TAKE-OFF HIP EXTENSION ANGLE INFLUENCE ON THE TUCKED BACK SOMERSAULT PERFORMANCE

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Abstract
Back somersault is a basic element of gymnastics; its performance is strongly influenced by the take-off phase. The present work aimed to study how hip extension in the take-off of the tucked back somersault influences the velocity of rotation and the height of the somersault. To this end, we recorded a total of 60 somersaults by 4 gymnasts (i.e., 15 somersaults each). There were three groups of somersaults based on the instructions that were given to the gymnasts: no specific instruction, somersault as high as possible and rotate as fast as possible. The records were then analyzed in order to quantify the following variables: maximal height of the mass center and maximal body angular velocity during somersault, the hip angle and the knee angle at the take-off. Gymnasts seemed to be inclined to bend their knees rather than extend their hips in order to carry out the instruction.

Keywords: *hip angle, angular velocity, mass trajectory center, back somersault.*

INTRODUCTION

One of the basic elements that gymnasts have to learn early in their career is the back somersault. The mastery of this exercise is fundamental for the gymnast to acquire the more complex skills that are needed for appropriate performance on all apparatuses, as claimed by Mkaouer, Jemni, Amara, Chaabène and Tabka (2013).

The quality of performance of back somersaults can be evaluated by two variables: the vertical displacement of the center of mass (COM) and the body angular velocity in the transverse axis (Mkaouer, Jemni, Amara, Chaabène & Tabka, 2012). Adequate equilibrium of height of the COM and rotational velocity signify that the gymnast is more likely to learn complex exercises. A good mastery of these two variables can also minimize the possibility of injuries and ensure gymnast’s safety.

The take-off phase of somersaults is crucial for the adequate performance of the flight phase according to Mkaouer et al. (2013), see Figure 1. The ground reaction forces and positions of joints at the take-off have been analyzed in various studies. For example, Sadowski, Boloban, Wiśniowski, Mastalerz and Niźnikowski (2005) studied the round-off tucked back somersault in tumbling. According to them, favorable joint angles at the take- off are: shank-thigh 180°, thigh-trunk 180°, trunk-shoulder 152° and shoulder-forearm 165°. Furthermore, in a study on a double layout in tumbling, Sadowski, Boloban, Mastalerz and Niznikowski

(2009) reported that in the preparatory phase of somersaults, typical errors include: flexed knee joints, flexed hip joints, or extreme inclination of the gymnast in respect to the vertical line. Additionally, according to Hraski (2002), the average angular momentum in the flight phase was greater with higher horizontal and lower vertical velocity at the take-off. King and Yeadon (2004) indicate that, during the take-off phase, the gymnast is able to change the linear and the angular momenta of the somersault by applying muscular torques. Furthermore, they demonstrate that the main error gymnasts make is the bad timing of muscle contraction at the take-off. Mikl (2018) investigated the torques that should be applied to joints in order to maintain a determinate posture in somersaults, but her work is more focused on the flight phase.

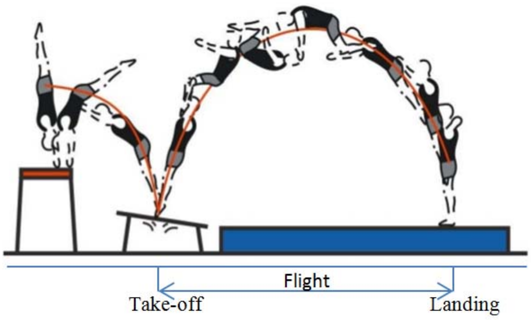

Figure 1. Phases of back somersault.

The hip angle is mentioned in various publications, and Mkaouer et al. (2012) note that this articulation seems to have a great importance during the back somersault, since they found a highly significant correlation between the vertical peak power and the angle of the hip joint. However, to our knowledge, no previous work has focused exclusively on the effect that the hip angle at the take-off has on specific characteristics of the back somersault. Consequently, the aim of the present work is to study how the hip angle at the take-off influences the maximal height of somersault (MHOS) and the maximal body angular velocity (MBAV) in the back-tuck somersault.

METHODS

Four female gymnasts were recruited for our study. Their characteristics were: IMC 19±1.63 kg/m^2, height 1.55 ± 0.04m, age 13.50 ± 0.18 years, weight 46 kg ± 1.97 kg, more than three years of experience in level 2 performance according to the FBG (Bolivian Federation of Gymnastics) standards. All gymnasts and their parents were informed in writing and orally and all parents signed a consent form. The experimental protocol was carried out in accordance with the Declaration of Helsinki (1964) and was approved by the Ethical Committee.

The following material was used for the exercises: a vault regulated at 1.35m; two mats of 0.30x2.00x1.50m; a 0.05x1.90x1.20m reception mat, a minitrampoline with an inclination of 7°. The exercises were carried out in front of a white background. Minitrampoline was chosen to help gymnasts change their usual technique without the risk of injury.

Each gymnast wore black clothes to contrast with the white background. The model utilized was “Havanan full body left side”. Therefore, each athlete had ten markers on her left side that were situated at the toes, at the lateral malleolus, at the lateral femoral condyle, at the great trochanter, at the acromion, at the medial epicondyle, at the ulna styloid process, at the chin and at the top of the head.

Each gymnast’s movements during the exercises were recorded with a Samsung android camera (S8) with 240 fps and 1280x1020 pixels resolution placed at 4.30 meters apart from the data acquisition region. We recorded and analyzed 15 somersaults (5x3 execution modes) for each gymnast.

The study started with ten minutes of a general warm-up. Next, the gymnasts had five minutes of a special warm-up to try the material that was used for our trial. Immediately after the last warm-up, the trial started.

The exercises that were analyzed began with a handstand on the vault table. Then, the gymnasts hit the minitrampoline and started to perform the back somersault as in Figure 1. In order to study the movement, the data starting at the take-off of the somersault and finishing at the reception mat was analyzed.

The somersaults carried out by the gymnasts were classified in three groups (5 somersaults per group), depending on the given instruction type. For the first group, no special instruction for the exercise was given (NI). For the second group, gymnasts were told to perform somersaults as high as possible (HS). Finally, for the third group, gymnasts were instructed to do back somersaults as fast as possible (FR). Each gymnast had five tries for each group of exercises. They had an average of 15 seconds to recover between tries and two minutes rest between the groups of different instructions. No feedback was given to the gymnasts about their somersaults.

Once the trial was finished, the field of view of the camera was calibrated. Two polystyrene sheets were located in the place where the gymnasts had performed the exercises. Each sheet was 50x100cm in size and was marked with 25x25cm squares, making a set of 45 calibration points.

All videos were analyzed with the software SkillSpector 1.3.2® (Mkaouer et al., 2013). From the data generated by this software, we used the hip angle, the knee angle, the MHOS and the MBAV. The angle of the knee and the hip at the take-off was measured in the first frame in which the toes lost contact with the minitrampoline.

Initially, the normal distribution of the data was tested by the Shapiro-Wilk test. However, since many data sets did not have normal distribution, mostly non-parametric methods were employed. As the four gymnasts carried out fifteen somersaults (five per modality), we first applied the Friedman K related samples test and then the Wilcoxon test for pairwise comparisons. Spearman Correlation Coefficient was applied to evaluate the correlation between variables. Finally, a polynomial fit was conducted with the hip angle as the regressor and MHOS and MBAV as the dependent variables: these three variables had normal distribution. The effect size was calculated in these three tests. The software used was: Tibco® statistica 13.0, ibm spss® statistics 26 and g*power 3.1®. The results were considered significant at 0.05.

RESULTS

As shown in Table 1, the instructions given to the gymnasts gave rise to statistically significant differences in the knee angle at the take-off, MHOS and MBAV, with p=0.000, and respectively p=0.008 and p=0.047. The effect size of Friedman test was w=0.574. Only the hip angle at the take-off did not vary significantly with the given instruction. Post-hoc Wilcoxon analysis with single-rank test was conducted for each variable with Bonferroni correction applied, resulting in a significance level set at p<0.017 and the effect size was w=0.440. The results of this post-hoc analysis are shown in Table 1 and the conclusion was that there was a statistically significant difference in knee flexion when the instruction “rotate as fast as possible” was given as compared to “no instruction” or “somersault as high as possible” (p=0.001 and p=0.000 respectively). For the hip angle at the take-off, none of the pairwise comparisons between the different instructions showed significant differences. For MHOS, a significant reduction in height was observed for the instruction “rotate as fast as possible” against “no instruction” (p=0.003). In MBAV, there was a significant increase of angular velocity for “rotate as fast as possible” as compared to “somersault as high as possible”.

The Spearman correlation coefficients obtained when all data from the three modalities were pooled (Table 2) had an effect size of q=0.616. This data showed a negative correlation between the hip angle and the knee angle at the take-off (r=-0.57). The knee angle at the take-off was positively correlated to MHOS (r=0.32); when the knees were more extended, the somersaults were higher. Finally, MHOS was negatively correlated to MBAV (r=-0.28) implying that higher somersaults can be detrimental to angular velocity. A significant polynomial regression was obtained for MHOS and MBAV with the hip angle (Table 2).

Polynomial regressions by the hip angle had significances for MHOS and MBAV (p=0.003; R^2=0.18 and p=0.02; R^2=0.13). Figures 2 and 3 highlight the relationships between the hip angle at the take-off and MHOS and between the hip angle at the take-off and MBAV in general data.

Table 1
Comparative Statistics of three modalities "NI" no instruction, "HS" somersault as high as possible and "FR" somersault as fast as possible.

Friedman K related test

Variables	χ^2	Sig.
Knee angle at the take-off	21.700	0.000**
Hip angle at the take-off	5.700	0.058
MHOS	9.700	0.008**
MBAV	6.100	0.047*

Wilcoxon single-rank test

	"NI" vs	"HS"	"NI" vs	"FR"	"HS" vs	"FR"
Variables	Z	Sig	Z	Sig	Z	Sig
Knee angle at the take-off	-1.381	0.167	-3.397	0.001**	-3.771	0.000**
Hip angle at the take-off	-1.083	0.279	-2.203	0.028*	-1.643	0.100
MHOS	-0.859	0.391	-2.949	0.003**	-2.128	0.330
MBAV	-0.542	0.588	-1.867	0.062	-2.389	0,017*

MHOS: Maximal height of somersault, MBAV: Maximal body angular velocity. (*) significant at p<0.05 and (**) significant at p<0.01

Table 2
Spearman correlation and Polynomial regressions.

	Variables	MHOS	MBAV
Spearman C.	Knee angle at the take-off	0.321*	0.212
	Hip angle at the take-off	0.109	-0.213
		R	p value
Polynomial Reg.	MHOS vs Hip angle at the take-off	0.425*	0.003*
	MBAV vs Hip angle at the take-off	0.355*	0.021*

MHOS: Maximal height of somersault, MBAV: Maximal body angular velocity. (*) significant at p< 0.05

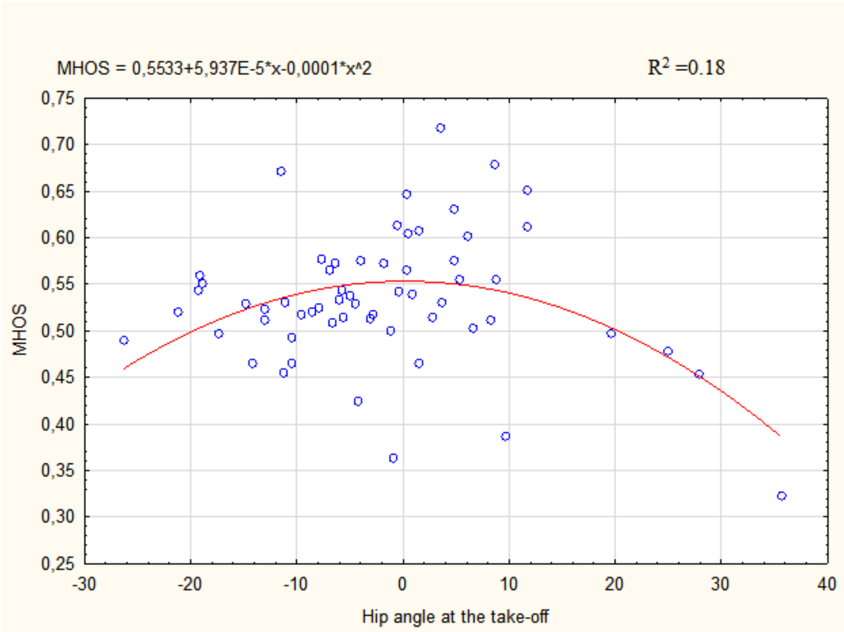

Figure 2. Polynomial regressions by the hip angle had significances for MHOS.

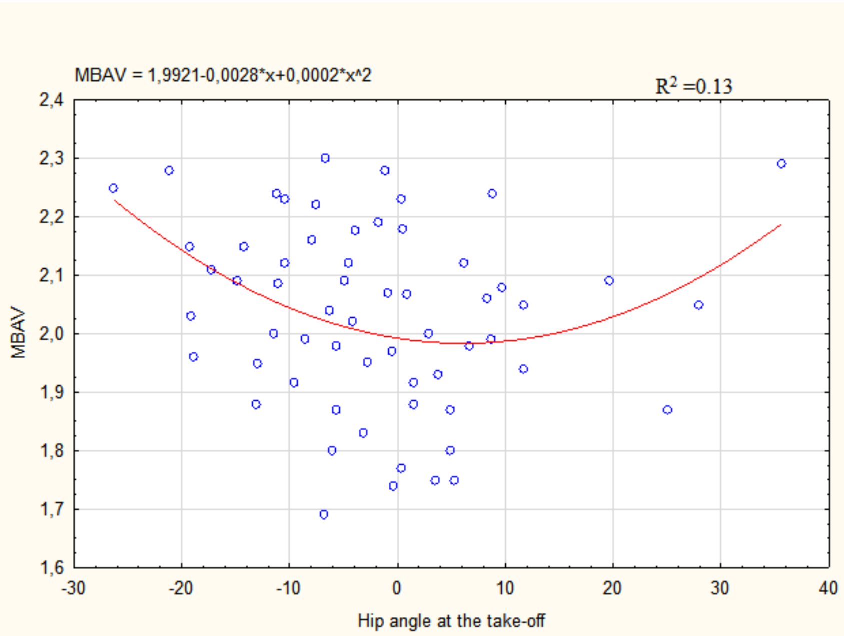

Figure 3. Polynomial regressions by the hip angle had significances for MBAV.

DISCUSSION

The purpose of this study was to find a correlation between the hip angle and MHOS and/or the hip angle and MBAV. We used three different instructions to increase the variability of the hip angle. However, the given instructions influenced the knee angle instead of affecting the hip angle. One reason for this result might be in that the gymnasts adopted less favorable biomechanics because the instruction gave rise to an "unplanned" motion, as described by Brown, Brughelli and Hume (2014). Gymnasts were instructed to perform somersaults in a way that was different from what they normally did and, since they could not correctly plan the somersault, the neuromuscular contraction was not the expected one. Additionally, Asseman, Caron and Crémieux (2008) indicate that previous training for different skills advantages gymnasts only if they perform the exercises in their usual training conditions.

Gymnasts bent more their knees when they were instructed to “rotate as fast as possible” in comparison to when “no instruction” or “somersault as high as possible”. At the same time, when gymnasts were told to “rotate as fast as possible”, the MHOS was significantly lower and the MBAV was significantly higher. Flexed knees seem to cause a decrease in the somersault height and an increase in angular velocity. Moreover, MHOS was significantly correlated to the knee angle for pooled data. Flexed knees are considered one of the main errors in the preparation for the somersault (Sadowski et al., 2005). It is therefore not surprising to lose height when these errors appear. Knee flexion means a relaxed extensor musculature of the lower limbs and absorption of forces exerted by the trampoline at this level according to Caine, Russel and Lim (2013). The absorption of forces could cause a decrease in MHOS. At the same time, knee flexion produces an important inclination of the body. In such cases, the take-off velocity vector does not pass through the COM and by then the somersault height decreases (Król, Małgorzata, Sobota & Nowak, 2016). On the other hand, this inclination carries the center of mass backward, which causes more lever arm (the distance in the horizontal axis between the center of mass and the point of contact between the feet and the trampoline) and consequently more torque as per Król et al. (2016). We recommend that trainers monitor the gymnast to avoid body inclination.

The hip angle did not have significant linear correlations with MHOS or MBAV. However, a relatively weak but significant polynomial regression between MHOS or MBAV and the hip angle was obtained (Figure 2 and 3). The hip angle influenced indirectly MHOS and MBAV. One trend that was observed in our pooled data was the correlation between the hip and the knee angles at the take-off (Table 2). Therefore, if the knee angle influenced MHOS and MBAV, the hip angle also had an indirect effect. This trend can be explained by the fact that a kinematic closed chain is formed in the lower limbs by the contact between the feet and the trampoline (Donskoi & Zatsiorski, 1988).

Finally, the negative correlation obtained between MHOS and MBAV (r=-0.28) is in agreement with Hraski (2002) who reported that the average angular momentum in the flight phase was greater with greater horizontal velocity and lower vertical velocity at the take-off.

CONCLUSIONS

Our gymnasts tended to bend their knees rather than extend their hips in order to carry out the given instructions. Knee flexion is considered a technical error and causes a decrease in the height of somersault. However, knee flexion favored a higher angular velocity. The hip angle and the knee angle were connected in the same closed kinematic chain. Therefore, the hip angle indirectly influenced the height and the angular velocity. We recommend further studies of the effect of the hip angle at the take-off in somersaults. In such studies, gymnasts should be given instructions that are more specific to this angle.

We recommend that coaches carefully monitor the position of the gymnast’s knees and avoid backward body inclinations that are detrimental to the technique. Also, coaches should consider that non-specific instructions can lead to knee flexion due to “unplanned” movements.

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