficult variations of the same exercises and is performed at a quicker pace side to the bar or on the floor;

Combination №3 comprises a variety of battement tendu, battement tendu jete (French: hurl) – kick movements with the strained leg on 25^0 coupled with plie and releve and is performed at a quick pace side to the bar or on the floor.

3) As additional exercises, plie and releve are included in every combination;

4) Many exercises are performed with the support leg on half-toe position or in plie. Traditional choreography trainings were at a frequency of three lessons per week, for 90 min. We based ours on the alternation of two and three partial lessons. As we used all four phases of a traditional lesson (bar exercises, floor exercises, jumping, training in the ballet shoes) six lesson variations have been composed. They shifted during the two weeks (Table 3).

5) The results of the experimental study in regards to our methods on improving female gymnasts' feet performance quality by means of traditional choreography are demonstrated in Table 4. On the whole, our data confirms the effectiveness of the suggested methods. The improvement of the female gymnasts' feet performance quality resulted positively ($p<0.05$) from the experimental study of the following indexes: the height of rising to half toe

position, the capacity to balance for a long time in high turnout half toe position, the capacity to perform for a long time on one foot and maintain its turnout and the height of half toe position. Even though there is no reliable evidence ($p>0.05$) of positive dynamic concerning the feet turnout (ankle joints flexibility), we can see that the limit angle of feet spreading in the sitting position with hands behind increased by 3.84^0.

Table 3. The organization of traditional choreography classes aimed to improving the female gymnasts' feet performance quality

Classes variations	Content of classes	Time
Variation №1	Combination on plie-releve №1 at the bar	10 min
	Bar exercises	30 min
	Floor exercises	20 min
	Training in the ballet-shoes	25 min
Variation №2	Combination plie-releve №1 at the bar	10 min
	Bar exercises	45 min
	Combination on plie-releve №2 on the floor	10 min
	Jumping	25 min
	Combination on plie-releve №2 at the bar	10 min
Variation №3	Floor exercises	40 min
	Combination on plie-releve №1 on the floor	10 min
	Training in the ballet-shoes	25 min
Variation №4	Combination on plie-releve №1 at the bar	10 min
	Bar exercises	45 min
	Combination on plie-releve №2 on the floor	10 min
	Jumping	25 min
Variation №5	Combination on plie-releve №2 at the bar	10 min
	Bar exercises	30 min
	Floor exercises	30 min
	Training in the ballet-shoes	25 min
Variation №6	Combination on plie-releve №2 at the bar	10 min
	Floor exercises	45 min
	Combination on plie-releve №1 on the floor	10 min
	Jumping	25 min

* During trainings in ballet shoes the participants had 5 minutes to change shoes.

Table 4. *The estimation of feet performance quality of gymnasts (n=27) before and after the training on experimental training*

№	Index	Before the experiment M±m	After the experiment M±m	Diff.	p (t-test)
1	Feet turnout (angle of feet spreading, in degrees)	156.33±2.44	160.17±1.99	3.84	p>0.05
2	Height of half toe position (angle between the floor and the arch of foot in half toe position, in degrees)	55.81±0.81	62.32±0.72	6.51	p<0.05
3	Rises to high half toe position from the lower rail of the wall-bar (the amount of times per 30 seconds)	41.04±1.68	49.56±0.82	8.52	p<0.05
4	Rise to half toe position on right foot (the amount of times)	19.48±1.66	37.89±1.48	18.41	p<0.05
5	Rise to half toe position on left foot (the amount of times)	20.70±1.57	35.82±1.14	15.12	p<0.05
6	Balance on left foot in passe (sec)	12.90±1.26	21.81±1.84	8.91	p<0.05

7	Balance on right foot in attitude (sec)	14.61±1.39	27.75±2.75	13.14	p<0.05
8	Tour lent rotations on right foot (the amount of times)	5.17±0.35	7.96±0.49	2.79	p<0.05

On one hand the results of our study correspond with the opinions of Borisenko (2000), Karpenko (2003, 2007), Kalinski, Božanić, Atiković (2011), confirming that traditional choreography trainings are necessary and the feet performance quality need to be improved. On the other hand, our results lead us into a controversy with Nesterova, Makarova (2009) who surveyed a number of coaches many of whom deny the effectiveness of traditional choreography exercises.

CONCLUSIONS

In summary, we can make *the following conclusions*:

- it has been proved that the quality of feet performance is a significant constituent part of the sport skills in gymnastics and among other components it influences gymnast's success in competitions;
- the height of rise to half toe position, the capacity to perform for a long time on one foot and maintain its turnout and the height of half toe position, the capacity to balance for a long time in high turnout half toe position, the degree of toe pointing, feet turnout are the key points of female gymnasts’ feet performance quality;
- traditional choreography exercises including training in ballet shoes are effective ways of improving female gymnasts’ feet performance quality;
- our methods help improve female gymnasts’ feet performance quality.

Ultimately, our methods of improving female gymnasts’ feet performance quality by means of traditional choreography, if included in the training process, can raise the chances to success in sports. Experimental testing of this fact will constitute the subject matter of our future study.

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KINEMATIC AND KINETIC TUMBLING TAKE-OFF COMPARISONS OF A SPRING-FLOOR AND AN AIR FLOOR™: A PILOT STUDY

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Research article

Abstract

Tumbling take-offs on floor exercise apparatuses of varying stiffness properties may contribute to apparatus behaviors that lead to increased injury exposure. The purpose of this pilot study was to compare the kinematics, kinetics, and timing performance characteristics of a spring-floor and a spring-floor with an added Air Floor™. Five male international gymnasts performed a forward handspring to forward somersault and a round off, flic flac, backward somersault on a standard spring-floor and a spring-floor with an Air Floor™. Performances were measured via high-speed video kinematics (lower extremity joint angles and positions), electromyography of eight lower extremity muscles, mean peak forces on the feet, and timing. Comparisons of spring-floor types, lower extremity joint angles, lower extremity muscle activations, foot forces, and selected durations were determined. The spring floor with Air Floor™ resulted in longer take-off contact durations than spring-floor alone. Dynamic knee angles may indicate an unexpected and potentially injurious motion of the triceps surae musculotendinous structures. This pilot and hypothesis generating study has suggested future research examining dynamic knee position and angle changes, the role of spring-floor vibration and stiffness in take-offs, and take-off muscle activation alignment with the stiffness of the spring-floor. Pragmatically, there appears to be a convergence of evidence indicating that a slower frequency response of the spring floor may assist tumbling performance and reduce stress and strain in the lower extremity.

Keywords: *Spring-floor, tumbling, take-off, electromyography, foot forces, joint angles.*

INTRODUCTION

Tumbling and floor exercise apparatuses have evolved from dirt, sand, and grass to gymnasium wooden floors, horsehair-filled canvas encased mats, wrestling mats, and various types and thicknesses of polyethylene foam sheets

(Hughes, 1966; Joseph, 1949a, 1949b; Weiker, 1985). Spring-floors, involving metal coil-springs, closed-cell, or combination closed- and open-cell foam pieces under a raised plywood or wood and fiberglass laminate, have been used in international gymnastics competition since at least 1979 (Wilson, Swannell, Millhouse, & Neal, 1986). Prior to spring-floors, a wooden floor apparatus was common with narrow, staggered wooden strips between semi-rigid wooden panels that allowed the wooden surfaces to flex on impact. Spring-floor technology evolved quickly to include metal conical, cylindrical, accommodating compression rate coil-springs (Weller, 2011), and foam blocks of various sizes and designs (Federation Internationale de Gymnastique, 1989; Janssen, 2007; Wilson, Neal, & Swannell, 1989; Wilson et al., 1986). Initially, the height of metal coil-springs or foam blocks was approximately 5cm. Later, the height of the metal springs and foam blocks was increased to approximately 10cm. The matting on the top of the floor exercise apparatus also evolved from approximately 2.5cm to approximately 5cm. A short-pile rugged carpet or other fabric covers the entire 12m x 12m floor exercise area, including a border area serving as an "out of bounds" region (International Gymnastics Federation, 2009).

Investigations of elastic sport surfaces have included gymnastics spring-floors, running tracks, gymnasium floors, and others (Greene & McMahon, 1979; McMahon & Greene, 1978, 1979; Nigg, Yeadon, & Herzog, 1988). Although the initial idea for the spring-floor involved a desire for enhanced safety through reduced landing impact "harshness" (Arampatzis, Bruggemann, & Klapsing, 2000; Nigg, Luethi, Denoth, & Stacoff, 1983; Wilson et al., 1986), the evolution of the gymnastics spring-floor has led to increased elastic behavior with corresponding increases in tumbling height and skill difficulty (Holvoet, Lacouture, & Duboy, 1999; McNeal, Sands, & Shultz, 2007; Paine, 1998). The ultimate outcome of continued increases in elasticity may involve a "revenge effect" (Tenner, 1996) of rapidly increasing skill difficulty exceeding the spring-floor's design characteristics for safety. The increased height of tumbling skills necessitates an increased fall distance and correspondingly greater impact forces (Stefanyshyn & Nigg, 2000). Increasing impact forces (both take-off and landing) may result in exposing the lower extremity to unaccustomed stresses such as those leading to sprains, strains, fractures, and Achilles tendon ruptures (Arndt, Bruggemann, Koebke, & Segesser, 1999; Arndt, Komi, Bruggemann, & Lukkariniemi, 1998; Bieze Foster, 2007; Bruggemann, 1985, 1999).

The elastic characteristics of the modern gymnastics spring-floor requires modification of lower extremity muscle-tendon stiffness characteristics, particularly those muscles and tendons acting on the ankle and knee (Arampatzis & Bruggemann, 1999). Muscle activation and peak force parameters may also vary based on the skills performed (i.e., forward versus backward and twisting versus non-twisting) (Bruggeman, 1987; McNeal et al., 2007). However, in spite of increased elastic characteristics of the spring-floor, injury incidences and rates have continued at a high level (Caine, Lindner, Mandelbaum, & Sands, 1996; Sands, 2000, 2002; Sands, McNeal, Jemni, & Penitente, 2011; Sands, Shultz, & Newman, 1993). Gymnastics training activities have sought to enhance the softness of landings and explosiveness of take-offs that may push lower extremity structures to the edge of their performance envelopes and beyond via repeated execution of high-impact skills (Sands, 2000; Sands et al., 1993).

A relatively recent addition to floor exercise tumbling apparatuses is the "Air Floor™." The Air Floor is a tumbling apparatus formed in long plastic air-filled sections approximately 10cm thick and manufactured in varying widths and lengths. A hand-pump is used to inflate the Air Floor to a desired pressure achieving a selected combination of stiffness and rebound characteristics. The Air Floor section or sections are placed on top of a traditional spring-floor or spring-tumbling-strip and used to augment tumbling skills by modifying both take-off and landing impact properties. The Air Floor is expected to reduce the “harshness” of take-offs and landings, acting elastically like a trampoline, affording the gymnast the ability to perform more skill repetitions and thereby lead to enhanced learning. However, no literature was found supporting or refuting such claims. As such, the Air Floor may be a beneficial training apparatus for floor exercise tumbling skills, allowing the gymnast to perform more repetitions of higher trajectory skills with reduced take-off and impact “harshness.”

The purpose of this pilot study was to compare the kinematics, kinetics, and technique timing characteristics while using: 1) a standard spring-floor and 2) a standard spring-floor with an added Air Floor. Specifically, the comparison will involve: 1) lower extremity joint angles, 2) lower extremity muscle activations, 3) peak forces on the plantar surfaces of the feet, and 4) examine the effects of the Air Floor addition to a standard spring-floor on tumbling somersault take-off techniques.

METHODS

Subjects: Five male national team gymnasts, including two Olympians, (Mean ± SD, Mass 63.9 ± 3.2 kg; Height 164.6 ± 1.1 cm; 24 ± 2.6 yr) training at the U.S. Olympic Training Center in Colorado Springs, CO, USA volunteered to participate. The athletes were all international level gymnasts who competed in the all-around event consisting of competitive routines on six apparatuses: floor exercise, pommel horse, still rings, vault, parallel bars, and horizontal bar. Data collection preceded all training on each testing day. All data collection and athlete consent and participation followed the requirements of the United States Olympic Committee and data were analyzed retrospectively via approval from the East Tennessee State University Institutional Review Board on the study of human subjects.

Instrumentation and Equipment: Athletes performed a forward handspring to forward layout somersault and a round off, flic flac, backward layout somersault, on a full-size floor exercise area (American Athletic, Inc. Ames, IA. USA). The floor exercise apparatus consisted of a 12 x 12 m square area of 50 wood and fiberglass laminate panels (1.23 x 2.44 x 0.013 m) held together at the edges by metal fasteners. Each panel had 32 cylindrical coil-springs placed evenly in 37 cm squares attached to the under-surface. The metal coil-springs were 10.7 cm in height and 5cm in diameter with 9 coils. Each spring was fastened to the panel undersurface with round plastic socket-like fasteners held with wood screws. The panels and entire floor exercise apparatus area was completely covered by Ethafoam^{TM} matting (416-745 Foam, 0.05 m thick). The matting was covered by a polypropylene backed carpet (60oz weight, 1.7 kg).

A tumbling Air Floor^{TM} (Tumbl Trak, Mount Pleasant, MI, USA) (6.0 x 1.52 x 0.10 m) provided the second tumbling condition. The Air Floor was placed on top of the existing spring-floor. Tumbling elements were performed on the spring-floor alone or on the Air Floor lying atop the spring-floor. The run-up to the Air Floor was performed on the underlying spring-floor. The run-up and tumbling elements were performed within the space of the 12 m side dimension of the spring-floor. Figure 1 shows the spring configuration on the underside of a wood and fiberglass laminate spring-floor panel. Figure 2 shows a side view of a fully inflated Air Floor depicting the inner fiber orientations that hold the Air Floor’s shape.

Figure 1. *Spring configuration on the underside of a spring-floor fiberglass wood laminate panel.*

Figure 2. *Side view of an Air Floor segment showing the flexible fibers linking the top and bottom surfaces and ensuring the maintenance of the shape of the Air Floor.*

Muscle activation magnitudes were measured via surface electromyography (sEMG) using a Noraxon^{TM}, Telemyo^{TM} telemetered electromyographic system (Noraxon, Inc. Scottsdale, AZ, USA). The sEMG signal was amplified at the transmitter with a gain of 500 and an additional gain of 500 at the receiver, achieving a total gain of 1000 for all channels and sampling at 1000 Hz. Surface-type Noraxon Dual Electrodes^{TM} (Ag/AgCl, 2.0 cm center-to-center spacing, 10 mm diameter detection area, product #272) were adhered unilaterally on the right side muscle bellies of the following muscles: soleus, lateral gastrocnemius, biceps femoris, gluteus maximus, lumbar erector spinae, anterior tibialis, vastus lateralis and peroneus longus. The electrode longitudinal axes were placed parallel to the muscle fiber orientation of each muscle as described by the Noraxon^{TM} MRXP Master Software (Version 1.03.05). Skin preparation consisted of cleaning and rubbing the area with an alcohol-soaked gauze pad, light sanding with fine-grain sand paper, followed by a second cleaning of the skin area with an alcohol-soaked gauze pad. Electrode cables were then attached to the electrodes and taped with elastic tape to the athlete's lower extremity. Cables were connected to a transmitter held in a small belt pack secured around the gymnasts' waist. Data were transmitted to a receiver interfaced to a laptop computer (Dell Latitude D820, Round Rock, TX, USA) using Noraxon^{TM} MRXP Master software (Version 1.03.05). Crosstalk was minimized by placing electrodes in the cross-sectional center of the muscle belly.

On the second test day the athletes were instrumented with a Tekscan^{TM}, F-Scan Mobile Research^{TM} system (Version 6.31, South Boston, MA, USA) that recorded forces from the plantar surfaces of the feet via thin (0.15 mm) force and pressure sensitive insoles (Tekscan 3000E). The insole sensors were trimmed with scissors to fit the foot plantar surface of each athlete. The pressure insoles had 960 resistive sensor areas per insole with a pressure range from 345-517 kPa. Each pair of insoles was used once per athlete and test day by taping the insoles to the plantar surfaces of the athlete's feet using elastic tape. Each pressure insole ribbon was connected to a pair of Versa Tek "cuffs" interfaced to a data logger (sampling 500 Hz) worn on a belt fastened securely about the athlete's waist as per manufacturer's instructions. Figure 3 shows an example of the mapping of average peak forces from the soles of the feet during a backward layout somersault take-off.

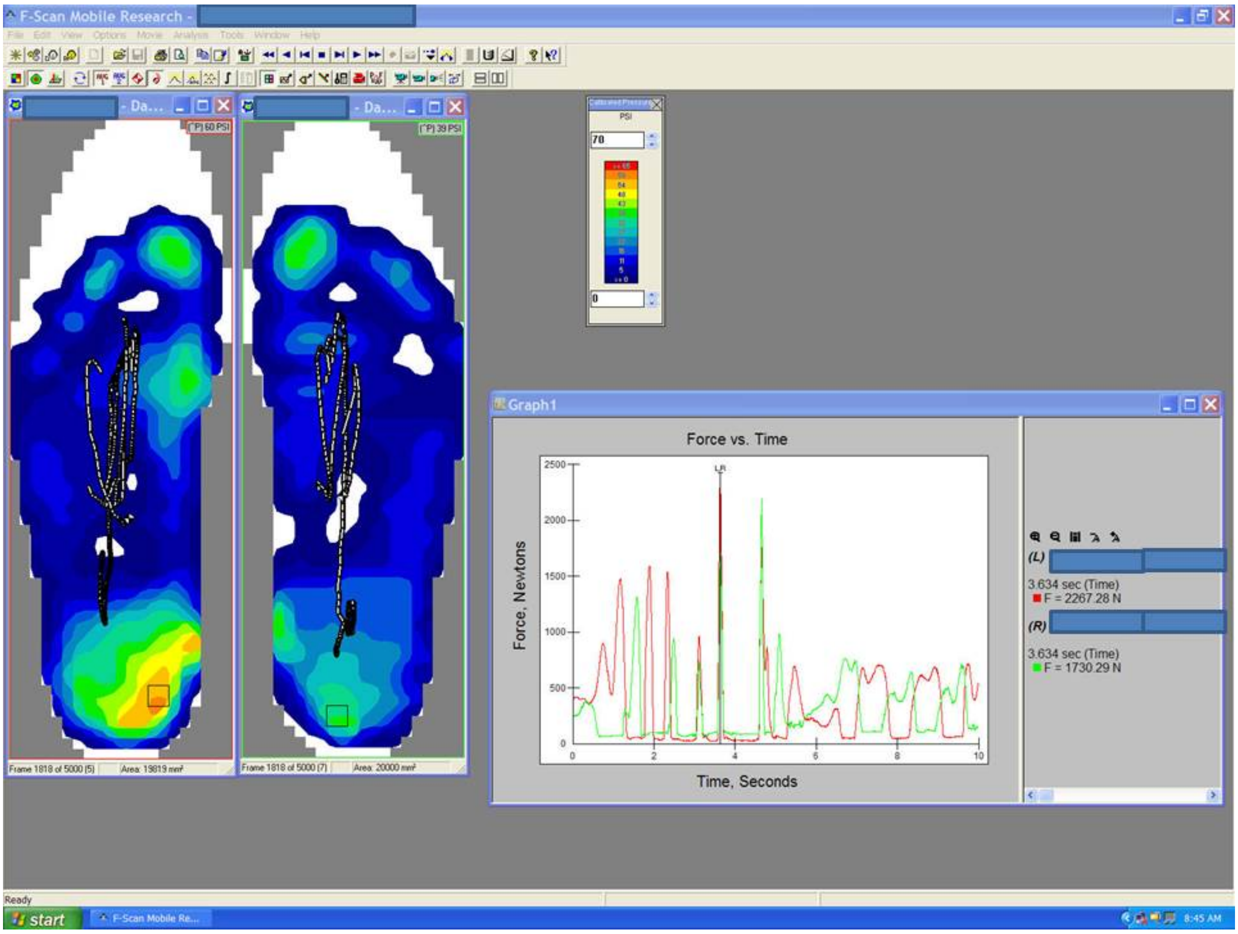


Figure 3. *Example of a computer screen image showing a backward layout somersault take-off. Force "maps" for each foot plantar surface are shown on the left, and the total force data on each plantar surface is shown on the line graph on the right. The black line near the long-axis center of the plantar force map (left) is the center of pressure of the foot derived from the total forces on each foot plantar surfaces across the entire tumbling pass. Note that the non-colored areas indicate the trimming of the sensors to fit the athlete's feet.*

Videography and Kinematics: A high-speed color-video camera (Photron^{TM}, Model 1280, Photron USA, San Diego, CA, USA) was placed perpendicular to the sagittal plane of motion. Video images were captured by Photron^{TM} software at 500 Hz (FASTCAM, Version 2.4.3.2, Photron, San Diego, CA USA). Two-dimensional kinematics of joint angles (ankle, knee, hip, and torso), during the take-off phase of the somersaults, were obtained from the lower extremity using PEAK Motus^{TM} software (Peak Performance Technologies, Motus Version 9.0, Centennial, CO, USA). Two-dimensional calibration was performed using a rectangular calibration frame (1.00 x 1.10 m) following manufacturer's instructions. Tumbling direction was fixed so that the gymnast had his left side nearest the camera during backward somersault take-offs and his right side during forward somersault take-offs. Circular (2 cm) reflective markers were placed bilaterally on the 5th metatarsals, lateral malleoli, lateral knees at the joint line, lateral hips at the greater trochanter, and lateral torso at level of the xiphoid process and on the 12th rib at the inferior-lateral angles. Digitizing of the side of the athlete's lower extremity began 10 video fields prior to foot contact and ended 10 video fields following foot departure. Relative joint angles were identified for lower extremity positions at toe contact with the floor surface, at the midpoint of the take-off foot contact duration, and at toe departure. The angles were derived as follows (Figures 4 and 5): hip - vertex at the hip joint and the two end points were the torso center and the knee and knee - vertex at the knee and the two end-points were the hip and ankle. A quintic spline algorithm was used to smooth the digitized marker trajectory data (Woltring, 1985).

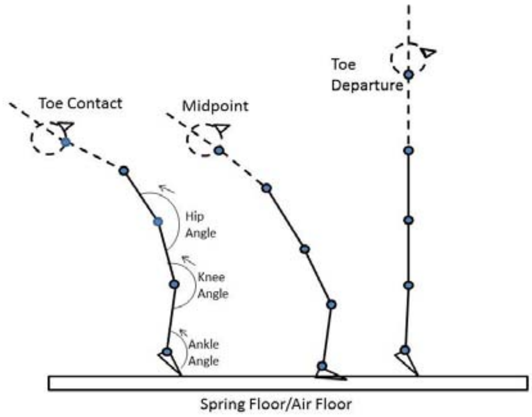


Figure 4. *Layout forward somersault take-off with lower extremity contact positions, joint angle positions, and joint angle directions. Dotted segments indicate non-digitized and non-analyzed segments.*

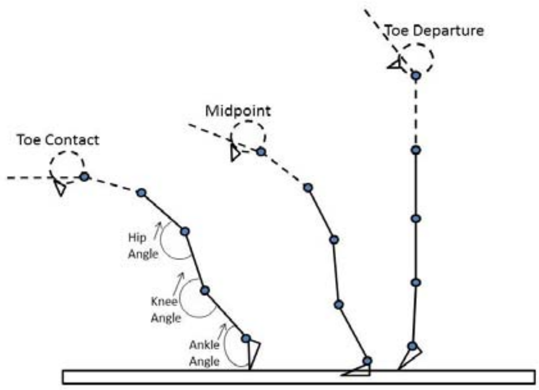


Figure 5. *Layout backward somersault take-off showing lower extremitycontact positions, joint angle positions, and joint angle directions. Dotted segments indicate non-digitized and non-analyzed segments.*

Procedures: The athletes reported to the U.S. Olympic Training Center gymnastics training facility on two separate days. Two days were required because of the added weight of the instruments and the inherent interference of the cables of the two instruments (sEMG and foot plantar surface forces).

The athletes performed a self-selected warm-up prior to testing. Following the warm-up, the athletes were instrumented with either the sEMG or foot plantar force systems and performed two or more familiarization tumbling passes on the spring-floor or the spring-floor with the additional Air Floor. Two data collection trials of a round off, flic flac, layout backward somersault, and two trials of a forward handspring to forward layout somersault were performed on each tumbling surface. The trials were randomly assigned by athlete, floor-type, and instrumentation.

Surface electromyography (sEMG) was assessed using the Noraxon™ MRXP Master software (Version 1.03.05). For the entire take-off period, sEMG processing included full-wave rectification of the raw voltage (μV) signal. The sEMG voltage was integrated to produce an integrated EMG (iEMG, μV·s) and used for further data analysis. All iEMG data were scaled by conversion to percentages of the maximum iEMG for each muscle. Onset and termination of iEMG were determined as the first sample in which the iEMG voltage signal rose to a level greater than 200% above noise or visual inspection of the signal indicated that the take-off muscle activation had begun in spite of the intermediate iEMG signal never dropping below 200% above the signal threshold (McKinley & Smith, 1983). The termination of the iEMG muscle activation signal was the first sample in which the iEMG signal voltage descended below the 200% of voltage signal threshold or visual inspection of the signal indicated that the take-off muscle activation had declined from take-off activation in spite of the intermediate iEMG signal never dropping below the 200% signal threshold.

Calibration of the foot plantar forces device was performed via the single-leg stance method prior to data collection as defined by the instrument manufacturer's software. The foot plantar surface forces were obtained by software (Tekscan™, F-Scan Mobile Research™ system, Version 6.31, South Boston, MA, USA) (Figure 3). An individual sample of peak forces of the entire foot plantar surface was selected and the mean peak force value for all plantar force sensors for each foot was calculated and used for further data reduction and analyses. Peak force was defined as the peak average force across the entire plantar surface of each foot during each type of somersault take-off. The average peak forces were obtained as an included function of the TekScan software.

Analysis: As a pilot study, this was a hypothesis generating investigation. As such, this study was statistically underpowered and, although traditional statistics were used, the primary objective of the study was descriptive searching for promising aspects of performance that could lead to a greater understanding of the gymnast to spring-floor and Air Floor tumbling take-off interactions. Reliability statistics along with hypothesis tests, confidence intervals, statistical power, and effect size estimates were determined (Ellis, 2010). Three repeated measures ANOVAs were calculated for each type of tumbling take-off (6 total). Three angles were extracted from kinematic contact position data and analyzed via a 2 (floor-types) by 3 angles (hip, knee, ankle) x 3 lower extremity floor contact positions (toe contact, midpoint, and toe departure) factorial ANOVA with repeated measures on all dimensions. The iEMG data, previously converted to percentages of the maximum iEMG for each muscle were analyzed with 2 (floor-type) by 2 (take-off-type) by 8 (muscles) repeated measures ANOVAs. A 2 (floor-type) by 2 (left and right feet) repeated measures factorial ANOVA was calculated on mean peak foot plantar surface forces. Total contact times were assessed by a 2 (floor-type) by 2 (tumbling skills) repeated measures ANOVA. Due to the exploratory nature of this study, each analysis was conducted at $\alpha \leq 0.05$ (Huberty & Morris, 1989). All data were statistically analyzed with IBM SPSS Statistics, Version 19.0, Armonk, NY, USA.

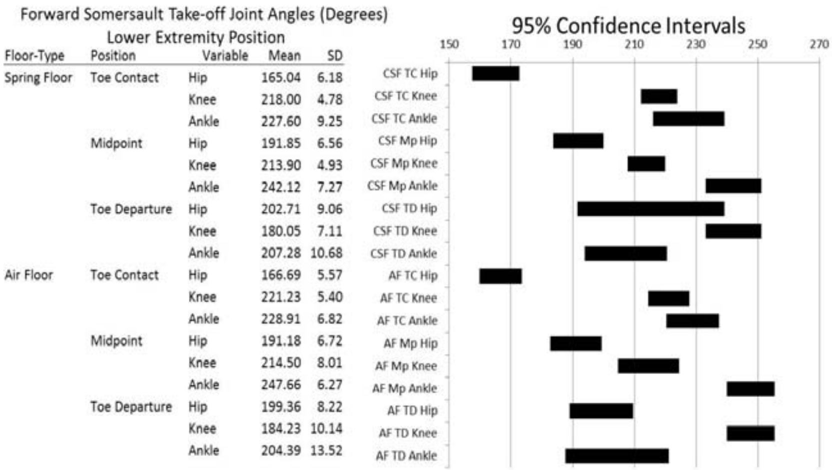
RESULTS

Reliability: Two trials of both tumbling take-offs on both floor-types were assessed. Three joint angles were obtained with regard to floor-type, skill, and take-off positions with intraclass correlations across all conditions ranging from r = 0.90 to r = 0.99, and with relative technical errors of measurement ranging from 0.7% to 7.5%. Intraclass correlations for total foot contact times across all conditions ranged from r = 0.96 to r = 0.99, with relative technical errors of measurement ranging from 3% to 5.2%. Muscle activations intraclass correlations were obtained from the muscle iEMG values across all conditions and ranged from r = 0.86 to r = 0.99, with technical errors of measurement ranging from 4% to 47%. The gluteus maximus and biceps femoris muscles activations accounted for the majority of the large variability of measurement. Technical errors of measurement for muscle activations ranged from 3% to 32% when the gluteus maximus and biceps femoris iEMGs were excluded. Mean peak foot plantar force values showed intraclass correlations across all conditions that ranged from r = 0.98 to r = 0.99, with technical errors of measurement ranging from 5.1% to 15.5% (Hopkins, 2000a, 2000b).

Joint Angle Comparisons

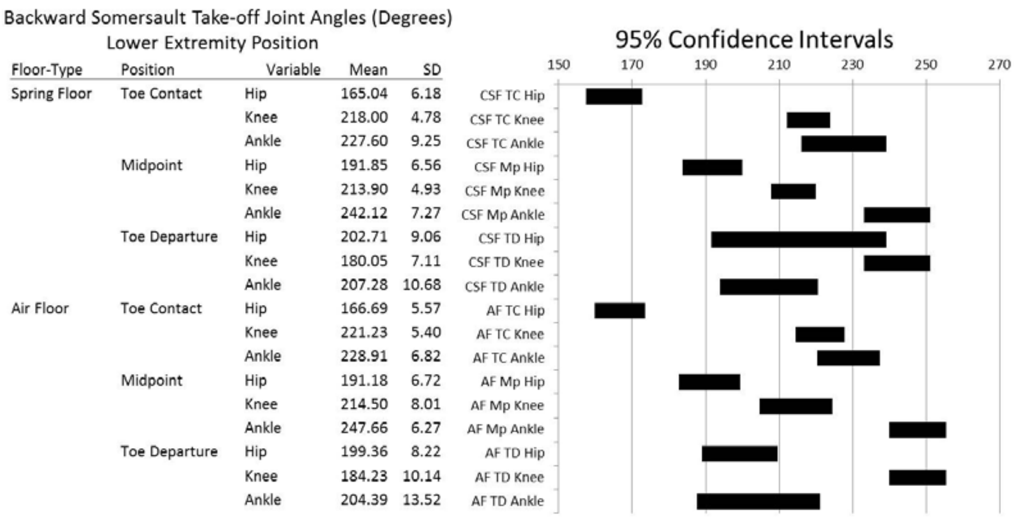
The forward handspring to forward layout somersault take-off joint angles did not show a statistical main effect for spring-floor-type ($F_{(1,4)} = 0.5$, $p = 0.52$, $\eta^2_{partial} = 0.11$, power = 0.09). The floor-type by joint angle interaction ($F_{(2,8)} = 0.93$, $p = 0.43$, $\eta^2_{partial} = 0.19$, power = 0.16) and floor-type by lower extremity floor contact positions interaction ($F_{(2,8)} = 1.56$, $p = .27$, $\eta^2_{partial} = 0.28$, power = 0.24) were not statistically significant. Joint angles and lower extremity floor contact positions were statistically different (joint angle: $F_{(2,8)} = 70.3$, $p < 0.001$, $\eta^2_{partial} = 0.95$, power = 1.0;

lower extremity floor contact position, $F_{(2,8)} = 24.2$, $p < 0.001$, $\eta^2_{partial} = 0.86$, power = 0.99). The joint angle by lower extremity floor contact positions interaction ($F_{(4,16)} = 143.83$, $p < 0.001$, $\eta^2_{partial} = 0.97$, power = 1.0) and the spring-floor-type by joint angle by lower extremity floor contact position interaction ($F_{(4,16)} = 3.72$, $p = 0.025$, $\eta^2_{partial} = 0.48$, power = 0.77) were statistically significant. Figure 6 shows the results of the spring-floor-type, lower extremity floor contact position, and joint angle comparisons for the forward handspring to forward layout somersault.


Forward Somersault Take-off Joint Angles (Degrees)

Floor-Type	Lower Extremity Position	Variable	Mean	SD
Spring Floor	Toe Contact	Hip	165.04	6.18
		Knee	218.00	4.78
		Ankle	227.60	9.25
	Midpoint	Hip	191.85	6.56
		Knee	213.90	4.93
		Ankle	242.12	7.27
	Toe Departure	Hip	202.71	9.06
		Knee	180.05	7.11
		Ankle	207.28	10.68
Air Floor	Toe Contact	Hip	166.69	5.57
		Knee	221.23	5.40
		Ankle	228.91	6.82
	Midpoint	Hip	191.18	6.72
		Knee	214.50	8.01
		Ankle	247.66	6.27
	Toe Departure	Hip	199.36	8.22
		Knee	184.23	10.14
		Ankle	204.39	13.52

Figure 6. *Forward layout somersault take-off joint angle comparisons.*


Backward Somersault Take-off Joint Angles (Degrees)

Floor-Type	Lower Extremity Position	Variable	Mean	SD
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		Knee	213.90	4.93
		Ankle	242.12	7.27
	Toe Departure	Hip	202.71	9.06
		Knee	180.05	7.11
		Ankle	207.28	10.68
Air Floor	Toe Contact	Hip	166.69	5.57
		Knee	221.23	5.40
		Ankle	228.91	6.82
	Midpoint	Hip	191.18	6.72
		Knee	214.50	8.01
		Ankle	247.66	6.27
	Toe Departure	Hip	199.36	8.22
		Knee	184.23	10.14
		Ankle	204.39	13.52

Figure 7. *Backward layout somersault take-off joint angle comparisons.*

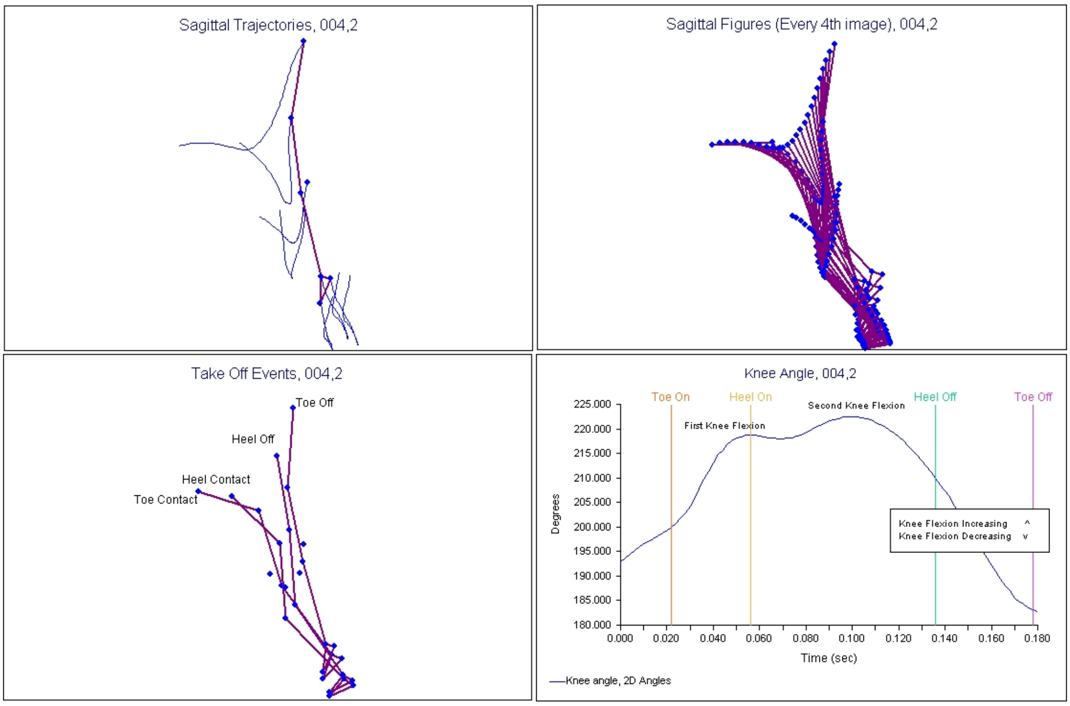

Figure 8. *Kinematic marker trajectories during the layout backward somersault take-off. Moving clockwise from the top-left image panel: 1) all digitized marker trajectories shown for the duration of the take-off, note the abrupt change in knee position: 2) every fourth video field from the 500 fields/s video to ensure that separate images can be displayed, 3) changes in knee angles during the period from toe contact, heel on, heel off, and toe departure, 4) individual digitized images of the four contact positions. Note the distinct two periods of knee flexion in the lower right panel.*

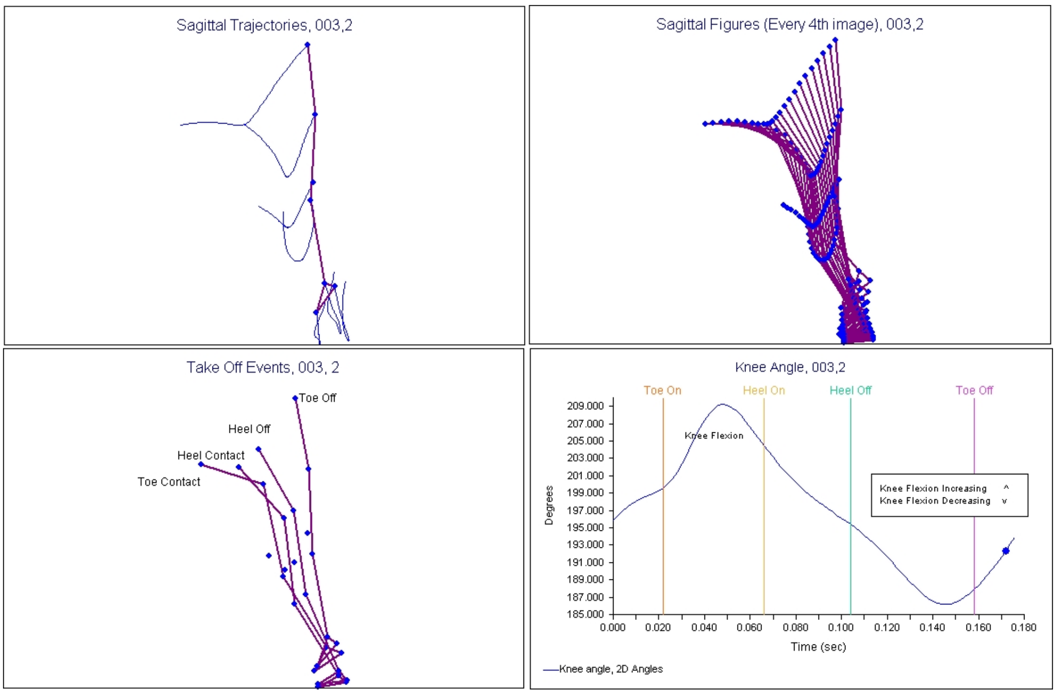

Figure 9. *Kinematic marker trajectories. Note that the lower right panel shows only a single knee flexion period.*

The round-off, flic flac, to layout backward somersault take-off angles did not show a statistically significant main effect for floor-type ($F_{(1,4)} = 0.45$, $p = 0.54$, $\eta^2_{partial} = 0.10$, power = 0.08), floor-type by joint angle interaction ($F_{(2,8)} = 15.22$, $p = 0.08$, power = 0.49), floor-type by lower extremity floor contact position ($F_{(2,8)} = 2.12$, $p = 0.18$, $\eta^2_{partial} = 0.35$, power = 0.31), and floor-type by joint angle by lower extremity floor contact position ($F_{(4,16)} = 1.38$, $p = 0.28$, $\eta^2_{partial} = 0.26$, power = 0.33). Statistically significant main effects included joint angle ($F_{(2,8)} = 200.81$, $p < 0.001$, $\eta^2_{partial} = 0.98$, power = 1.0) and lower extremity floor contact position ($F_{(2,8)} = 120.59$, $p < 0.001$, $\eta^2_{partial} = 0.97$, power = 1.0). A statistically significant interaction was observed only for joint angle by lower extremity floor contact position ($F_{(4,16)} = 230.15$, $p < 0.001$, $\eta^2_{partial} = 0.98$ power = 1.0), accompanied by a large effect size. Figure 7 shows the results of the spring-floor-type, lower extremity floor contact position, and joint angle comparisons for the backward flic flac to backward layout somersault.

Knee Angles During Take-off

In keeping with the pilot and hypothesis generating nature of this study, it can be noted that knee angles changed dynamically throughout the entire backward somersault take-off period. Fifteen of the twenty spring-floor trials showed two brief knee flexion periods (Figure 8). Nine of the twenty Air Floor trials showed a similar knee angle pattern as the spring-floor trials, during backward somersault take-offs. Figure 9 shows an example of a layout backward somersault take-off with a single knee flexion period. Both knee flexion examples in Figures 6 and 7 came from the spring-floor trials. The forward handspring to forward layout somersault knee angles showed no unusual pattern with an unremarkable smooth knee angle motion change through the take-off period.

Electromyographic Comparisons

The scaled muscle activation comparisons for the forward handspring to forward layout somersault take-off showed statistical significance only in terms of muscle activations within the skill. Scaled muscle activations main effects for floor-types were not statistically different ($F_{(1,4)} = 0.1$, $p = 0.77$, $\eta^2_{partial} = 0.02$, power =0.06), nor was the floor-type by scaled muscle interaction ($F_{(7,28)} = 1.08$, $p = 0.40$, $\eta^2_{partial} = 0.21$, power = 0.38). The main effect for scaled muscle activation was statistically significant ($F_{(7,28)} = 2.51$, $p = 0.04$, $\eta^2_{partial} = 0.39$, power = 0.78). Figure 10 shows the electromyographic data for the forward layout somersault take-off.

Forward Layout Somersault Take Off
Scaled Muscle iEMG (µV·s)

Floor-Type	Muscle	Mean	SD
Spring Floor	Soleus	69.62	22.16
	Gastrocnemius	44.29	11.72
	Biceps Femoris	37.87	7.12
	Gluteus Maximus	44.33	34
	Lumbar Erector	53.85	4
	Peroneus Longus	63.75	18.75
	Anterior Tibialis	70.94	29.98
	Vastus Lateralis	69.93	24.43
Air Floor	Soleus	68.21	24.37
	Gastrocnemius	48.08	10.14
	Biceps Femoris	42.49	4.21
	Gluteus Maximus	33.89	21.24
	Lumbar Erector	55.69	6.3
	Peroneus Longus	62.54	19.12
	Anterior Tibialis	72.33	29.09
	Vastus Lateralis	66.73	26.84

Figure 10. *Forward layout somersault take-off scaled iEMG comparisons.*

Backward Layout Somersault Take-off
Scaled Muscle iEMG (µV·s)

Floor-Type	Muscle	Mean	SD
Spring Floor	Soleus	67.2	24.15
	Gastrocnemius	59.21	24.19
	Biceps Femoris	84.97	14.44
	Gluteus Maximus	50.49	31.57
	Lumbar Erector	71.44	17.48
	Peroneus Longus	63.67	24.13
	Anterior Tibialis	71.07	21.47
	Vastus Lateralis	57.92	24.27
Air Floor	Soleus	64.19	17.47
	Gastrocnemius	58.71	14.13
	Biceps Femoris	86.59	10.91
	Gluteus Maximus	46.19	18.32
	Lumbar Erector	67.86	11.04
	Peroneus Longus	66.86	23.67
	Anterior Tibialis	74.95	25.42
	Vastus Lateralis	53.78	14.87

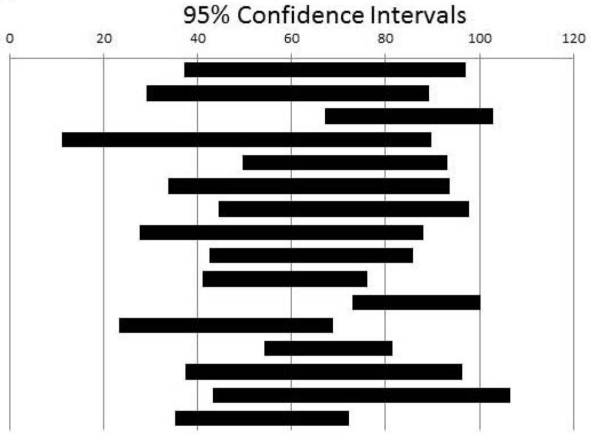

Figure 11. *Backward layout somersault take-off scaled iEMG comparisons.*

Forward Somersault Take-off Force (N)

Floor-Type	Foot	Mean	SD
Spring Floor	Left	1322.25	676.44
	Right	1327.90	675.30
Air Floor	Left	1277.58	618.70
	Right	1273.21	625.72

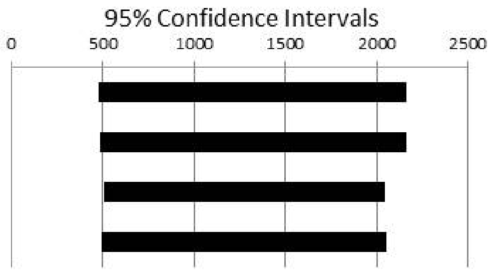

Figure 12. *Forward layout somersault take-off feet plantar surfaces force comparisons.*

Backward Somersault Take-off Force (N)

Floor-Type	Foot	Mean	SD
Spring Floor	Left	1817.56	769.22
	Right	1754.98	779.54
Air Floor	Left	1885.55	495.82
	Right	1674.61	482.25

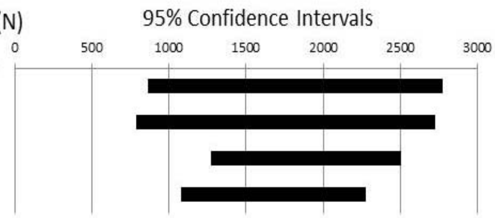

Figure 13. *Backward layout somersault take-off feet plantar surfaces force comparisons.*

Contact Time Duration (s)

Floor-Type	Direction	Mean	SD
Spring Floor	Forward	0.127	0.011
	Backward	0.138	0.007
Air Floor	Forward	0.149	0.014
	Backward	0.157	0.007

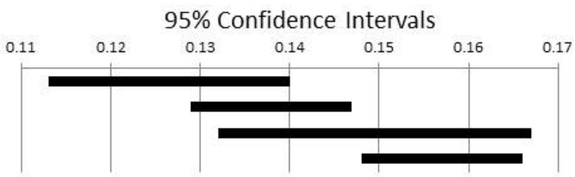

Figure 14. *Take-off total foot contact time durations by somersault direction*

Scaled muscle activation comparisons for the backward layout somersault take-off on both floor-types showed no statistically significant differences on any dimension. The floor-type main effect was ($F_{(1,4)} = 0.86$, $p = 0.78$, $\eta^2_{partial} = 0.02$, power = 0.06), the scaled muscle activations was ($F_{(7,28)} = 1.82$, $p = 0.12$, $\eta^2_{partial} = 0.31$, power 0.62), and the floor-type by scaled muscle activation was ($F_{(7,28)} = 0.31$, $p = 0.94$, $\eta^2_{partial} = 0.07$, power = 0.13). Figure 11 shows the electromyographic data for the backward layout somersault take-off.

Feet Plantar Surfaces Force Comparisons

The handspring to layout forward somersault take-offs were not statistically different in measures of mean peak foot plantar surface forces (floor-type: $F_{(1,4)} = 1.86$, $p = 0.24$, $\eta^2_{partial} = 0.32$, power = 0.19; left versus right foot: $F_{(1,4)} = 0.007$, $p = 0.94$, $\eta^2_{partial} = 0.002$, power = 0.05; floor-type by mean peak foot plantar surface forces interaction: $F_{(1,4)} = 0.95$, $p = 0.39$, $\eta^2_{partial} = 0.19$, power = 0.12). Figure 12 shows the forces on the foot plantar surfaces comparisons.

Similarly, the round off, flic flac, to layout backward somersault take-offs were not statistically different in measures of mean foot plantar surface peak forces (floor-type: $F_{(1,4)} = 0.001$, $p = 0.97$, $p = 0.39$, $\eta^2_{partial} < 0.001$, power = 0.05; Foot: $F_{(1,4)} = 2.32$, $p = 0.20$, $\eta^2_{partial} = 0.37$, power = 0.22; floor-type by foot interaction: $F_{(1,4)} = 2.74$, $p = 0.17$, $\eta^2_{partial} = 0.41$, power = 0.25). Figure 13 shows the foot plantar surface force comparisons.

Take-off Floor Contact Durations Comparisons

Floor contact durations statistically differed by floor-type ($F_{(1,4)} = 44.19$, $p = 0.003$, $\eta^2_{partial} = 0.92$, power = 1.0). The forward or backward tumbling take-off direction contact times did not reach statistical significance ($F_{(1,4)} = 3.84$, $p = 0.12$, $\eta^2_{partial} = 0.49$, power 0.33) nor did the floor-type by tumbling take-off direction interaction ($F_{(1,4)} = 1.18$, $p = 0.34$, $\eta^2_{partial} = 0.23$, power 0.14). Figure 14 shows the foot contact durations comparisons.

DISCUSSION

This is a pilot study, attempting to discern the relative promise of future analyses of the gymnasts' interactions with these types of tumbling floors. As such, there were modest, but not surprising, statistical differences in some comparisons with an overall judgment indicating that the Air Floor probably "feels" softer and slower than the spring-floor alone. Beyond the take-off contact durations and probable decreased stiffness of the Air Floor, take-off techniques do not appear to be distorted by the Air Floor. The Air Floor may be a welcome addition to gymnastics tumbling training based on a reduced harshness of take-offs.

Reliability values across the tumbling pass trials were uniformly high based on intraclass correlations. Electromyography data were the most variable demonstrating high technical errors of measurement for some muscles across trials. The mean peak foot plantar surface force measures also showed modestly high, technical errors of measurement across trials, again indicating that some intra-individual performance variability was observed.

The kinematic analyses showed primarily that the lower extremity joint angles during take-off in the forward handspring to forward layout somersault may have resulted in some floor-type technique dependencies based on the statistically significant spring-floor-type by joint angle by lower extremity floor contact position interaction. Inspection of the confidence intervals and effect size indicators may indicate that the reason for the significant three-way interaction lies primarily with the obvious joint angle differences required by the take-off skill performance and selected body position time-points at the different contact positions, as opposed to a factor specific joint angle differences caused by the spring floor-types.

The backward somersault take-off presented a more puzzling and perhaps important variation in take-off technique both within and between floor-types. A more thorough investigation of the dynamic changes in knee angles and positions during the backward somersault take-off opens a line of questions regarding what would cause a gymnast to flex his knees twice during what is primarily a rapid jump that follows a flic flac and leads to a somersault.

The two knee flexions in the lower extremity during a single jump may be the result of several mechanisms, acting individually or in concert:

- the spring-floors may have produced an intermediate vibration of such magnitude that the gymnasts' knees are forcefully "re-flexed" due to an asynchronous or intermediate timed recoil,
- the spring-floors' stiffness may be out of sync and/or inappropriate for the natural stiffness of the gymnasts' lower extremity muscles,
- and/or the gymnasts' second knee flexion may not contribute to the rebound-type jump of the gymnast but rather contribute to enhancing the rotational momentum of the backward somersault.

A statistical difference in muscle activations was found in the forward layout somersault take-off for muscle-by-muscle comparisons, while the backward layout somersault showed no statistical differences on any dimension. However, the effect size estimates for the forward layout somersault scaled muscle iEMG values and the floor-type by scaled muscle iEMG values interaction indicated a modest effect. The variability of performance variables may have influenced traditional statistical analysis because of the small sample size and pilot-nature of this study. The backward layout somersault showed a modest effect size for the scaled muscle iEMG values only. Consulting Figures 10 and 11, the 95% Confidence Intervals provide a visual distinction between the two directions of take-offs, and to a lesser extent, the potential influences from the floor-types. Figures 10 and 11 also appear to show that the backward layout somersault take-offs elicit more muscle involvement and at higher levels than the forward layout somersault take-offs via the 95% Confidence Intervals (McNeal et al., 2007). Drop jumps onto two types of spring-floors from 0.22 m and 0.42 m showed no statistical differences between floor-types, while a statistical difference was evident between the EMG data from the gastrocnemius and rectus femoris muscles (Gormley, 1982).

Mean peak foot plantar surface forces were not statistically different in any of the comparisons. As expected, the overall peak force values were obtained during the backward layout somersault take-offs (Figures 12 and 13). The mean peak plantar surface forces in this study ranged from 1273 N to 1885 N, well below the maximal peak forces of 5000 N documented as the maximal permissible force limit of floor impacts (Wilson et al., 1986). The greater backward somersault take-off forces is supported by McNeal and colleagues' investigation of muscle activation comparisons (McNeal et al., 2007). A non-statistically significant trend was noted in the forward handspring to forward layout somersault take-off with the spring-floor exhibiting greater forces. In the backward layout somersault, the non-statistically significant trends were mixed. Effect sizes for these comparisons may indicate potential floor-type and left/right foot effects that were probably overwhelmed in the analysis because of variability and the small sample in this pilot study. Of particular anecdotal interest (the gymnasts did not perform twisting somersaults in this study), but requiring more investigation, was the 100% correspondence of greater plantar surfaces forces arising from the foot opposite to the gymnast's preferred twist direction. In other words, if the gymnast twists to the left, he demonstrated relatively higher mean peak forces on the right foot plantar surface. Again, foot plantar forces dependence on twist direction was supported by bilateral EMG comparisons by McNeal and colleagues (McNeal et al., 2007).

Spring-floor contact durations were greater in this study than those of McNeal and colleagues (McNeal et al., 2007), while comparing almost identically to the floor contact durations provided in a spring-floor comparison study of cylindrical springs with conical springs (114 ms to 120 ms) (Gormley, 1982). The 115 ms contact time for the forward layout somersault take-off and 117 ms contact time for the backward layout somersault take-off may have occurred because of the increased size and mass of the male tumblers contrasting with the McNeal and colleagues (2007) findings. However, the Air Floor take-offs were statistically longer in this study than those of McNeal and colleagues (2007), 149 ms for forward somersault take-offs and 157 ms for backward somersault take-offs. Both studies and surfaces followed the same trend that backward somersault take-offs required slightly more time than forward somersault take-offs.

The premise that spring-floors are too stiff has been proposed by Paine (1998) in a bioengineering doctoral dissertation based on frequency analysis of the backward somersault take-off from a round off and flic flac. An earlier study using drop weight tests found that two types of spring-floors demonstrated stiffness values approximately 2.3 to 2.4 times the stiffness of lower extremity muscles in running and jumping activities (Gormley, 1982). Paine (1998) also determined that by reducing the fundamental frequency of the spring-floor of that era by half, take-off velocities were enhanced. In short, by "softening" the floor Paine was able to achieve a more comfortable and effective backward somersault tumbling take-off. A study of layout backward somersault flight trajectory distance on a spring-floor versus a foam block floor among U.S female national team members showed that the foam block floor resulted in longer flight trajectories from take-off to landing (Sands & George, 1988). The investigators speculated that the reason for the lengthened trajectory distance was because of the reduced stiffness of the foam block floor thus allowing the gymnast to prolong her foot contact phase and depart from the floor surface with slightly more rearward horizontal velocity.

CONCLUSION

This initial comparison of two types of tumbling surfaces showed that while there are some modest differences in the surfaces, there does not appear to be deleterious effects on tumbling take-off technique. The Air Floor, as expected, appears to be a softer surface permitting less harshness in both directions of take-offs. A limitation of this study was the inability to measure the pressure of the inflated Air Floor. However, practitioners are unable to measure the inflation pressure and rely exclusively on the "feel" of the surface's stiffness to gauge pressure level.

There appears to be a consensus among scientists and practitioners that softer take-off and landing surfaces may contribute to injury prevention. If this is true, the Air Floor has many of the indicators of decreased impact harshness and may allow gymnasts to perform more repetitions with less lower extremity stressors than the spring-floor alone. However, one should be cautioned that a potential revenge effect could occur in that a feeling of decreased harshness may lead to over training via too high volume of repetitions of difficult skills.

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NEW TOOL TO ASSESS THE FORCE PRODUCTION IN THE SWALLOW

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Research article

Abstract

8 men artistic gymnasts were evaluated with a new test protocol in order to assess isometric strength in an specific hold position on still rings. The proposed test protocol measures the force applied the gymnast on the rings from an initial lying prone position on a force platform while he is trying to achieve the Swallow (or Hirondelle) position. The vertical force (FZ) from the forcetime curve registered (100 Hz) was used and it showed a descent from the initial body weight level caused by the gymnast force on the rings and, later, a maximal isometric force period. Fundamental and derivate variables to extract from the evolution of Fz were defined. Results showed significant statistical differences between gymnasts that could perform the Swallow (P) from those that could not (NP) (p<0.05). Performer gymnasts were characterized by a higher percentage of body weight descent and higher strength in relation to body mass (p<0.05). The practical application of this tool could be to provide coaches with information about how close the gymnast is to perform the Swallow.

Keywords: *Men's Artistic Gymnastics, Biomechanics, Rings, Swallow.*

INTRODUCTION

Measuring the athletes' performance is crucial to determine their progress and potential in any sport. The measurement and evaluation of the different components of performance is part of the training monitoring process, which aims to provide consistent information about the effects of the training load and the physical and technical condition of the athlete. This valuable information helps the coach to individualize the training process and provides the athlete with adjusted and individualized stimuli in order to obtain the optimum performance. Optimize and contextualize the evaluation of the athlete is necessary for a proper diagnosis and monitoring of the training (GonzálezBadillo & Izquierdo Redín, 2006).

Gymnast performance is not based in the objective measurement of distances, weight or times, but it depends on a subjective scoring of the judges. Therefore, competition results cannot be the single source of information to guide the work of the coach. However, during the training process, measurement of valid and objective quantitative variables as the force can provide both the athlete and coach, with helpful information about the progress made during the slow and limited teaching-learning process in rings. It would be useful for coaches and gymnasts to know how close or far that is the gymnast from performing static force elements in order to focus the training on a selected element due to the proximity of the gymnast to the levels of force required to perform it, or to abandon the idea of perform the element because this level of force is not possible to acquire by the gymnast in short-term (Dunlavy et al, 2007).

There are several studies that attempt to analyse the variables with a greater impact on the gymnast's performance. Back in the '60s, Pool, Binkhorst & Vos (1969) related the anthropometric and physiological data of female artistic gymnasts with their performance at the European Championships in 1967, indicating significant correlations between the chest circumference and the total score. In this sense, Sharma & Nigam (2010) indicate no relationship between physiological variables such as heart rate and blood pressure with the performance in competition for college male and female artistic gymnasts. On the other hand, Grande et al. (2008) found correlations between the legs power measured using jump test and "D" and "E" scores on different events in high level artistic female gymnasts.

Leon-Prados et al. (2011) found interesting correlations between different variables recorded by specific physical test in men and performance in parallel bars, high bar and pommel horse. These authors showed how the maximum number of repetitions to Swiss press from L-sit showed a significant correlation with the gymnast performance of parallel bars ($r=0.825$, $p<0.05$) and high bar ($r=0.678$, $p<0.05$).

Despite these references, to measure and evaluate the athlete during the training process and the validity of that information in order to guide the coach work is still an open field for researching and innovation.

Along the learning process of any element, it would be very useful for coaches to have a tool which allowed determining the gymnast level of assimilation or learning in any specific technical element to focus the gymnast on weakness points in order to accelerate progress towards more advanced elements. This fact is specially emphasized in the still rings event and especially in the strength and maintenance difficulties (Group IV, Code of Points - Men's Artistics Gymnastics) (FIG, 2009). One of the disadvantages of the training process of these difficulties is that information on the progress and potential of the athlete are absolutely unknown along the period of preparation of the gymnast (Sands, Dunlavy, Smith, Stone, McNeal, 2006).

If we focus on the studies carried out in still rings, most of them are developed in the field of biomechanics, and they applying three methods of analysis: photogrammetry, electromyography and force platforms. Based on the analysis mathematical simulation of human motion applications, multiple studies have been conducted on this event. Sprigings et al. (1997) showed that using computer simulation can help to reduce intermediate rings swings between the long-swing elements. By using a combination of photogrammetry and tensionmetric gauges, Brewin et al. (2000) demonstrated that the changes in the technique and flexibility reduced force peaks on the gymnasts' shoulders while they performed long-swings. Yamada et al. (2002) developed a simulator robot of long-swing elements in the still rings.

Moreover, the contributions of electromyography (EMG) have been conducted primarily at determining the specific muscle groups involved in performing a particular difficulty and the ability to reproduce patterns of actions through facilitated positions. Bernasconi et al. (2004) found significant differences in muscle coordination in the performance of cross in rings with and without forearm support devices. Bernasconi et al. (2009) differentiated specific muscle coordination for three different Swallow (or Hirondelle) training methods. Campos et al. (2011) demonstrated that the coordinated action of the biceps and triceps, serratus anterior, lower trapezius, pectoralis major, latissimus dorsi, anterior deltoid and the infraspinatus is responsible for the successful completion of the Swallow.

Studies that used the force platform in gymnastics are very specific and they study variables related to balance, proprioception and strength on hold positions. Vuillerme et al. (2001) showed that the gymnasts are able to use remaining sensory capabilities to compensate the lack of vision in unstable positions.

Dunlavy et al. (2007) used force platforms to assess the force performance on simulated rings cross positions. This work was based on a clear premise: to achieve the holding of a strength hold position on rings, the gymnasts must be able to produce, in that specific body position, a level of force equal to or greater than their own body weight. Under this premise and applying it to the Cross position (Element 14, Group IV, Difficulty B) (FIG, 2009), these authors conducted a study simulating the execution of this element over two force platforms located on two supports. This analysis demonstrated that the sum of the recorded data by both force platforms was sufficiently accurate to distinguish between gymnasts “performers” and “no performers” of this element.

This latter approach is the framework of our work, in this case applied to Swallow element (Figure 1), which is a support scale maintained at rings height for at least two seconds (Element 10, group IV, Difficulty D) (FIG, 2009). In the technical implementation of the Swallow, commonly called butterfly, the body must show a position parallel to the ground, while the upper extremities are in the same horizontal plane with a slight shoulder abduction (García Carretero, 2003). The upper extremities, trunk, lower limbs and the lower part of the rings must be maintained in the same horizontal plane for the perfect execution of the element.

This element was selected because is a very common element that the vast majority of high level international gymnasts have in their competition routines.

Figure 1. *Gymnast performing a Swallow in still rings.*

Developing a measurement tool of this specific capacity of force applied to each still rings strength hold position, determining the minimum amount of strength required for a correct execution and, consequently, to have a tool to predict when an element may be ready for inclusion in a competition routine, it would be helpful to improve individualized technical learning plans for each gymnast on this event.

The main aim of this study was to develop a tool for measuring specific strength production of the gymnast performing the Swallow in the still rings, using a single force platform.

Associated with this main target several secondary objectives were established: (1) defining the specific variables analysis of element, (2) testing the reliability of the measurements with this tool, (3) determining the ability of tool to discriminate between performers and no performers gymnasts on this element and (4) determining the minimum level of force required by the athlete to run this strength hold position.

METHODS

Instruments

To develop this measurement tool, a portable force platform (FP) Kistler Type 9286B forces (Kistler, Switzerland) which records the three force components (Fx, Fy and Fz) was used. Only the vertical force values (Fz) were used at a sampling frequency of 100 Hz. BioWare software was used for recording measurements of force (N) respect to time (s). Training still rings adjustable in height, a plinth with a solid top surface and weighted belts (79.5 N) were used as supplementary material.

For the test, FP was placed on the plinth (height 62 cm). A structure of wood and metal was located on top of the plinth to achieve stability and robustness to support FP. This material placement brought up similar conditions to the completion of the element (sensation of suspension at a height above the ground) and prevented the athlete hit the floor with the rings or the lower limbs, something that was observed during the implementation of the pilot trials.

A fitness bar with two discs on each side with a total weight of 367.76 N was placed between the rings to adjust the height of them, to generate sufficient tension in the cables and to serve the horizontal reference between the FP surface and the upper edge of the lower part of the rings (Figure 2).

Figure 2. *Detail of the height adjustment of the rings and material setting*

The FP was calibrated with the additional weight carried by the gymnast. Thus, when the gymnast was located on the FP with the extra weight, only the weight of the gymnast was recorded. Measurements of the noise recorded by the platform on the floor and at the selected high were done, and no statistical differences were found between both situations.

Procedures

To perform the test, the gymnast lay in prone position on the FP, wearing the weighted belt, with the abdomen in the central part. The weighted belts were used for preventing elevation of the gymnast over the FP and losing the record of vertical force (Fz) during the whole test.

The gymnast adjusted his grip on the rings and placed in a comfortable position without touching any part of his body in other surface than the FP and the rings.

When the gymnast confirms he was ready, he began the test without making force on the rings. After a previously known beep, he applied an explosive force on the rings to achieve the position in the shortest time possible (i.e. avoiding performing a maximum isometric strength slowly and gradually). The gymnast was previously instructed to keep the element indicated for a minimum of 5 seconds (González Ribas-Badillo & Serna, 2002).

The test was aborted and repeated if the gymnast got in contact with any part of his body a surface different to the FP or the rings during the test.

Three attempts were recorded for each gymnast (González-Badillo & Gorostiaga Ayestarán, 1995) with a rest period of approximately 3-5 minutes between each attempt (Zatsiorski, 1982). The average of the three records obtained from each gymnast was used for the presentation of results and statistical calculations.

The recording time for each trial was programmed scheduled in 10 seconds. During that time, three phases were distinguished:

- Phase 1. *Body weight baseline record*. Recording time about 3 seconds before the beep tone, in which the gymnast was in lying prone position without applying force. The record is a horizontal line corresponding to approximate body weight of the gymnast (Figure 3).

- Phase 2. *Force explosive phase*. After the signal the gymnast applied an explosively force on the rings. Is reflected in the graph F / t as a descent steep slope corresponding to the time of release from the gymnast body weight.

• Phase 3. *Isometric force phase*. The gymnast performed strength levels close to his maximal isometric force (MxIF) values and try to maintain this level for 5 seconds. Graph shows an almost horizontal line around the value 0.

Figure 3. *Starting position and grip of the gymnast on the FP*.

The tests were performed during a regular training session at the High Performance Centre (CAR) of the National Sports Council (CSD) in Madrid after a 20 minute warm-up, with exercises appropriated to this kind of effort.

Participants

Eight gymnasts from the Men's Artistic Gymnastics (MAG) Spanish National Team voluntarily implemented the proposed test (Table 1). Subjects were informed of the nature and details of the test run, signing an informed consent which was approved, as the rest of the study, by the ethics committee of the Technical University of Madrid (UPM).

Participants were divided into two groups for analysis of the results. Group 1: Gymnasts Performers of the Swallow (n= 4). Group 2: Gymnasts No Performers (n= 4).

	Age (years)	Height (m)	Body weight (N)
Group (n=8)	20,5±4,4	1,68±5,67	646,33±63,1
No Performers (n=4)	17±1,2*	1,71±0,05 *	662,25±71,5
Performers (n=4) *	24±3,6*	1,65±0,05 *	630,41±51,6

Table 1. Features of age (years), height (m) and body weight (N) of the sample expressed in Mean ± SD (* $p < 0.05$).

Variables

The variables selected were divided into two groups:

a. <u>General or fundamental variables (Figure 4):</u>

• Slope (S): Slope of the F/t curve in the first 100 ms of application of force. The starting point of the application of force was established in the first instant that there was a continuous decrease of the curve F/t. The slope recorded in a given time period has been used in other studies as in the case of Willson et al. (1993) and Christ et al. (1994).

• Maximal Isometric Force (MxIF): It was the lowest recorded force value due to the release of the weight due to the effort of the gymnast.

• Mean Isometric Force (MnIF): Mean isometric force calculated for the period of 2 seconds with a lower standard deviation (higher stability of the strength). This period of two seconds was selected based on MAG Code of Points criteria for a properly maintained hold position on still rings is properly maintained (FIG, 2009). Dunlavy et al. (2007) used this variable in their study, although the selection criteria of the time interval were different.

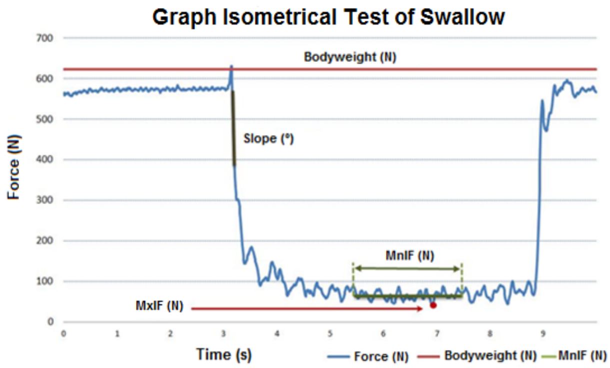

Figure 4. *F/t graph locating fundamental variables: Slope (S), Maximal Isometric Force (MIF) and Mean Isometric Force (MnIF).*

b. <u>Specific or derived variables:</u> two groups of variables are defined to be calculated based on the MxIF or MnIF:

b.1. Variables calculated from the value of MxIF:

- Absolute Released Force (MxIF-ARF): Difference between the gymnast body mass (N) and the MxIF (N). This reflects the total of the gymnast strength of about MxIF.
- Percentage of Released Force (MxIF-%RF): Percentage value (%) of MxIF-ARF by bodyweight of the gymnast.
- Relative Released Force (MxIF-RRF): Relationship established between the MxIF-ARF (N) and the value of the gymnast mass (kg). This reflects the strength capacity of the gymnast per body mass relative to MxIF. It is measured in N * kg^{-1}.

b.2. Variables calculated from the value of MnIF :

- Absolute Released Force (MnIF-ARF): Difference between gymnast body mass (N) and MnIF (N). This reflects the total strength of the gymnast regarding MnIF.
- Percentage of Released Force (MnIF-%RF): Percentage value (%) of the value MnIF-ARF (N) by bodyweight of the gymnast.
- Relative Released Force Unleashed (MnIF-RRF): Relationship established between the MxIF-ARF (N) and the value of the gymnast mass (kg). This reflects the strength capacity of the gymnast per body mass relative to MnIF. It is measured in N * kg^{-1}.

Statistical Analysis

Were calculated descriptive statistics (mean, minimum, maximum and standard deviation) of the variables of age, height and bodyweight of the sample used and the defined variables of strength tests performed.

An analysis of the reliability of the measurements obtained from the variables was performed by calculating the Intra-class Correlation Coefficient (ICC) and the Coefficient of Variation of the Standard Error of Measurement (CV_{SEM}), (Leon-Prados, Gómez-Piriz, and González-Badillo, 2011).

U of Mann-Whitney was run used to assess the statistical differences of the variables of the strength test between groups of gymnasts NR and R.

The minimum statistical significance was set at p=0.05 for all statistical tests.

Collection and calculation values of the variables were performed using a Microsoft Office Excel 2010 sheet. For statistical analysis of the results SPSS software version 18 was used.

RESULTS

Table 1 shows the characteristics of the eight gymnasts in this study (4 P and 4 NP of the Swallow). P gymnasts showed a mean age of 24±3.7 years, height of 1.65±0.05 m, and body mass of 630.4±51.6 N, and NP Gymnasts a mean age of 17±1.27 years, height of 1.71±0.05 m, and body mass of 662.2± 71.5 N.

The results of the analysis using the nonparametric U of Mann-Whitney test showed that age (Z=3.753, p<0.001) were significantly higher for gymnasts P and height (Z=2.10, p<0.05) significantly higher for NP. While the bodyweight was not significantly different between P and NP (Z=1.05, p=0.32).

Table 2 shows the overall results for fundamental and derived variables selected on the study.

Table 2. *Overall results for fundamental and derived variables.*

	Mean	Standard Deviation	Minimum	Maximum
Slope (º)	86,31	5,07	68,92	88,77
MxIF (N)	81,39	88,21	-50,37	171,30
MnIF (N)	122,35	86,71	-16,54	223,58
MxIF-ARF (N)	564,94	109,86	762,27	360,07
MxIF-%RF (%)	75,75	7,46	62,50	85,89
MnIF-ARF (N)	523,98	106,90	728,44	340,86
MnIF-%RF (%)	80,90	12,85	58,97	103,59
MnIF-RRF (N * kg^{-1})	7,93	1,26	5,78	10,15

Table 3. *Study of reliability through the Intraclass Correlation Coefficient (ICC) and the Coefficient of Variation of the Standard Error of Measurement (CVSEM) for MxIF- ARF (N), MxIF-%RF (%), MIF-RRF (N * kg-1), MnIF- ARF (N), MnIF-%RF (%) and MnIF-RRF (N * kg-1).*

	ICC	CV_{sem}(%)	p
MxIF-ARF (N)	0,993	3,82	< 0,01
MxIF-%RF (%)	0,988	3,14	< 0,01
MxIF-RRF (N * kg^{-1})	0,988	3,14	< 0,01
MnIF-ARF (N)	0,995	4,00	< 0,01
MnIF-%RF (%)	0,992	3,24	< 0,01
MnIF-RRF (N * kg^{-1})	0,992	3,24	< 0,01

Table 4. *Results for fundamental variables and derived variables used in the study differentiating by groups (* p <0.05).*

	Group	Mean	Standard Deviation
Slope (º)	P	87,25	2,18
	NP	85,38	3,58
MxIF (N)	P	5,62 *	37,91
	NP	157,16 *	37,54
MnIF (N)	P	48,11 *	45,70
	NP	196,60 *	27,47
MxIF-ARF (N)	P	624,69	93,22
	NP	505,09	99,60
MxIF-%RF (%)	P	98,75 *	5,65
	NP	75,75 *	8,05
MxIF-RRF (N * kg^{-1})	P	9,68 *	0,55
	NP	7,42 *	0,79
MnIF-ARF (N)	P	582,30	102,44
	NP	465,66	84,27
MnIF-%RF (%)	P	91,86 *	7,54
	NP	69,93 *	6,18
MnIF-RRF (N * kg^{-1})	P	9,00 *	0,74
	NP	6,85 *	0,61

Table 3 shows the results of the reliability analysis for the measures of the variables obtained by the Coefficient of Variation of the Standard Error of Measurement (CV_{SEM}) and Intra-class Correlation Coefficient (ICC).

The reliability analysis results showed CV_{SEM} values below 5% for MxIFARF, MxIF-%RF, MxIF-RFU, MnIF-ARF, MnIF-%RF and MnIF-RFU, being these variables also among those that did not differ significantly between trials with high rates of ICC.

Differentiated results for P and NP regarding the selected fundamentals and derived variables are shown in Table 4.

The results for MxIF-ARF (Z=1.73, p=0.11) and MnIF-ARF (Z=1.44, p=0.20) showed not significant differences between NP and P. While results for MxIF, MnIF,

MxIF-%RF, FIM-RRF, MnIF-%RF and MnIF-RFU were significantly different between P and NP (always Z=2.31, p<0.05). The calculated value of slope showed no statistically significant difference between NP and P (Z=0.87, p=0.49).

DISCUSSION

As it has shown in the methods section, we have developed a tool for measuring specific isometric force to perform the Swallow in MAG still rings, which requires a single portable force platform for assessing the availability or possibilities of the gymnast to perform the element. The evaluation methodology applied to this element can be adapted to other positions of strength hold in rings and it could have multiple applications for controlling the training of gymnasts.

As positive aspects of the proposed tool, it should be noted that it can be used in the training hall and during the training process. The information provided by the proposed protocol cover the requirements of the coach for knowing the degree of assimilation of the technical element that the gymnast is learning.

For example, a NR gymnast with lower strength levels and a weight 557.65 N was able to release on the force plate a MxIF of 360.05 N, which is a 65% of his weight and a relative force to his weight (MxIF-RRF) of 6.33 N * kg^{-1}.

Considering the mean force during 2 seconds (MnIF) of 340.86 N, which is a 61% of his weight, and a MnIF-RRF of 5.99 N * kg^{-1}. In order to correctly perform the Swallow, the gymnast should reach a MxIF until 557.65 N (100% of his weight) by increasing his maximum strength or reducing his weight (something impossible because he is a very light gymnast); in that way he will improve his currently poor MxIF-RRF above 9 N * kg^{-1}. Increasing his maximum strength levels will probably elevate his levels of MnIF and MnIF-RRF until 90% of his weight and close to 9 N * kg^{-1}, respectively, which are the values obtained by the P gymnast.

As weak negative points, it can be pointed out that: (1) the use of the software for data collection and the interpretation of the data requires an appropriate training, (2) The information is not provided real time; in order to achieve the defined variable values an specific data processing of the collected data is required, so that, the information cannot be used as instant feedback for the gymnast. However, this is a research work, and its results and conclusion can be in future implemented by a software that automatically establish the fundamental and derived variables and provide the coach and gymnast with a real-time feedback.

Definition of variables

Associated with the protocol definition of test execution valuation, general (i.e. MxIF, MnIF and S) and specific variables (MxIF-ARF, MxIF-%RF, MxIFRFU, MnIF-ARF, MnIF-%RF and MnIF-RFU) have been defined. These latter variables are more useful for specific evaluation of gymnast and they can help determine the degree of assimilation of the analysed element.

The application of the proposed protocol in two groups of gymnast characterized by the performance or non-performance of the Swallow showed interesting results. The groups have different ability to apply force and release bodyweight of the force platform in specific the test. This was evident in the statistically significant differences found in multiple variables: MxIF, MnIF, MxIF%RF, MxIF-RFU, MnIF-%RF and MnIF-RFU.

The analysis of the slope of curve F/t in the first 100 milliseconds of force application showed no statistically significant differences between the two groups analysed. The analysis of this slope did not provide useful information for the coach so it seems not recommended for controlling the improvement in this element. In agreement with our results regarding the limited information provided by the rate of force development, González-Badillo & Ribas Serna (2002) indicated that this variable is the less reliable of all that can be extracted from an isometric measurement.

González-Badillo & Izquierdo Redín (2008) indicated that one factor to consider during an isometric test is the characteristics of the instructions provided to the subject. This test differentiates a progressive from explosive muscle activation. Sahaly et al. (2001) indicate that the instruction modifies the gymnast transmitted force production per unit time (RFD), so we will not get the same result if the instruction is "as fast as possible" than if is indicated "as hard and fast as possible”. In our case we select the protocol with rapid muscle activation for two reasons: first, to try to be closer to the nature of gymnast effort on rings, which is not possible a progressive activation and, second, to calculate the slope of the F/t curve a possible indicator of the RFD.

We should also highlight that the variables MxIF-ARF and MnIF-ARF do not reach statistically significant differences between groups of P and NP gymnasts. Using this protocol, the absolute value of the released weight would not be a valid variable to predict the execution of the Swallow in male gymnastics.

P gymnasts are characterized by generate a significantly greater percentage of force considering their body weight with values of 98.75 ± 5.65% for the MxIF-%RF and 91.86 ± 7.54% for the MnIF-%RF with significant higher values on these two variables for the P gymnasts.

Other Important variables that showed significant differences between P and NP, were the relative values of strength in case of both MxIF-RRF and MnIF-RRF. These variables define the ability to generate force possessed by gymnasts per body mass (Arkaev & Suchilin, 2004).

Using our tool, variables expressed in percentage or relative values would be more valid as a predictor of execution of the Swallow. This agrees with the recommendation of expressing the variables as a relative to the bodyweight value (Ariza, 2004) in their work oriented to gymnast prediction performance.

Reliability and objectivity

The reliability analysis of repeated measures on more than one occasion shows no significant differences between trials, showing high values of CV_{SEM} and ICC always below 5%, indicating internal consistency between measures.

The test protocol has been described in detail so that it can be replicated by other researchers; this point has to be verified in order to probe its objectivity. Analysing the reproducibility of the proposed tool may be purpose of future studies

P versus NP

According to the characteristics of the sample, the gymnasts showed some differences which could affect the ability to apply force. This could be directly related to the age of the gymnasts, as the performers were significantly older than the non-performers. Similarly, the height would be inversely related to this capability and the performers show significantly lower stature to nonperformers. Regarding weight were not found significant differences between groups. However, these differences do not interfere with the ability of the protocol to discriminate between P and NP gymnasts.

The differences found between some variables support that the gymnast’s ability to apply force is a key factor that we should be controlled to get information on how close or far is the gymnast to perform the Swallow on still rings.

Regarding the relative strength to bodyweight, performer gymnasts show a significantly better outcome in the test (MxIF-RRF: 9.68±0.55 N * kg^{-1}; MnIFRRF: 9.00±0.74 N * kg^{-1}). NP Gymnasts show significantly lower values for both variables (MxIF-RRF: 7.42±0.79 N * kg^{-1}; MnIF-RRF: 6.85±0.61 N * kg^{-1}).

Minimum level of force

As seen in the data obtained for MnIF (Table 4), although in the case of P the value for this variable is very close to the total release of body weight (48.11 ± 45.70 N), it decrease below the value 0 only in two gymnasts. The reason of not reaching values below 0 N (despite having four gymnasts R) could be the location of the weight added to the gymnasts. Being this weight located at the waist, this could result on a small change in the location of the centre of gravity that could modify the actual conditions of execution. Given this situation, it could be proposed a new study placing the added weight on the chest, with a weight –vest.

Another reason for not producing the full liberation of body weight on the execution may be the location of the still rings for proper execution of the element (i.e. whether or not the position of the performer gymnast height is at the level of grip rings or slightly off, which is a penalty).A biomechanical study of the location of the centre of gravity and the position of the gymnasts in relation to the grip of the rings could also provide with useful information in this regard.

This methodology could make way for future research of other static elements on still rings, for example, the still ring cross, a static position very frequently used in competitions and highly representative in gymnastics which has been investigated with other methods,.

Reach a release of the body weight close to 100% on this protocol calculated by the variable MxIF-%RF and exceed a value of 90% approximately in the case of calculating the variable MnIF-%RF could indicate that the gymnast has the required specific strength to perform this element.

On the other hand reaching a MxIF-RRF value greater than 9 N * kg^{-1} or a MnIF-RRF value close to 9 N * kg^{-1} may indicate that the gymnast has adequate force capacity to execute this element.

CONCLUSIONS

It has been designed a specific tool, using a single force platform, for the assessment and evaluation of the ability to generate isometric force applied to the Swallow in still rings.

The reliability of the measurements made with our protocol has been proved, obtaining similar results from several attempts for the prediction variables of successful execution of the Swallow.

They have been reported reference values for associated variables which may discriminate between Swallow performers and non-performers. Reaching a MxIF-%RF value close to 100% on this protocol and exceeding the MnIF-%RF value approximately of 90% could indicate that the gymnast has the required specific strength to perform the Swallow. On the other hand reaching a MxIFRRF value greater than 9 N * kg^{-1} or a MnIF-RRF value close to 9 N * kg^{-1} may indicate that the gymnast has adequate force capacity to execute this element.

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RELATIVE STRENGTH REQUIREMENT FOR SWALLOW ELEMENT PROPER EXECUTION: A PREDICTIVE TEST

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Research article

Abstract

The present study analyzes the correlation between gymnast´s relative strength and the time in seconds that the athlete can hold the swallow on rings with the idea to identify the minimum relative strength required for the proper execution of this element. In addition, a dumbbells exercise is proposed as a convenient evaluation and training method for swallow conditioning. Furthermore, gymnast body ratios were evaluated in order to achieve whether these parameters represent an advantage or disadvantage for swallow execution on rings. A Spearman's correlation test was used to compare the relative strength, height/sitting height and height/wingspan ratios versus the swallow holding time of 14 senior Elite level male gymnasts from the Argentinean team. A significant correlation (p<0.01) between the relative strength and the time in seconds that the swallow was held by the athletes was found, proving that the execution of this element on rings is explained almost in a 90% by the gymnast´s relative strength. No correlation between the swallow holding time and the height/sitting height and height/wingspan ratios were found. These results could provide to gymnasts and coaches with a useful tool for easily recognize if the gymnast´s physical condition is appropriate to perform a swallow on rings.

Keywords: *male gymnastics, rings, metrics.*

INTRODUCTION

Within the six male artistic gymnastics (MAG) disciplines, rings event differs greatly from the rest because it demands an important show of strength from the upper body muscles when executing different skills requiring constant static, eccentric and concentric contractions. These movements imply a constant fight against gravity, having as a goal to overcome the own bodyweight load, thus giving an important role to the relative strength of the gymnast. According to Arkaev & Suchilin (2004), gymnast´s weight is the major obstacle to performing exercises. To move corporal weight it is necessary to apply strength and perform mechanical work of certain power. Here, relative indicators of muscle strength and speed-strength, and not the absolutes indicators, are more important because the first ones are calculated taking into account the gymnast´s own weight.

Gymnastics Code of Points stated that rings routine must be composed of different element groups such as swings elements, swings-to-hold elements and hold elements. Within the latter group, there are four key exercises for a high level routine: the cross, the support scale, the inverted cross, and the swallow. All those elements need to be held (*i.e.*, static strength) a minimum of two seconds for approval by the Jury (FIG, 2009). Among all of them, the swallow is the one that gives more bonuses to a rings routine. The swallow is a strength holding element, supported only by hands with the body and arms straight in a horizontal position at the rings level (Fig. 1) (Bernasconi & Tordi, 2005; Bernasconi, Tordi, Parratte, & Rouillon, 2009; Sands, Dunlavy, Smith, Stone, & Mcneal, 2006). This exercise is considered one of the most difficult strength elements to perform on rings routines (Čuk & Karacsony, 2002), and is frequently executed by the best world gymnasts (Campos, Sousa, & Lebre, 2011).

Figure 1. *The proper execution of the swallow element on rings (taken from http://www.chinasportsbeat.com)*

In the Artistic Gymnastics World Championships held in Stuttgart (2007), 212 rings routines were evaluated; most of the top teams included in their gymnast routines two variants of the swallow element, increasing the start value of the performance and getting a higher score for the classification (Campos, Lebre, & Corte-Real, 2009).

Some evidences show that swallow execution on rings demands a high coordination of the shoulder muscles. Bernasconi *et al*. (2009) compared muscle activity and coordination during a swallow performed on the rings, using a counterweight, and during two training exercises (using dumbbells or barbells). Analyzing electromyograms from the biceps brachii, triceps brachii, deltoideus (clavicular part), pectoralis major, serratus anterior, infraspinatus, trapezius (middle part), and latissimus dorsi in the right shoulder during the exercises, these authors demonstrated that for each one of the four exercises analyzed exist a specific shoulder muscle coordination. According to a research by Campos *et al*. (2011), different muscle forces act together to achieve a balance of the shoulder joint to execute a swallow. The activation of 8 upper body muscles was measured using an electromyographer during the swallow execution on the rings. This study showed that the higher muscular activation corresponded to infraspinatus with 69.3% of the maximum voluntary contraction (MVC), follow by the biceps brachii (60.9%), triceps brachii (58.1%), and anterior deltoid (54.3%). The muscles responsible for scapula mobilization, anterior serratus and inferior trapezium, achieved the corresponding MVC values of 53.3% and 45.1%, respectively. The muscle major pectoralis presented the lowest value of MVC (48.5%). On the other hand, latissimus dorsi was by far the lowest activated muscle during swallow performance on rings, with 15.0% of MVC. Near 50% of muscular co-activation indexes was represented by three agonist/antagonist muscles groups, biceps/triceps, serratus/trapezium. In the co-activation of biceps/triceps and serratus/trapezium the agonist muscles showed a slightly superior contraction in comparison to the antagonist muscles. In the case of deltoid/infraspinatus, the antagonist muscle (infraspinatus) was slightly more activated than the agonist (deltoid). The lowest co-activation index was represented by pectoralis/latissimus dorsi, indicating that pectoralis had superior levels of activation than latissimus dorsi. These results confirmed the interaction between muscles to support the body on the horizontal position (Gluck, 1982). In the particular case of serratus/trapezium co-activation, it seems that those muscles act to stabilize the scapula and to cause shoulder protraction. The high infraspinatus activation prevents humerus head forward dislocation, maintaining it on the glenoid cavity (Brukner & Khan, 1994; Kapandji, 2007; Kendall, McCreary, & Provance, 1993). The combined efforts between infraspinatus, anterior serratus and inferior trapezium are determinant for scapula and shoulder stabilization allowing the anterior muscles (pectoralis major, biceps brachii, deltoid anterior) to work as shoulder flexors and support the body in the horizontal static position at the rings level. Kapandji (2007) stated that triceps brachii push the humerus head forward at the elbow joint when the arm is extended. This means that the shoulder protraction could be related with the anterior serratus and the triceps brachii muscular actions, explaining the higher activation of infraspinatus to prevent the excessive forward action. During swallow execution, latissimus dorsi works only as scapula depressor explaining the lower activation shown by this muscle.

In the same study, Campos *et al*. (2011) also evaluated muscle activation working with auxiliary exercises not executed at the rings and commonly used to swallow training. These authors reported muscular activities below 50% of MVC for each muscle analyzed. The lowest muscular activation value found in the "dumbbells" exercise (lying on back with a dumbbell in each hand with elbows and body extended) belongs to anterior serratus and latissimus dorsi, with MVC of 36.4% and 26.6%, respectively. Inferior trapezium shows the highest activation index (48.2%) followed by anterior deltoid (46.5%), triceps brachii (44.6%), biceps brachii (44.1%), infraspinatus (42.7%), and major pectoralis (40.4%). Also, an identical level of co-contraction between agonist/antagonist muscular groups with values rounding 50% was reported (50.2% for biceps/triceps, 56.8% for serratus/trapezium, and 47.9% for deltoid/infraspinatus). The co-activation index of 39.7% informed for pectoralis/latissimus dorsi demonstrates that major pectoralis contracted more than latissimus dorsi during the swallow execution with dumbbells. After data analyzing, these authors performed a final conclusion recommending or not the use of each exercise in order to be functional as swallow educator, or simply a complementary exercise for the swallow conditioning. In the case of dumbbells, Campos *et al*. (2011) concluded that this exercise could be a useful complement for physical preparation because it gives the possibility to use different loading levels (weighs), but not recommended it for swallow position development because it has the limitation to provide a different coordination between muscles, altering or decreasing the muscular participation of scapula and shoulders stabilizers.

The study of Campos *et al*. (2011) is very interesting in order to chose exercises for swallow training but it has the disadvantage that this work was performed with only one gymnast, which is a limited sample and statistically not representative. In a related study, Bernasconi *et al*. (2009) compared muscles activation and coordination of six top-level gymnasts during training exercises using dumbbells. In this work, the authors proved that the deltoideus is more activated during the dumbbells exercise when comparing with the swallow on the rings concluding that the dumbbells exercise may be useful to carefully prepare the rotator cuff muscles for use.

In our study, we chose to evaluate the dumbbells exercise as an auxiliary and complementary exercise for swallow conditioning. We proposed that data obtained through a maximum isometric strength test could be translated into the body weight percentage that a gymnast should hold in a dumbbells test to be able to perform a valid swallow on rings. In this sense, the strength test could represent an important and useful tool that facilitates the evaluation and strength conditioning planning for swallow exercise. In addition, we evaluate some structural variables such as height, sitting height and wingspan in order to identify these variables as advantages or disadvantages for a gymnast to perform a swallow on rings.

METHODS

Population under study

Fourteen male amateur's gymnasts of senior Elite level, between 18 and 30 years old, were subjected to this study. The subjects (mostly member of the Argentinean team) were in competitive period at the time of the test (two days before the first qualification meet for the pre-Pan-American games, Guadalajara 2011). The analyzed group was relatively small because sample selection was not randomly selected.

Working design and study protocol

All gymnasts underwent two isometric strength tests (a dumbbells test and a swallow execution test on rings). Three weeks before the tests the gymnasts had training sessions involving the dumbbells exercise (simulating swallow) in order to become familiar with the execution technique, to know about the weight that they would try to hold the day of testing and to achieve the necessary adaptations at the elbow and shoulder, since it is an exercise that demands a lot of tension in the soft tissues such as tendons and ligaments of these joints. Evaluation protocols were sent by e-mail to each gymnast days before they were evaluated to be informed of tests procedures and, therefore, ensure an efficient process in the shortest possible time to minimize disruptions at the athlete's resting time before the competition. Evaluations were done in the morning at 9 am. Test started with fasting measurements of body weight, height, sitting height and wingspan. One hour after breakfast the subjects underwent the strength tests warming up previously as follows: 1) 5 min jogging with different displacements; 2) joint mobility, mainly upper body; 3) warm up movements for elbow and shoulder joint with elastic bands; 4) performing specific gymnastics exercises like 3 press handstand, 5 handstand dips, 10 V abs, 10 arch rocks, 2 straddle planche on parallel bars, and 3 muscle ups on rings. Following warm up they started with the isometric strength test with dumbbells, supine position, performing it with low weights to adapt the soft elbows and shoulders tissues to the exercise (Fig. 2). Prior to the valid attempt of maximal isometric strength they performed the same test with four different lower weights in ascending order. The initial practice weight was 20% of the bodyweight of each subject. The two subsequent practices could have a weight increase of 5 kg or less. Then, the two remaining attempts (one practice and the test attempt) could have a weight increase of 3 kg or less. Between each attempt, they had a resting period of 3 or 4 min (Zatsiorski, 1989). The dumbbell test was valid if the subject: i) do not bend elbows, ii) hold the position for three seconds, and iii) keep the arms in a horizontal plane at 45° of abduction respect to the trunk and parallel to the floor.

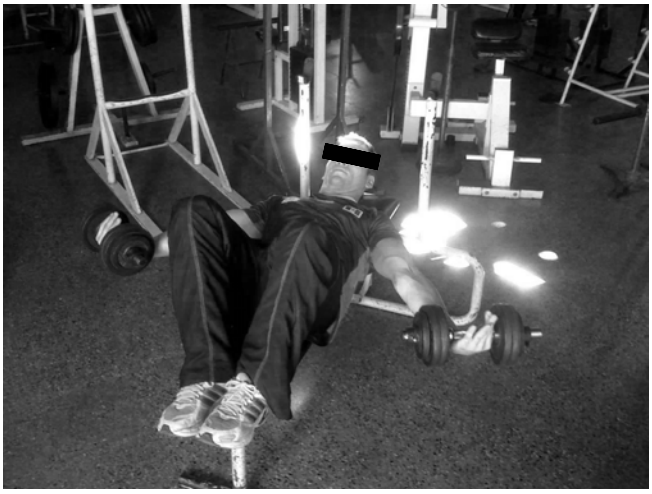

Figure 2. *The proper execution of the dumbbells test.*

After practice attempts the maximal isometric strength test was performed and the data recorded for subsequent statistical analysis. In the case that a gymnast decided to increase the load, a new attempt was performed. The swallow holding test on rings was performed after finished with the dumbbells test. All gymnasts had two turns on the rings for free warm up before executed the test and the data were recorded for statistical analysis**.** Subjects had two opportunities to hold the swallow element with 3 or 4 min of rest between each attempt (Zatsiorski, 1989). A digital camera (Panasonic Lumix) was used to record all the experience. Swallow holding time was measured by watching the recorded video in order to evaluate the correct execution of the exercise. Swallow test on rings was valid if the subject: i) do not bend elbows, and ii) the body was parallel to the ground (10° of tolerance).

Body variables measurement

Measurement of gymnasts' body weight, height, sitting height and wingspan were evaluated. Sitting height was measured as the height from a box (where the subject sits) to the vertex, with the head in the Frankfort plane. The evaluator places his hands in the jaws of the subject, with his fingers reaching the mastoid process. He asks the subject to take a deep breath and hold it and keeping his head in the Frankfort plane the evaluator applies a gentle pressure upward on the mastoid process (Norton & Olds, 1996). Height was performed with the same technique as for sitting height but with the subject standing instead of sitting (Norton & Olds, 1996). Wingspan was measure as the distance between the ends of the middle fingers of left and right hands, when the subject stands against a wall with the arms horizontally stretched (Norton & Olds, 1996). All these measurement were performed using a steel tape attached to the wall for better readability. Body weight was measured in the morning, twelve hours after food, and after voiding (Norton & Olds, 1996). It was used a digital scale brand Powerpack 600.G BLD-model with a 100g scale.

Statistical analysis

Kolmogorov–Smirnov test was used to evaluate variables normal distribution. Spearman´s linear correlation coefficients (r) between relative strength, height/sitting height ratio, and height/wingspan ratio versus swallow holding time (swallow test) were applied and calculated using Sigma-Stat® software (Version 3.1, Systat Software Inc., California, USA). Determination coefficients (r^2) were manually calculated in order to define the variation explained by the predictive variables.

RESULTS

Table 1 shows detailed information of the gymnast´s body variables measured at the present study. Data obtained from maximal isometric strength test (dumbbells test) and swallow element execution on rings is shown in Table 2.

The relative strength calculated between the weight supported by the gymnast in the dumbbells tests and the body weight was correlated with the maximum swallow holding time for each gymnast (Table 3 and Fig. 3). At this point, it is important to notice that the variable swallow holding time failed the Kolmogorov–Smirnov test, so we applied the Spearman´s linear correlation test that is best suitable for not normally distributed variables. As we can see in Table 3, we found a significant linear correlation ($r = 0.952$; $p<0.001$) between the relative strength and the time in seconds that a gymnast can properly hold a swallow on rings. Our result shows that gymnast relative strength is related in a 90% (determination coefficient, $r^2 = 0.906$) with the swallow holding time on rings (see Table 3). Additionally, we could estimate that the minimum percentage (%) of body weight than a gymnast must hold in the dumbbell test to be able to hold the swallow element on rings for 3 sec is about 60% of their body weight.

In order to asses if some body structural factors may influence the correct execution of the swallow, variables such as height, sitting height and wingspan were measured and correlated with the maximum swallow holding time for each gymnast. As can be seen in Table 4, no significant linear correlation was found between the height/sitting height ratio or the height/wingspan ratio and the swallow holding time (r = -0.159; $p>0.5$ and r =0.391; $p>0.1$, respectively). These results suggest that none of such variables appears to be an important factor to execute a swallow. Therefore, gymnast´s body structure may not represent an advantage or disadvantage to correctly perform the swallow element on rings.

Table 1. *Body variables measures for the gymnasts evaluated at the present study.*

Gymnast	Age	Body weight (kg)	Height (cm)	Sitting height (cm)	Wingspan (cm)
1	21	71.6	165.8	87.0	185.0
2	25	76.4	173.5	90.5	185.0
3	27	66.7	164.5	88.0	171.0
4	26	62.4	156.8	84.0	166.0
5	26	72.3	169.0	89.0	180.0
6	29	61.2	164.0	88.0	175.0
7	30	66.4	162.0	86.0	175.0
8	22	76.5	167.0	89.0	173.0
9	20	67.9	166.5	85.0	175.0
10	20	65.8	164.5	90.0	168.0
11	22	63.4	170.9	90.0	183.0
12	20	62.2	161.0	87.0	168.5
13	22	68.3	165.0	85.0	174.5
14	18	72.3	176.0	92.0	185.0
Mean	23	67.8	166.0	87.8	176.0
SD	4	5.3	5.0	2.3	6.6

Table 2. *Results from dumbbell test and swallow holding time on rings for each gymnast.*

Gymnast	Weight (kg) held in one hand at the dumbbell test					Swallow test (sec)
	attempt 1	attempt 2	attempt 3	attempt 4	attempt 5	
1	14	19	22	23	24	6
2	15	17	19	20	20	0
3	13	18	23	25	27	12
4	12	17	19	20	20	5
5	14	17	18	19	19	0
6	12	15	17	19	19	2
7	13	15	16	17	17	0
8	15	20	23	25	27	6
9	14	15	16	0	16	0
10	13	17	20	22	24	6
11	13	15	16	17	17	0
12	12	16	18	0	18	0
13	14	18	23	25	27	7
14	14	18	20	22	22	4
Mean					21.2	3.4
SD					3.9	3.7

Table 3. *Determination of the relative strength and the correlation and relative coefficients.*

Body weight (kg)	Isometric dumbbell test (rm)	Relative strength*	Swallow test (sec)	Spearman´s correlation coefficient for relative strength/swallow test	Determination coefficient for relative strength/swallow test (%)
71.6	24	0.67	6	0.952	90.6
76.4	20	0.52	0		
66.7	27	0.81	12		
62.4	20	0.64	5		
72.3	19	0.53	0		
61.2	19	0.62	2		
66.4	17	0.51	0		
76.5	27	0.71	6		
67.9	16	0.47	0		
65.8	24	0.73	6		
63.4	17	0.54	0		
62.2	18	0.58	0		
68.3	27	0.79	7		
72.3	22	0.61	4		

*Relative strength is calculated as: (rm/body weight) x 2

Table 4. *Practical example of the dumbbells test application.*

Gymnast´s results during dumbbells test				
Weight held in one arm (kg)	Total amount held in test (kg)	Gymnast´s body weight (kg)	Relative strength*	Percentage (%) of body weight held
17	34	62	0.55	55
Target weight to be achieved				
Weight held in one arm (kg)	Total amount held in test (kg)	Gymnast´s body weight (kg)	Relative strength*	Percentage (%) of body weight held
18.6	37.2	62	0.60	60

*Relative strength is calculated as: (total amount held/body weight)

DISCUSSION

Until we know, there is no scientific evidence indicating the minimum static relative strength needed by a gymnast to execute a valid swallow on rings. Moreover, there is no research based evidence proposing an indirect and objective method able to evaluate swallow condition by using alternative exercises that do not include the use of the rings, such as the complementary dumbbells exercise used at the present study. Furthermore, it is unknown in what percentage swallow execution is governed by other body structural variables. Our results showed a significant linear correlation between the isometric relative strength and the time that a gymnast held a swallow at rings. These findings support the idea to apply an evaluation method to predict what percentage of body weight must to be held by a gymnast in a dumbbells test to be able to perform a valid swallow on rings. For example, after three or four weeks performing the dumbbell exercise to be more familiar with the correct execution of the exercise, the gymnast should perform a 3 seconds maximum static test with the dumbbells. Then, dividing the total weight supported during the test by the gymnast´s body weight we obtain the relative strength. According to the results presented at the present work, a gymnast should hold at least 30% of his body weight on each hand (*i.e.*, a total of 60% of his body weight) during a dumbbell test to be able to perform a valid swallow on rings. Table 4 shows a practical example. Based on our evidence, a 62 kg gymnast should hold in the dumbbell test 37.2 kg to perform a swallow on rings because this load is the 60% of his body weight.

In other hand, the lack of correlation between anthropometric variables (height, sitting height and wingspan) and the swallow holding time can be interpreted as these variables are minor when executing a swallow.

At this point, it is important to notice some limitations of the present study. First, we have only evaluated 14 gymnasts. It would be interesting to repeat this study with a larger number of athletes. In our case, it was not possible because this is the total of senior Elite gymnasts in Argentina. Second, it would be very interesting not only measure the height, sitting height and wingspan, but also a more complete anthropometric scheme in order to identify different variables such us muscle distribution between the upper and the lower body that could affect the swallow execution.

CONCLUSIONS

The present study demonstrated a high correlation between the isometric relative strength and the swallow holding time, confirming the dumbbells test as a valid predictive method to identify the body weight percentage that must to be supported by a gymnast in an isometric test with the aim to hold a swallow at the rings. Variables such as height, sitting height and wingspan showed no significant correlation with the swallow holding time suggesting these variables are not such important during exercise execution. This work provides to gymnasts and coaches with a useful tool to easily recognize if the physical condition of a gymnast is adequate to perform the swallow element on rings. In addition, the proposed test does not require expensive equipment or tools, thus being available for any coach who wants to apply it. In fact, depending on the results obtained from the dumbbells test, this information could also provide additional data for setting a goal to achieve by the gymnast.

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BALANCING IN HANDSTAND ON THE FLOOR

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Review article

Abstract

The contribution is a review study dealing with a handstand as one of the basic movement structures in artistic gymnastics. Balancing in this inverse position is a complex process based on physiological and physical principles. From physiological point of view the important results are from research dealing with function of vestibular apparatus, visual system, proprioception, central nervous system and motor units and their participation in balance maintaining. Another important question is a relationship between the strength of particular muscle groups and a level of balancing ability. Based on stabilometric measurements and 3D kinematic analysis of correcting movements equalizing the perturbations during a handstand we can distinguish several strategies of maintaining balance. Other important factors influencing the holding time in handstand position in gymnastics, mainly in tool disciplines, are a visual control and position of head.

Keywords: *gymnastics, balance, physiology, biomechanics.*

INTRODUCTION

Historically, artistic gymnastics in its basis derives from acrobatics for which positions and movements headfirst are typical. Handstand is one of the basic elements in both man and woman acrobatic gymnastics. Handstand in its static form is the initial and final position of many movement structures and in its dynamic form is either the basis of motion or its component. For this reason the movement structure is drilled with a great attention from the very beginning of a gymnastic life. As the exercise technique was developing, the handstand technique and balancing strategies in this position were changing as well. The handstand technique plays an important role as an initial and final position of some of the gymnastics elements mainly in artistic gymnastic of men, where the stabilized handstand determines a referees' recognition/ non-recognition of a movement structure. This is typical for acrobatics, rings and parallel bars. The stabilized handstand is not only important for balance beam, it is far more important for uneven bars in female gymnastics. Dynamic movement structures (circles, giant circles with twisting) performed without penalization must end in a handstand without follow-up persistence. Here the technical perfection of a handstand is important since the final position of one movement structure becomes an initial position of another one. The correct balancing strategy is an important part of methodology; therefore we focused on an in-depth analysis of this issue.

We can have a look at the principle of balancing from biological and physical points of view (Hudson, 1996). Both systems work in cooperation to create conditions for balance. Whether we talk about either static or dynamic balance, "owing to perturbations unsteadiness effects and bifurcations occur in a system resulting in the system becoming discontinuous, diffused. Balance at its basis, a characteristic of a quality of a system, is simultaneously a process of the system" (Brtníková & Baláž, 2007).

While it may be claimed that there is no absolute balance, every position or movement is a permanent process of balance creation by means of correcting movements. That is why we do not consider these movements disturbing. However, the tendency is to minimalize these correcting movements. By means of these movements we are able to eliminate the range and transfer of disturbing movements to different body parts, particularly the centre of gravity. Therefore a quick reaction to the stimulus informing brain about balance disruption is necessary.

Physiological principle of balancing

From physiological point of view, balancing consists of a number of phases: The first phase is a detection of a specific situation via sensory systems. When maintaining an upright position, a man uses a combination of information from vestibular apparatus, visual and proprioceptive information (Fransson, Kristinsdottir & Hafström, 2004, Vuillerme, Pinsault & Vaillant, 2005).

The function of vestibular apparatus may be limited by an uncommon head position, e.g. head bending backwards, or during handstand or fast head movements (Strešková, 2003, Asseman & Gahéry, 2005). The function of vestibular apparatus may be improved by physical exercise. Simultaneously, there is a direct relation between the functional status of vestibular apparatus and a quality of formation of some movement routines (Strešková, 2003).

Visual system provides very important information about where the body is located with respect to the environment in which it moves; eventually it provides information about the speed of the movement (Nasher, 1997, Shumway-Cook & Woollacott, 2007). The quality if visual system, mainly visual acuity and stereoscopic vision, in other words the depth of vision may influence the quality of performance of a balancing element. The influence of a visual control over the balance was investigated by more authors who generally came to the same conclusion, and it is that when the visual control is limited, the correcting movements are of greater extent. Vuillereme at al. (Vuillerme, Teasdale & Nougier, 2001, Vuillerme et al., 2001) broadly explored the role of visual stimuli in postural control of ballet-dancers and female gymnasts. He concluded that repeating of specific movements during a training improved postural regulations. A close relationship was discovered between the level of a sport training and postural abilities and a fact that limitation of visual control considerably disrupted postural performance.

Proprioception is based on a function of mechanoreceptors in skin, muscles and connective tissue and provides information about relative configuration and position of body segments, thus proprioception is essential for coordinated functioning of muscles (Nasher, 1997, Latash, 1998, Goldstein 1999, Zemková & Hamar, 2005, Shumway-Cook & Woollacott, 2007, Míková, 2007). Proprioception may as well influence the velocity and type, i.e. strategy of muscle response on balance disturbing perturbations. The function of proprioceptors may be improved by training. However, certain stimuli, e.g. joint injury, could result in incorrect movement perception of corresponding body segments (Barrett, Cobb & Bentley, 1991, Ashton-Miller, Woijtys, Huston & Fry-Welch, 2001). The experimental works of Lephart et al. (Lephart, Giraldo, Borsa & Fu, 1996) prove that artistic gymnasts have better proprioceptive perception. He investigated proprioceptive perception in knee joint in women gymnasts. He came to same results as Ramsay and Riddoch (2001) when he found out that gymnasts have better proprioceptive sensibility of a knee joint than untrained individuals. Results of both these studies imply that sportsmen who during the training process put the accent on precise movement control show proprioceptive perception of a higher level on both upper and lower extremities.

Various authors have different opinions on how much the different components – vestibular, visual and proprioceptive – contribute to balancing. Astrand et al. (Astrand, Rodahl, Dahl & Stromme, 2003) and Vařeka (2002), based on an experiment, came to a conclusion that proprioceptive organs play the most important role in maintaining a stable position. Mysliveček and Trojan (2004) and others think that the most important component is vestibular system. Sometimes, a certain sense conflict may appear when an important part is the ability to choose which information acquired by visual, somatosensoric and vestibular systems are reliable and which are not (Shumway-Cook & Horak, 1986).

The received information is then analyzed by central nervous system, where cerebellum and its functional circuits play an unsubstitutable role. From CNS (central nervous system) the information is taken via efferent pathways to muscle groups as stimuli to their activation. There, a contractive muscle force is generated which results, based on leverage of joints, in movement or stabilization of certain muscle segments, in terms of balancing we call these correcting movements.

In their works several authors have already dealt with question of the third phase of balancing process. They were investing a relationship between balancing ability and amount of muscle strength of a corresponding muscle group into which an impulse from CNS is delivered in order to maintain the balance position of body. Most previous studies focused on analysis of influence of muscle strength on static and dynamic balance in people with a significant increase in muscle flaccidity (Carter, Khan & Mallimson, 2002, Lord, Murray, Chapman, Munro & Tiedemann, 2002).

Several studies have shown that strength training improve balance (Pintsaar, Brynhildsen & Tropp, 1996, Blackburn, Guskiewicz, Petscgauer & Prentice, 2000, Hideyuki, Taketzo, Satoshi, Miho & Ukitoshi, 2000, Heitkamp, Horstmann, Mayer & Weller, 2001, Carter, Khan & Mallimson, 2002, Binda, Culham & Brouwer, 2003, Kalapotharikos, Michalopoulou, Tokmakidis, Godolias, Strimpakos, & Karteroliotis, 2004, McCurdy & Langford, 2006). Balckburn et al. (Blackburn, Guskiewicz, Petscgauer & Prentice, 2000) state that an activated muscle with its strength helps neuromuscular control in the way that during contraction it increases the sensitivity of proprioceptors detecting the muscle extension and owing to this the duration of electromechanical reflex of muscle contraction decreases. Other studies found out that, reversely, the balance training improves strength (Heitkamp, Horstmann, Mayer & Weller, 2001, Heitkamp, Mayer, Fleck & Horstmann, 2002). In contrast to these results, Wolfson et al. (Wolfson, Whipple, Judge, Amerman, Derby & King, 1993) and Verfaille et al. (Verfaillie, Nichols, Turkel & Hovell, 1997) did not find any changes in balancing skills after strength training. These contradictory results may be caused by different measuring methods. Insufficient relation between strength and balance may be due to differences among the muscle groups which are involved in strength and balance tests.

From different point of view Zemková (2004) dealt with a relationship between development of strength and balance. The authors state that owing to proprioceptive stimulation the neuromuscular system slightly fatigues which impairs balance of body position right after the strain. During longitudinal observation Zemková (2004) found out that strength training using the proprioceptive stimulation (combination of vibrations with active strength stimuli) resulted in reinforcement of balancing skills.

Postural control is thus a very complicated process with several phases. Postural control, whether in dynamic or static conditions, is dependent on body being able to react to sensory, inner and outer perturbations. During a balancing process it is important to observe the time characteristics of individual phases. When passing through individual phases there always is a certain time delay depending on structural and functional status of the system (Vařeka, 2002). Regarding the timing, postural control and motor reactions may proceed in two ways, depending on what kind of movement activity is done. The first option is anticipating postural corrections which are performed c. 80 – 500 ms before the acquired movement is initiated. These preliminary processes serve to creation of postural correction just before balance is disrupted by perturbations. The second option is a reverse action. As a reaction to inner perturbations, deviations in body posture occur, which are detected. As a response to these a reaction occurs, motor reaction, which regulate muscle strength in order to compensate the outer perturbations and keep the body in a steady position. These reflex reactions occur firstly in short-term responses 30 – 50 ms after the deviation to which they react. Then there are medium-term reactions approximately 100 ms after the deviation occurs, and finally long-term reactions, deliberate regulating actions, which occur up to 1 s after deviation (Nasher, 1997).

Physical principle of balancing

When analyzing the balance positions it is necessary to take into consideration that human body is not a compact matter but a set of connected items from which every deviation results in change of position of centre of gravity (Zemková & Hamar, 2005). In many works, mainly those focusing on mechanics (e.g. Adrian & Cooper, 1995, Hamill & Knutzen, 1995) the authors state that static balance is equal to a stable position. But as Kreighbaum and Barthles (1990) note, there is no absolute balance in human activity because human body constantly passes through certain changes in position. Every position or movement is a continuous process of recreating a balanced position using correcting movements. The processes taking place inside the human body, i.e. respiration, activity of blood circulation, deflect body from a given position. If we then, with a certain simplification, consider the resting positions as static, we may, from point of view of action of force, characterize them as following: Body lies in a static equilibrium if the forces acting on the body cancel out and body persists in rest. From biomechanical point of view, the body lies in equilibrium if it complies with two conditions:

The resultant of all forces acting on the body is equal to zero:

$$\boldsymbol{F} = \boldsymbol{F_1} + \boldsymbol{F_2} + \ldots + \boldsymbol{F_n} = \boldsymbol{0}\,.$$

The resulting torque (with respect to any axis) acting on the body is equal to zero:

$$\boldsymbol{M} = \boldsymbol{M_1} + \boldsymbol{M_2} + \ldots + \boldsymbol{M_n} = \boldsymbol{0}\,.$$

In a stationary body position the postural control is perceived as an ability of body to resist the force of gravitation and to keep the centre of gravity above a small base of support (Nasher, 1997). Hudson (1996) states that balance is disturbed more by horizontal forces than forces acting in vertical plane. A factor of balancing stability thus depends on ability of body to resist the horizontal changes of positions.

Balancing strategies

As we have already stated, keeping body in a static position is a continuous process of recreating balance by correcting movements. Therefore these movements are not considered disturbing. However, the tendency is to minimalize their extent. By means of these movements it is possible to eliminate extent and transfer of real disturbing movements to other body segments, mainly to centre of gravity. At locomotion system we may look as a system of inverse pendulum with more or less levels of freedom of movement depending on fixation of individual joints by isomeric contraction. Some authors have described the system of regulation of postural balance in an upright position as a three-level hierarchic system which begins at ankles, moves up to knees and finally to hips (Nashner & McCollum, 1985), whereas the knees are used to correct the big deviations.

Two possible strategies, two possible responds of locomotion system by which perturbations may be corrected in an upright position were in detailed described by Horak and Nashner (1986). When a body bends forward, either "ankles strategy" may be used during which ankle extensors are activated, knee flexors and hips extensors, or "hips strategy" with activation of knee extensors hip flexors. These two strategies differ in direction of rotary movement in hip joints. "Ankles strategy" is preferable for smaller perturbations, whereas "hips strategy" may be used for extensive or fast perturbations or when the area of support is small and only minimal rotations are possible in ankles (Horak & Nahner, 1986).

Míková (2007) summarizes and arranges the possible balancing strategies in an upright position (Fig. 1). Whether we talk about deviations in frontal or saggital plane, possibilities are ankle strategy, hip strategy and step strategy which extends the two previously mentioned strategies and authors mentioned above. During this strategy, in order to keep the position of centre of gravity above the base of support, movement of one lower extremity in opposite direction is used before the trunk is deviated owing to perturbations. By this movement part of body weight is moved to the opposite side as the weight of trunk and the centre of gravity, which is situated at mass body centre, remains above the area of support.

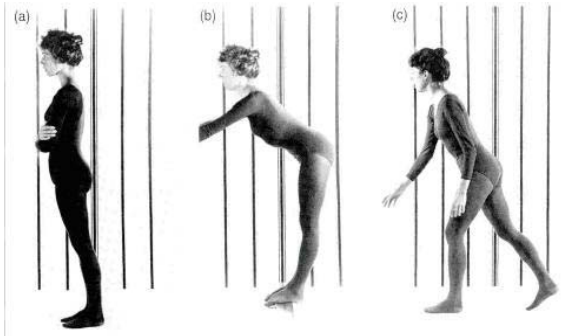

Figure 1. *Balancing strategies (Míková, 2007): a) ankles strategy, b) hips strategy, c) step strategy*

Characteristics of handstand

From the more demanding positions, handstand balancing is the one which is analyzed the most (Gauthier, Marin, Leroy & Thouvarecq, 2009, Kerwin & Trewartha, 2001, Mochizuki, Oishi, Hara, Yoshihashi & Takasu, 1997, Sobera, 2007). Handstand is a basic movement structure in the system of activities in artistic gymnastics. It is a static unstable balance position. From mechanical point of view, its specificity is determined by the height of centre of gravity, size of support area and the overall difficulty of the balance position in which we maintain stability. Last but not least, the atypical position of body (headfirst) contributes to it as well. The optimal actions of locomotion system also depend on characteristics of environment with whom it interacts. In artistic gymnastics, the balance positions are often made difficult by equipment (handstand on parallel bars, beam) whose mechanical properties and stability influences the difficultness of balancing (Croft, Zernicke, & Tscharner, 2008). The difficultness may be also increased by the fact that during these conditions already small deviation causes the centre of gravity not being over the base of support.

Balance is held by a chain of muscle actions which contribute to joint movements, manage different body configurations and control the movement of the centre of gravity (Hayes, 1988). "In order to hold balance, individual body segments have to be strengthened by means of isometric contraction of active muscle groups which fixate the spinal connections, hip and knee joints. The final position of handstand is characteristic by a flat angle between "longitudinal" body axes – arms – trunk – legs, straight head position (eyes following the hand finger tips). In order to increase the size of the area of support, fingers are slightly outstretched and placed in the area of support in the sportsman's shoulder width." (Zítko & Chrudimský, 2006). The technically correct performance involves sufficient strength of arms which carry the whole sportsman's weight, shoulder girdle and space orientation.

Balancing strategies in a handstand position

There are several ways of conducting a thorough analysis of processes contributing to balancing in a handstand position. Most often we choose the analysis of COP (centre of preasure) movement with a combination of a visual control, peripheral vision, and variants of head positions. In their researches authors start from the mechanism of balancing in an upright position. The body configuration in a handstand is similar to one in an upright position, which means that transfers occur between upper and lower extremities (Clement & Rezette, 1985). For handstand position, following differences with respect to an upright position are characteristic: The area of support is smaller, whereas the distance between the base and the centre of gravity is bigger due to a support of extended arms, which increases the instability (Slobounov & Newell, 1996). Handstand position requires an extraordinary muscle activity of upper extremities which substitute for the antigravitational task of lower extremities. Although the muscle activity of upper extremities is more precise, they succumb to fatigue.

More authors have already dealt with strategies of balancing in a handstand position; their opinions are not uniform, though. Nashner and McCollum (1985) state that the configuration of a handstand position is different from the one in an upright position because instead of three there are four joints (wrists, elbows, shoulders and hips) involved and this requires a specific postural coordination. Also Asseman et al. (Asserman, Caron & Crémieux, 2004) are of the same opinion when he states that balancing in a handstand position is more complex as it requires the presence of four joints instead of three of them.

Sobera (2007) analyzed the process of balancing in a handstand position and in a tip toe position, which comprise the basic elements in artistic and rhythmic gymnastics. The research group consisted of 10 gymnasts whose handstand position was analyzed, and 5 female modern gymnasts who were in a tip toe position. The sportsmen stood on a platform KISTLER for a period of 10 s and 20 s. COP trajectory was recorded. The measurements showed that in a handstand the deviations occurred mainly in the sagittal plane, which differed from the tip toe position where the frontal movement of COP is more important for the stability. Also Slobounov and Newell (1996) confirm bigger deviations in a sagittal plane in comparison to an upright position. Considering the strategies of balancing in a handstand position Sobera (2007) found out the most significant corrections in the wrist joints: "The control of balance in a handstand position is realized in a similar way to an upright position, i.e. via moving COP towards the fingers or the wrist joints in the sagittal plane or to right or left in the frontal plane. Holding balance in a handstand position requires maximal balancing in the wrist joints. Control of balance in this unnatural position is done mainly via increasing the pressure of fingers on the ground as a result of movement of the centre of gravity towards the fingers or the increase of pressure under the wrist joints during the movement of the centre of gravity towards the wrist."

Yedon and Trewrthe (2003) confirm the most considerable activity in wrists, where the perturbations in a sagittal plane corrected by wrist flexors and extensors with synergistically cooperating shoulder joints and hips contribute to maintaining the fixed body configuration. Rotations in wrist together with rotations in shoulders and hips generally work in the same direction as the direction of rotation in wrist.

These results are identical to the results of Kerwin and Trewarth (2001) who found out that rotations in wrists, shoulders and hips significantly correlate with the shift of the centre of gravity, and the rotation in wrist was dominant. The results of a work by Gautier et al. (Gauthier, Thouvarecq & Chollet, 2007) in which they analyzed the strategy of balancing in a handstand position in gymnasts show considerable movement in shoulders (5.56°) and wrists (12.39°), elbows almost did not move (1.21°), but reached a maximal deviations, and hips hardly moved (0.88°).

A different technique involving a flexion in an elbow joint described Slobounov and Newell (1996). According to Yedon and Trewarh (2003) the flexion is probably used just after the failure of balancing using the "wrist strategy". Gautier et al. (Gauthier, Thouvarecq & Chollet, 2007) explain that flexion in elbow joints enable gymnasts to lessen the centre of gravity in case of extreme misbalance, as do knees in an upright position. The result is a bigger tolerance of fluctuations and possible rebalancing. The configuration in a handstand position is therefore similar to the one in an upright position with the wrist functions being similar to the ankle functions, elbows are similar to knees and shoulders are analogous to hips.

Visual control in a handstand position

Postural balance is controlled by a system of sensors including vestibular, proprioceptive and visual systems. Understanding the function of visual perception during postural regulation contributes to a better understanding of how a man moves in environment. Perception is the prime condition for a postural regulation. It enables us to record and control a direction of our movement (Stoffregen, 1985, Warren & Hannon, 1988, Li & Warren, 2000, 2002). Visual control may also compensate a lack of postural control resulting from muscle fatigue (Vuillerme et al., 2001).

The consequence of visual control during balance regulation was investigated by Gautier et al. (Gauthier, Thouvarecq & Chollet, 2007). The aim of this study was to deepen the knowledge about the postural regulations in a handstand position. Authors evaluated the influence of peripheral and central vision on balance in a handstand position in gymnasts. COP shift, angles between body segments and gymnasts' height was analyzed during this movement task. The similarities appeared between the ways of postural regulation in a handstand position and in an upright position. In both positions the COP oscillation increases when eyes closed, which confirms the influence of visual control on balance (Clement & Rezette, 1985).

Lee and Lishman (1975) showed that the closer the visual target, the smaller the sagittal oscillations. In a handstand position owing to a lowered head position the visual surrounding is closer than in an upright position. From this point of view it should be easier to visually control the handstand position rather than an upright position. Clement et al. (1988) found out that the viewpoint is placed app. 5 cm in front of the wrist in the centre of the area between arms. They continue that gymnasts unite this point with an optimal vertical projection of the centre of gravity.

Gautier et al. (Gauthier, Thouvarecq & Chollet, 2007) analyzed the handstand performance in ten gymnasts aged 18 – 25 years. The sportsmen performed the handstand on a stabilometric platform equipped with meters which recorded COP changes in mm in sagittal (Y) and frontal (X) plane. Simultaneously a video was recorded from which the angles, dimensions and angular velocity were evaluated. The characteristics of handstand were compared during following conditions: eyes open, eyes closed, central darkness, peripheral darkness. The results showed that in gymnasts there are no significant differences among these four conditions regarding the COP shifts. The biggest oscillations were recorded in a sagittal plane – 42.6 mm, saying that the oscillations were mainly towards the fingers.

Asseman and Gahéry (2005) analyzed the influence of the head position on balancing in gymnasts who were asked to perform handstand with different head positions and with eyes open and closed. The professional gymnasts had no problem with balance in a handstand position with their eyes closed. However it was found out that it was much more difficult for them to balance when their neck was in flexion, probably because of the change of orientation of head together with vestibular apparatus. It shows main influence of had position on the postural regulation in handstand.

CONCLUSION

We support the notion that in a handstand position the body is in an upside down position and the equivalents of ankles and hips in an upright position are wrists and shoulders. The new trends in the technique of performance deal with three segmental strategies of balance correcting in a handstand position. An effort is to achieve a perfect body strengthening by isomeric contraction of abdominal, gluteal and back muscles, resulting in connection of segments legs – trunk and correction is done at a level wrist – shoulder.

As the gymnast's aim is to minimalize the correcting movements, we assume that the "wrist strategy" will be used when the whole body stays fixed in a vertical position. On the other hand, when the area of support is small, the "shoulder strategy" may necessarily be used. If the oscillations are so big that the gymnast's shoulder girdle is not strong enough to correct them with help of wrist and shoulders, then hips and elbows follow.

As we mentioned above, the position of head influences the stability on a handstand position, the handstand technique itself and it has its development. Formerly, when the exercise difficulty was not the crucial variable in artistic gymnastics competitions, the flexion of head was not considered a mistake, moreover it was the other way round. Head was in most movements the leading force. In recent periods, however, in exercise techniques we moved towards the head positioned as a continuation of neck. This technique can be used by some coaches. We agree with the opinion that head should not be fixed in any extreme position (bending forward, backward). For a gymnast the visual contact with the ground without extreme head bending is necessary.

Some authors focused only on 3D analysis or a stabilometry, however in future we want to focus on a complex analysis of balancing strategy, i.e. 3D synchronization of a kinematic analysis and a stabilometry complemented with EMG. We want to find a difference between the balancing strategies in boys and girls, juniors and seniors. We wonder if the the level of strength abilities of arms and trunk muscles and balance abilities of a gymnast influences the quality of performance the handstand and if it affects the choise of a segmental strategy of balance correcting in this static movement structure. We think that a complex perspective may reveal the little nuances applicable in a handstand drill and may make the drill more effective.

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Slovenski izvlečki / Slovene Abstracts

Tomaž Pavlin

»DOLŽNOST SOKOLA JE DA ŠE ENKRAT STOPI V PRVO VRSTO NARODA« (OB 150. OBLETNICI USTANOVITVE JUŽNEGA SOKOLA)

V srednji Evropi ima telovadba korenine v 19. stoletju. Telovadba – po grškem vzoru in nazivu gimnastika – je bil naziv za sistem telesnih vaj. Tako se pojavijo različni sistemi telesnih vaj imenovani po njihovih ideologih (Jahnov, Lingov, Nachteglov in Tyršev - sokolski). Sokolski sistem je ob športnem kmalu postalo tudi pomembno politično, zdravstveno, rasno in vojaško orodje pri oblikovanju narodne identitete v 19 stoletju. Med srednjeevropskimi Slovani je bil prvi gimnastični Sokol ustanovljen v Pragi leta 1862, vendar je v istem letu že tudi namen, da se organizira telovadno društvo v Ljubljani, neodvisno od dogodkov v Pragi. Zaradi nasprotovanja upravnih cesarskih organov je bil prvi Sokol na ozemlju današnje Slovenije organiziran leta 1863 in postal družbeni center med Slovenci . V letih pred WW I. se sokolstva širi po Sloveniji in združi v zvezo. Z vzpostavitvijo jugoslovanske države po WW I. se slovenski Sokol pridružil Srbom in Hrvatom v jugoslovanski Sokol . V prispevku je opisna zgodba Sokola s poudarkom na nekaterih ključnih trenutkih.

Ključne besede: Sokol gibanje, telovadba, zgodovina, Slovenija.

Olga Rumba

POVEČANJE GIBLJIVOSTI STOPALA RITMIČARK Z VSEBINAMI TRADICIONALNE KOREOGRAFIJE

Strokovnjaki za ritmiko so določili ključne dejavnike gibljivosti stopala in njihovo uspešnost v ritmiki. Najpomembnejši dejavniki so višina vzpona do polovice prstov, sposobnost dolgotrajnega vztrajanja v stoji na eni nogi in ohranjanje vzpona pri zasukih stopala ven, stegnjenosti stopala (plantarna fleksija) in sukanja stopala. Pripravljeni so bili testi za merjenje izbranih dejavnikov ter določene vsebine tradicionalne koreografije izboljšanja le-teh. Z vsebino tradicionalne koreografije lahko močno izboljšamo gibljivost stopala.

Ključne besede: ritmična gimnastika, gibalne sposobnosti, kulture gibanja , gibljivost stopala, tradicionalna koreografija.

William A Sands, Wendy L Kimmel, Jeni R McNeal, Sarah L Smith, Gabriella Penitente, Steven Ross Murray, Kimitake Sato, Satoshi Mizuguchi, Michael H Stone

KINEMATIČNE IN DINAMIČNE ZNAČILNOSTI ODRIVA NA AKROBATSKI STEZI IN ZRAČNI PREPROGI AIR FLOOR^{TM} (ŠTUDIJ PRIMERA)

Odrivi pri akrobatskih skokih na orodjih z različno elastičnostjo in trdoto lahko pripomorejo k povečanju nevarnosti poškodb. Namen študije je bil primerjati kinematične, dinamične in časovne značilnosti odrivov na akrobatski stezi in zračni preprogi AIR FLOOR^{TM} . Pet telovadcev mednarodnega razreda je izvajalo premet naprej in salto naprej ter premet vstran z obratom za 90 stopinj nazaj, premet nazaj in salto nazaj na obeh orodjih. Izvedbe serije skokov so bile merjene z visokofrekvenčno kamero, EMG osmih mišic nog, povprečna maksimalna sila na stopala in časovnimi parametri. Primerjava akrobatske steze z vzmetmi pokaže razlike v kotih sklepov nog, v aktivaciji mišic nog, sil na stopala in posamezne časovne spremenljivke. Pri zračni stezi je trajanje odriva daljše. Dinamične spremembe kota v kolenu lahko povzročajo nepričakovano in potencialno nevarno gibanje golenske mišice. Ta pilotska študija priporoča nadalnje raziskave dinamičnih sprememb v kolenu, vpliva tresenja in trdote podlage pri odrivih in aktivnost mišic glede na trdost podlage. Lahko zaključimo, da počasnejša frekvenca odgovora podlage lahko pomaga pri izvedbi skokov in zmanjša obremenitev in pričetek poškodb nog.

Ključne besede: akrobatska steza, skoki, odrivi, EMG, sile stopala, koti v sklepih

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Benjamín Bango, Manuel Sillero-Quintana, Ignazio Grande

NOVO ORODJE ZA OCENO SILE PRI RAZOVKI VODORAVNO

Osem telovadcev je bilo ocenjenih z novim merskim inštrumentom za oceno izometrične moči in posebnega položaja na krogih. Predlagani merski protokol meri silo, ki jo telovadec uporablja na krogih iz leže na trebuhu na pritiskovni plošči in poskuša izvesti razovko vodoravno. Navpična sila (FZ) pri zajemu 100 Hz pokaže najprej zmanjšanje sile teže telesa na podlago do največje izometrične sile. Osnovne in izračunane spremenljivke pokažejo, značilne razlike med telovadci, ki lahko izvedejo razovko vodoravno in tistimi, ki ne morejo. Telovadci, ki jo lahko izvedejo imajo večji odstotek mase telesa, ki ga dvignejo in večjo relativno moč (proizvedena sila/maso telesa). S testom lahko trenerji dobro ocenijo telovadčevo pripravljenost na razovko vodoravno.

Ključne besede: moška športna gimnastika, biomehanika, krogi, razovka vodoravno.

Mario A. Gorosito

NAPOVEDNI TEST RELATIVNE MOČI POTREBNE ZA IZVEDBO RAZOVKE VODORAVNO NA KROGIH

Preverjena je bila povezanost med relativno močjo telovadcev in časom trajanja drže telovadčeve izvedbe razovke vodoravno na krogih s ciljem določiti najmanjšo potrebno relativno moč, ki jo telovadec potrebuje za izvedbo prvine. Ob tem pa so bile uteži (ročke) izbrane kot primeren način za razvoj primerne telesne pripravljenosti na prvino in oceno – napoved izvedbe prvine. Izračunani so bili Spearmanovi koeficienti korelacije med relativno močjo, višino/sedečo višino, in višino/razponom rok in časom izvedbe drže prvine med 14 vrhunskimi telovadci Argentinske reprezentance. Značilna korelacija ($p<0.01$) je bila med relativno močjo in časom, kar pomeni, da je 90% razovke pojasnjene z relativno močjo. Med ostalimi spremenljivkami ni bilo povezanosti. Rezultati in metodologija lahko pomagajo trenerju pri pripravi telovadca na razovko vodoravno.

Ključne besede: moška športna gimnastika, biomehanika, krogi, razovka vodoravno.

Petr Hedbávný, Jana Sklenaříková, Dušan Hupka, Miriam Kalichová

OHRANJANJE RAVNOTEŽJA V STOJI NA ROKAH NA PARTERJU

Pregledni znanstveni članek obravnava eno najosnovnejših prvin v telovadbi – stojo na rokah. Vzdrževanje strmoglavega ravnotežnega položaja je zapleten fiziološki in fizični proces. S fiziološkega vidika je potrebno predvsem opredeliti delovanje vestibularnega aparata, vidnega sistema, propriorecepcije, centralnega živčnega sistema in motoričnih enot, ki sodelujejo pri ohranjanju ravnotežnega položaja. Drugo vprašanje pa je povezanost med mišično silo posameznih mišičnih skupin in ravnotežnih sposobnosti. Glede na vrsto biomehaničnih raziskav o korektivnih gibih pri ohranjanju ravnotežja razlikujemo različne tipe strategije ohranjanja ravnotežja. Obstajata še dva pomembna dejavnika ohranjanja stoje na rokah in sicer vidna kontrola in položaj glave.

Ključne besede: gimnastika, stoja na rokah, ravnotežje, biomehanika, fiziologija.