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Science of Gymnastics Journal (ScGYM®)

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

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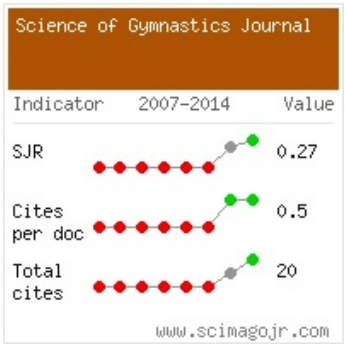

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Fundacija za šport

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CONTENTS

EDITORIAL

Dear friends,

We are entering into the eight year of our joint travel through science of gymnastics. We are starting new year with excellent news. Our journal will be now visible also in Web of Science in Core Collection. Web of Science have now new part, which is called ESCI- Emerging Sources Citation Index and it was established last year. We received information of inclusion after we published October issue last year. So our articles are now included into two very important data bases – Scopus and Web of Science.

The first four article are from biomechanics and the first article comes from Slovene and Czech authors Maja Bučar Pajek, Petr Hedbávný, Miriam Kalichová and Ivan Čuk. They did simple research by methods, but important by results. Women gymnastics on balance beam significantly influences one sided load, therefore rises bilateral asymetries, which are one of important reasons for ijnuries.

The second article is from United States of America, authors Timothy J. Suchomel, William A. Sands and Jeni R. Mcneal are sharing their experience with US male junior national team on their abilities measured on tensiometric plate. As their subjects are one of the best in the world it is worth to take their results to compare with your juniors.

The third article is from combined France and Canadian team of researchers Aurore Huchez, Diane Haering, Patrice Holvoet, Franck Barbier, Mickael Begon, thir article is about women artistic gymnastics, uneven bars, transition from low to high bar. Comparision between low and high level of gymnasts give coaches clear guideline where to direct their attention.

The fourth article is from Serbian and Slovene contributors Saša Veličković, Miloš Paunović, Dejan Madić, Vladan Vukašinović, Edvard Kolar, with similar idea as previous article, to focus coaches on their gymnasts when perform basket to handstand on parallel bars.

The fith article is from Spain researchers María Alejandra Ávalos Ramos, María Ángeles Martínez Ruiz, Gladys Merma Molina and thir resarch is valuable for all us teachers who do teach students about gymnastics, the most important guide to us is we should focus to real conditions which are in classes in primary and secondary schools.

The sixth article is from a huge Brazilian and Portugal team (consisted of 10 members) and they give us information about general gymnastics, more specific we get insight on how Pan American Gymnastics Union members contribute to the World Gymnaestrada.

The last article is also combined with researchers from two countries, Spain and Portugal. Catarina Leandro, Lurdes Ávila-Carvalho, Elena Sierra-Palmeiro, Marta Bobo-Arce prepared analyse of technical content of elite rhytmic gymnastics. It is worth to notice, their analysis would be benefitial to FIG RGTC to improve their rules.

Anton Gajdoš in Short Historical Notes V prepared a memo about Alois Hudec, Eugen Mack and men Czechoslovakia team of 1938. New content in journal is list of reviewers, who helped us last year with their knowledge.
Just to remind you, if you quote the Journal: its abbreviation on 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 ASYMMETRY OF LOWER LIMB LOAD IN BALANCE BEAM ROUTINES

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Original article

Abstract

The asymmetry of use of lower limbs may influence balance beam results and injury risk. This research was performed to study how many elements which asymmetrically load lower extremities are included in balance beam routines of professional female gymnasts. We video-recorded all exercises of qualification round on balance beam at an international competition B World Cup in Ljubljana 2014. We analysed take-offs and landings to define the actions done by left leg, both legs simultaneously, or right leg. A delay of at least 0.01 second in recruitment of one of the lower limbs defined the action as being from a single leg. In the routines of 19 included gymnasts we found significant asymmetry of load: right leg initiated 42.87% of actions (on average 12.47±3.32 per routine), while left leg and both legs initiated 29.08 and 28.05 % of actions (on average 8.58±2.97 and 8.21±3.07 per routine, respectively). The load on right leg was significantly larger compared to left leg and both legs (p=0.002 and 0.003). Only 4 gymnasts (20.8%) loaded left leg more than right leg. Additional review of code of points revealed that it mostly contains elements (in 60% of cases) where a single leg at take-off or at landing is loaded. We conclude that asymmetric lower limb loading is present at balance beam routines in elite gymnasts. We hypothesize that the unilateral distribution of load may be associated with the unilateral predominance of injuries and this should be analysed in further research.

Keywords: *female, artistic gymnastic, injuries, lateralization.*

INTRODUCTION

It was already in 1926 when body symmetry was recognised as a component of beauty and ideal body was supposed to always be symmetrical regarding the ratio of its parts as well as its physical abilities (Tyrš, 1926). In the Sokol gymnastic organization (one of the main middle Europe's gymnastic societies in the first half of 20th century) special emphasis was laid on equal involvement of musculoskeletal apparatus through distributed employment of exercises for various body parts (Fikar, 1947). Gymnastic exercises require coordination of muscle activities in space and time and this may be influenced by morphological or functional asymmetry (Sovak, 1962). Regarding the fact that motor abilities are a direct limiting factor of

performance, the level of lateral asymmetry of extremities may determine the gymnast's performance as well.

Strešková (2006) claimed that somatic and functional asymmetries are constantly influenced by the character of sport activity in a dynamic process independently of the dominance of lower and upper limbs. As stated by Marchetti (2009) and Bernaciková, Kapounkova, & Novotny (2011), preferential use of one of the lower limbs leads to adaptations at morphological, structural and functional levels. This may result in a functional specialization of the limbs such that one is more skilled in strength performance, such as bouncing, whereas the contralateral one is more skilled in performances requiring accuracy and in the art of swipe (Drnková & Syllabová, 1983; Sadeghi, Prince, Sadeghi, & Labelle, 2000). Niu, Wang, He, Fan, & Zhao (2011) examined biomechanical differences between the dominant and non-dominant limb during double-leg landing. They concluded that the non-dominant ankle has a more effective protective mechanism regarding excessive joint motion and that the dominant ankle joint is at a greater injury risk during drop landing.

By repeating asymmetrical physical activities the difference in somatic structure becomes evident: in athletes, the non-dominant leg showed greater cortical bone mineral density (BMD) than the dominant leg which is used for mobility or manipulation whereas the non-dominant leg lends support during the actions of the dominant leg (Sone, Imai, Joo, Onodera, Tomomitsu, & Fukunaga, 2006). Achilles tendon (AT) properties were also examined with regard to symmetry between legs in male healthy adults who were physically active (Bohm, Mersmann, Marzilger, Schroll, & Arampatzis, 2015). The AT of the dominant leg featured a significant higher Young's modulus and length but a tendency toward lower maximum strain compared with the non-dominant leg.

In artistic gymnastics, specifically in balance beam exercises, the differences between activities of the lower extremities are minimal; therefore the significant influence of asymmetry of lower limbs can be expected. When creating balance beam routine, which is the area of this study, athlete can choose from six groups of elements: 1. mounts, 2. gymnastic leaps, jumps and hops, 3. gymnastic turns, 4. holds and acrobatic non-flight, 5. acrobatic flight, 6. dismounts. The maximum of 8 highest difficulties including the dismount are counted for difficulty value (DV) score (maximum 5 acrobatic elements, minimum 3 dance elements) (FIG, 2013). Regarding the fact that landings and dismounts are the most common causes of injuries in artistic gymnastics (Marshall, Covassin, Dick, Nassar, & Agel, 2007; Lund & Myklebust, 2011), we are mainly interested in jumping elements. Here, the asymmetric reactions of the lower limbs when landing on a single leg were found, particularly in the size of the reaction forces (Chavet, Lafortune, & Gray, 1997). Čuk and Marinšek (2013) highlighted the asymmetric activity of the lower limbs when the jump element execution was not technically perfect. In such cases landing on both legs was associated with uneven load distribution. It is worth to note, that even elements which are supposed to be performed with both legs simultaneously, can have a significant asymmetrical load on lower limbs. This often happens in elements with turns (Čuk and Marinšek, 2013) and on balance beam we can find a lot of elements with turns in each element group.

There is a lack of data on association of asymmetries in artistic gymnastics and injury risk. There is some scarce data showing that increased lateral trunk sway (denoting asymmetric posture) is associated with knee ACL ligament injury (Hewett, Torg, & Boden, 2009) and asymmetry in functional movement screen score is a predictor of injury risk (Mokha, Sprague, & Gatens, 2016). However, none of these studies were performed in artistic gymnastics. Currently a theoretical hypothesis about asymmetry influence on injury risk states that asymmetries can influence muscle-skeletal relations such as

force-length relationship, alter the distribution of forces between the two legs, place the inert structures of joints under greater load, and put disproportionate demands on the musculature of one extremity. Asymmetries during bilateral tasks are surrogates of motor coordination and, therefore less coordinated athletes (who also exhibit greater asymmetries) are at a higher risk of injuries. Asymmetries in bilateral tasks may mean that excessive load is placed for example on one leg while the other leg is protected (and possibly de-trained) from successfully decelerating the body during landing. This may lead to increased risk of injury for both legs.

In the present study we were interested in the asymmetry of use of lower limbs due to its potential influence on balance beam results and injury risk. This research was aimed to find out how many elements which asymmetrically load lower extremities are included in balance beam routines of professional female gymnasts.

METHODS

At an international competition B World Cup in Ljubljana 2014 we video-recorded all exercises of qualification round on balance beam. Video-recording was done with Go Pro camera®, which was set to record 100 frames per second. Camera was placed in a proper position to capture mount, all actions on the balance beam and dismount. The position of the camera was perpendicular to the long axis of the beam as close to the middle point of the beam as possible. Taped material was retrieved with Kinovea® software to determine time codes at take-off and landings in 10 miliseconds time-marks.

On the balance beam we included into analysis all elements which are defined by the Code of Points (COP), simple steps and choreography were not taken into account. We analysed take-offs and landings (whether they were done with left leg, both legs simultaneously, or right leg). When a delay of at least 0.01 second of one of the lower limbs was noticed, we counted the action as being from a single leg. When there was recruitment of both legs in action in a shorter time interval we considered the action as being initiated by both legs. The time interval of delay between the legs was defined as a difference in time between the departure of first and last foot from the ground (or the time interval in the first ground contact in landing). The leg which left support last, was considered as the take-off leg and the leg which was first in support at landing was considered as the landing leg.

The reliability and validity in recognising left/right body side from the video-recorded routines in similar previous researches was high (Kovač, 2012). Two gymnastics experts (B.P.M. and H.P.) evaluated the taped routines, designated and counted the leg actions.

We calculated a sum of all take-offs and landings with left, right and both legs and a pairwise t-test between the number of left/right/both leg actions. As the number of take offs and landings were different by gymnasts we calculated also percentage of actions on left/right/both legs and again calculated a pairwise t-test between each left/right/both legs. Statistical analyses were done by using Microsoft Excel®.

This research was performed in accordance with the Declaration of Helsinki. The identity of all participants was blinded during evaluation process. Informed approval to study participation was given from all participants.

RESULTS

We included 19 exercises in the analysis. The scores of included 19 competitors are given in the Table 1. Competitors originated from 12 different countries and their average age was 19.1±3.3 years.

Main results (Table 2) show that gymnasts have a predominance of asymmetrical load. Gymnasts on average performed 12.47 actions with right leg, 8.58 with left leg and 8.21 actions with both legs. Right leg initiated 42.87% of actions, while

left leg and both legs initiated 29.08 and 28.05 % of actions. A large difference was found between the number of right and left leg initiated actions (the average of 5.05). Among all 19 gymnasts only one gymnast (5,2%, number 13) had a balanced load on left and right leg and almost an equal use of right (9)/left (9) or both legs (8) (Figure 1). On other side the most unbalanced gymnast (number 18) had the scores of right (16)/left (4)/both legs (11), which means 60% larger load on the right leg compared to the left (Figure 2). Only 4 gymnasts (20.8%) loaded left leg more than right leg.

Table 1
Difficulty (D), execution (E) and final score of competitors at balance beam routine (N=19).

Score	Mean	SD	Min	Max
Difficulty	4.71	0.5	3.5	5.5
Execution	6.79	0.72	5.4	7.9
Final	11.46	1	9.7	12.9

Table 2
Descriptive statistics.

Gymnast	Right leg	Left leg	Both legs	% Right leg	% Left leg	% Both legs	Abs. Difference R-L leg	% Difference R-L leg
1	17	11	5	51.52	33.33	15.15	6	21.43
2	11	8	12	35.48	25.81	38.71	3	15.79
3	13	7	3	56.52	30.43	13.04	6	30.00
4	15	11	9	42.86	31.43	25.71	4	15.38
5	14	11	7	43.75	34.38	21.88	3	12.00
6	15	9	10	44.12	26.47	29.41	6	25.00
7	19	8	5	59.38	25.00	15.63	11	40.74
8	12	4	13	41.38	13.79	44.83	8	50.00
9	12	4	5	57.14	19.05	23.81	8	50.00
10	16	10	2	57.14	35.71	7.14	6	23.08
11	10	8	7	40.00	32.00	28.00	2	11.11
12	9	12	8	31.03	41.38	27.59	3	14.29
13	9	9	8	34.62	34.62	30.77	0	0.00
14	11	12	10	33.33	36.36	30.30	1	4.35
15	7	9	10	26.92	34.62	38.46	2	12.50
16	12	11	10	36.36	33.33	30.30	1	4.35
17	12	3	10	48.00	12.00	40.00	9	60.00
18	16	4	11	51.61	12.90	35.48	12	60.00
19	7	12	11	23.33	40.00	36.67	5	26.32
XA	12.47	8.58	8.21	42.87	29.08	28.05	5.05	25.07
SD	3.32	2.97	3.07	10.77	8.92	10.11	3.42	18.68
SE	0.10	0.09	0.09	0.17	0.16	0.17	0.10	0.23

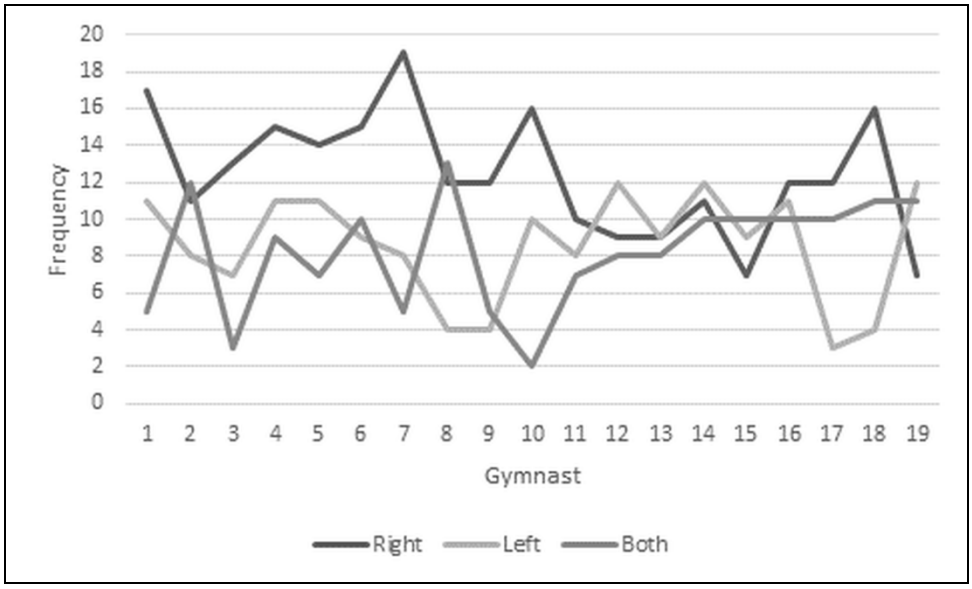

Figure 1. Load on legs by each gymnast (gymnasts are numbered by sequential numbers).

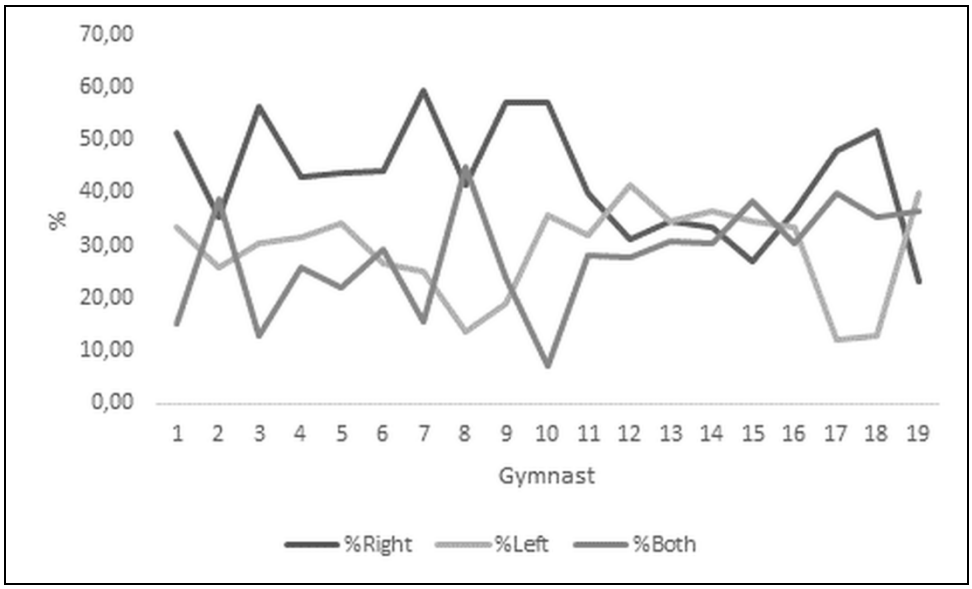

Figure 2. Load on legs in percentage according to all take offs and landings by each gymnast (gymnasts are numbered by sequential numbers).

Table 3
Probability (p) of pairwise t-test for significance of differences in the number and percentage of usage between pairs of variables.

Variable (absolute number of actions)	Left leg	Both legs
Right leg	0.002	0.002
Left leg	N/A	0.725
Variable (relative number of actions)	% Left leg	% Both legs
% Right leg	0.002	0.003
% Left leg	N/A	0.776

N/A – not applicable

Pairwise t-test (Table 3) showed a significant difference between the load on the right leg and left leg, right leg and both legs both for absolute values and relative values.

DISCUSSION

In the present study we analysed the asymmetry of usage of lower limbs in the take-off and landing phases of balance-beam gymnastic elements. We found a high and statistically significant predominance of unilateral (right leg) usage. From our results a critical question arises whether asymmetrical load of such a magnitude is acceptable not only for adults, but also children and youngsters. This asymmetrical load may have significant anthropometric, structural and safety impact.

The influence of long-term training on anthropometric parameters of rhythmic sports and artistic gymnasts was investigated by Douda, Laparidis, & Tokmakidis (2002) and they found significant differences in circumferences between the right and left legs, but surprisingly only in rhythmic gymnasts, not in artistic gymnasts. Another study assessed the position of the anterior and posterior iliac spinae (Barakatt, Smidt, Dawson, Wei, & Heiss, 1996). Gymnasts as a group were found to have asymmetrically positioned innominate bones as opposed to non-gymnasts representing the control group. By repeating asymmetrical physical activities bilateral differences between extremities and bones are expected to enlarge with time.

In regard to injuries, we know that elite female gymnasts may train on average 5.4 days a week and 5 hours a day (Caine, Cochrane, Caine, & Zemper, 1989), which exposes them to a high risk of serious injury. According to Purnell, Shirley, Nicholson, & Adams (2010) risk factors for injury are being older than 13 years and training for more than 8 h per week at the age of 11 years. In most of the surveys of injury locations, types and causative factors, two thirds of injuries were located in the lower extremities: 62 % percent of the injuries in the Swedish gymnastics team (Harringe, Renström, & Werner, 2007) and 69% in the study of Marshall, Covassin, Dick, Nassar, L, & Agel (2007). The most common acutely injured body parts were foot (21.0 %), ankle (19.3 %) and knee (14.0 %) (O'Kane et al, 2011). The most common injury was ankle sprain and the most frequent mechanisms were joint compression and joint rotation (Harringe et al., 2007). Concerning injury causes Lund and Myklebust found that 84 % of the injuries occurred in the landing phase of the gymnastic skills and most frequently the ankle was injured (Lund & Myklebust, 2011). The majority of competition injuries (approximately 70 %) resulted also from either landings or dismounts (Marshall et al, 2007). Other above-mentioned authors reported the same causes without percentages. Most injuries occurred on floor exercise (32.1 %), beam (20.7 %), and bars (17.0) (O'Kane, Levy, Pietila, Caine, & Schiff, 2011). These studies do not, however, evaluate which side of body was affected, whether it was an injury that occurred during performing symmetrical or asymmetrical elements and whether the dominant or non-dominant limb was injured. Kimmerle points out a similar problem in dancers, when he states that injury histories, injury reports, and surgical procedures could be a rich source of laterality data if they included the subjects' leg preferences for performing different dance skills and injured leg occurrences (Kimmerle, 2010). He stresses that it is important to include data on take-off and landing legs in jumps, range of motion and flexibility of the gesturing leg, and strength of the supporting leg when a balance task is difficult or the gesturing leg has to be held in the air for a long time.

Available literature mentions several cases of artistic gymnastics injuries where there was a bilateral injury of extremities, however such injuries are mostly reported as isolated cases (Syed & O'Flanagan, 1999; Fujioka et al, 2014; Oda, Fujiwara, Ichimaru, Morihara, Ikeda, & Kubo, 2015). Authors agree on the fact that these bilateral

injuries are rather exceptional, and predominantly we meet with unilateral injuries. Niu et al, (2011) examined biomechanical differences between the dominant and non-dominant limb during double-leg landing. They concluded that the non-dominant ankle has a more effective protective mechanism regarding excessive joint motion and that the dominant ankle joint is in at a greater injury of risk during drop landing. As we have already mentioned above, this fact can not be verified statistically because injury records do not provide sufficient information. As a result of the unilateral injuries further lateral differences can arise (Nadler, Malanga, DePrince, Stitik, & Feinberg, 2000): a significant difference in side-to-side symmetry of maximum hip extension strength was observed in female subjects who reported lower extremity injury or low back pain as compared to those who did not. Forkm, Koczur, Battle, & Newton (1996) compared ability to detect passive plantar flexion of the ankle in gymnasts with unilateral, multiple ankle sprains. For the injured ankle decreased level of the ability was found. Chilvers, Donahue, Nassar, & Manoli (2007) stated that if gymnast sustained serious injury of the lower limb requiring surgery, in most cases it led to career-ending (Chilvers et al, 2007).

On the basis of these reports we may infer that our data showing predominant unilateral load in the phases of routines strongly associated with injuries confirms a possible link between asymmetry of load and injuries and this hypothesis should be further explored in future studies.

Further important issue regarding the impact of asymmetry in load is the general structure of balance beam routines as defined by the COP (FIG, 2013). Elements are divided into following groups (added number of elements with difficulty, take offs and landing are counted for each figure within difficulty box):

- Mounts – 45 elements – take off with one leg 7, landing with one leg 6;
- Gymnastics leaps, jumps and hops – 35 elements, take off with one leg 17, landing with one leg 22;
- Gymnastics turns – 22 elements, take off (start of turn) with one leg 22, landing (end of turn) with one leg 22;
- Holds and acrobatic non –flight – 18 elements, take off with one leg 18, landing with one leg 12;
- Acrobatic flight - 34 elements, take off with one leg 15, landing with one leg 14;
- Dismounts - 29 elements, take off with one leg 16, landing with one leg 0;

It is evident that a vast number of elements are proposed as one leg take off or one leg landing. As can be seen in contemporary rules of artistic gymnastic, at any level of competition in gymnastics the symmetry of exercises is not emphasized neither in children, nor in adults (FIG, 2013). Furthermore, in COP there is no rule or statement on the symmetrical load. So it is evident that current COP and rules do not favour or acknowledge the symmetry of load.

The drawbacks of our study are a relative low number of included subjects and the absence of dominance definition of lower extremities. The dominant leg may be defined as the leg which a person uses for object manipulation and non-dominant leg maintains standing position (Gabbard & Iteya, 1996). However, a question arises what is the correct definition of dominant and non-dominant leg for gymnasts. Although the general consent is that the mobilising limb is considered the dominant leg, and the posture stabilizing leg is the non-dominant for practicing gymnasts perhaps predominant load-bearing extremity may be defined as the dominant one.

CONCLUSIONS

From our robust investigation on the symmetry of load we can conclude that asymmetric lower limb loading is present in balance beam routines in elite gymnasts. Asymmetrical load distribution is facilitated by the COP on balance beam, which mostly contains elements (in 60% of cases) where a

single leg at take-off or at landing is loaded. From the previous research and experience we can hypothesise that the unilateral distribution of load may be associated with the unilateral predominance of injuries with possible significant consequences. Further research should explore the impact and associations of the unilateral predominance of lower extremity load which was established in the present study and this would support coaches and gymnasts to construct their exercises with a higher symmetry of load.

REFERENCES

Barakatt, E., Smidt, G. L., Dawson, J. D., Wei, S. H., & Heiss, D. G. (1996). Interinnominate motion and symmetry: Comparison between gymnasts and nongymnasts. *J Orthop Sports Phys Ther*, *23*(5), 309–319.

Bernacikova, M., Kapounkova, K., & Novotny, J. (2011). *Fyziologie sportovních disciplín [Physiology of sports disciplines]*. Brno: Masarykova univerzita.

Bohm, S., Mersmann, F., Marzilger, R., Schroll, A., & Arampatzis, A. (2015). Asymmetry of Achilles tendon mechanical and morphological properties between both legs. *Scand J Med Sci Sports*, *25*(1), e124–32. doi:10.1111/sms.12242

Caine, D., Cochrane, B., Caine, C., & Zemper, E. D. A.-1989 N.-D. (1989). An epidemiologic investigation of injuries affecting young competitive female gymnasts. *Am J Sports Med*, *17*(6), 811–20 ST – An epidemiologic investigation of inj.

Chavet, P., Lafortune, M. A., & Gray, J. R. (1997). Asymmetry of lower extremity responses to external impact loading. *Hum Mov Sci*, *16*(4), 391–406. doi:10.1016/S0167-9457(96)00046-2

Chilvers, M., Donahue, M., Nassar, L., & Manoli, A. (2007). Foot and ankle injuries in elite female gymnasts. *Foot Ankle Int*, *28*(2), 214–8. doi:10.3113/FAI.2007.0214

Čuk, I., & Marinšek, M. (2013). Landing quality in artistic gymnastics is related to landing symmetry. *Biol Sport*, *30*(1), 29–33. doi:10.5604/20831862.1029818

Douda, H., Laparidis, K., & Tokmakidis, S. (2002). Long-Term training induces specific adaptations on the physique of rhythmic sports and female artistic gymnasts. *Eur J Sport Sci*, *2*(3), 1–13. doi:10.1080/17461390200072304

Drnková, Z., & Syllabová, R. (1983). *Záhada leváctví a praváctví [Mystery of left-handedness and right-handedness]*. Praha: Avicenum.

FIG. (2013). 2013-2016 Code of Points for Women's Artistic Gymnastics. *2013-2016 Code of Points*. Retrieved from http://www.fig-gymnastics.com/publicdir/rules/files/wag/WAG CoP 2013-2016 %28English%29 Nov 2014.pdf

Fikar, A. (1947). *O Sokole a sokolství [About Sokol]*. Praha: Československá obec sokolská.

Forkm, D. M., Koczur, C., Battle, R., & Newton, R. A. (1996). Evaluation of kinesthetic deficits indicative of balance control in gymnasts with unilateral chronic ankle sprains. *J Orthop Sports Phys Ther*, *23*(4), 245–250.

Fujioka, H., Nishikawa, T., Koyama, S., Yamashita, M., Takagi, Y., Oi, T., … Yoshiya, S. (2014). Stress fractures of bilateral clavicles in an adolescent gymnast. *J Shoulder Elbow Surg*, *23*(4), e88–90. doi:10.1016/j.jse.2014.01.004

Gabbard, C., & Iteya, M. (1996). Foot laterality in children, adolescents, and adults. *Laterality*, *1*(3), 199–205.

Harringe, M. L., Renström, P., & Werner, S. (2007). Injury incidence, mechanism and diagnosis in top-level teamgym: a prospective study conducted over one season. *Scandinavian Journal of Medicine & Science in Sports*, *17*(2), 115–9. doi:10.1111/j.1600-0838.2006.00546.x

Kimmerle, M. (2010). Lateral bias, functional asymmetry, dance training and dance injuries. *J Dance Med Sci*, *14*(2), 58–66.

Kovač, M. (2012). Assessment of gymnastic skills at physical education - The case of backward roll. *Sci Gymnastics J*,

4(3), 25–35.

Lund, S. S., & Myklebust, G. (2011). High injury incidence in TeamGym competition: a prospective cohort study. *Scan J Med Sci Sports*, *21*(6), e439–e444. doi:10.1111/j.1600-0838.2011.01362.x

Marchetti, P. H. (2009). *Investigação sobre o controle motor e postural nas assimetrias em membros inferiores*. Universidade de São Paulo.

Marshall, S. W., Covassin, T., Dick, R., Nassar, L. G., & Agel, J. (2007). Descriptive epidemiology of collegiate women's gymnastics injuries: National collegiate athletic association injury surveillance system, 1988-1989 through 2003-2004. *J Athl Train*, *42*(2), 234–240.

Nadler, S. F., Malanga, G. A., DePrince, M., Stitik, T. P., & Feinberg, J. H. (2000). The relationship between lower extremity injury, low back pain, and hip muscle strength in male and female collegiate athletes. *Clin J Sport Med*, *10*(2), 89–97.

Niu, W., Wang, Y., He, Y., Fan, Y., & Zhao, Q. (2011). Kinematics, kinetics, and electromyogram of ankle during drop landing: A comparison between dominant and non-dominant limb. *Hum Mov Sci*, *30*(3),614–623. doi:10.1016/j.humov.2010.10.010

O'Kane, J. W., Levy, M. R., Pietila, K. E., Caine, D. J., & Schiff, M. A. (2011). Survey of injuries in Seattle area levels 4 to 10 female club gymnasts. *Clin J Sport Med*, *21*(6),486–92. doi:10.1097/JSM.0b013e31822e89a8

Oda, R., Fujiwara, H., Ichimaru, K., Morihara, T., Ikeda, T., & Kubo, T. (2015). Chronic slipping of bilateral distal humeral epiphyses in a gymnastist. *J Ped Orthop*, *24*(1),67–70. doi:10.1097/BPB.0000000000000125

Purnell, M., Shirley, D., Nicholson, L., & Adams, R. (2010). Acrobatic gymnastics injury: occurrence, site and training risk factors. *Phys Ther Sport*, *11*(2), 40–6. doi:10.1016/j.ptsp.2010.01.002

Sadeghi, H., Prince, F., Sadeghi, S., & Labelle, H. (2000). Principal component analysis of the power developed in the flexion/extension muscles of the hip in able-bodied gait. *Med Eng Phys*, *22*(10), 703–10.

Sone, T., Imai, Y., Joo, Y.-I., Onodera, S., Tomomitsu, T., & Fukunaga, M. (2006). Side-to-side differences in cortical bone mineral density of tibiae in young male athletes. *Bone*, *38*(5), 708–13. doi:10.1016/j.bone.2005.10.002

Sovak, M. (1962). *Lateralita jako pedagogický problém [Laterality as a pedagogical problem]*. Praha: SPN.

Strešková, E. (2006). Morfologická a funkčná lateralita športujúcich dvojčiat [Morphological and functional laterality in sports twins]. In *Sport a kvalita života 2006*. Brno: Masaryk Univerzity.

Syed, A. A., & O'Flanagan, J. (1999). Simultaneous bilateral elbow dislocation in an international gymnast. *Br J Sports Med*, *33*(2), 132–3.

Tyrš, M. (1926). *Tělocvik v ohledu esthetickém [Exercise in terms aesthetic]*. Praha: Tyršův odkaz.

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COMPARISON OF STATIC, COUNTERMOVEMENT, AND DROP JUMPS OF THE UPPER AND LOWER EXTREMITIES IN U.S. JUNIOR NATIONAL TEAM MALE GYMNASTS

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Original article

Abstract

This study examined and compared static, countermovement, and rebound-type drop jumps from the upper and lower extremities among USA Junior National Team male gymnasts. Twenty-one gymnasts performed two repetitions each of upper (UE) and lower extremity (LE) static (SJ), countermovement (CMJ), and drop (DJ) jumps on a force platform. Average measures of maximum jump height (MXHT), peak force (PF), rate of force development (RFD), and peak power (PP) were calculated for analysis. In addition, sample-specific allometric scaling was used to scale PF and PP. Four 2x3 repeated measures ANOVAs were calculated for analyses. Statistically significant main effects were observed for UE vs LE for MXHT, PF, RFD, and PP (all $p < 0.001$). Statistically significant main effects for jump-type were also observed: MXHT, PF, RFD, and PP (all $p < 0.001$). Finally, statistically significant extremities x jump-type interaction effects were obtained for MXHT, PF, RFD, and PP (all $p < 0.001$). These gymnasts showed better performances in CJs relative to SJs, but performances were unexpectedly poorer in the DJs. Despite using rebound-type jumps in tumbling and vaulting with UE and LE, the DJs did not appear to capture the athletes' stretch-shortening cycle skill or may reflect poor stretch-shortening cycle skill.

Keywords: *stretch-shortening cycle, vertical jump, force analysis, gymnastics.*

INTRODUCTION

Gymnastics is an unusual sport in that primacy is placed on extreme levels of strength, power, and flexibility combined with small body size (Sands et al., 1994). Gymnastics-type jumps are performed regularly and systematically with both upper (UE) and lower extremities (LE) (Knoll, 2002; Li, Sun, & Ja, 2000). The floor exercise, tumbling, and vaulting events involve LE explosive jumps. Floor exercise, vaulting, pommel horse, and parallel bars incorporate UE jumping skills. As such, gymnasts, particularly male gymnasts, are an ideal group for the study of jump characteristics relationships between UE and LE combined with different types of jumps.

Jumping activities and tests, as a fitness measure, have long formed a key component in both the training and assessment of athletes in many sports at all levels. Jumps, whether from UE or LE, are often classified as a static jump (SJ), countermovement jump (CJ), or drop jump (DJ). A SJ is performed from a relatively low position (i.e. flexed elbows (UE) or flexed knees (LE)) that is held for a few moments in an effort to reduce or eliminate any stretch-shortening cycle (SSC) mechanism prior to an explosive push from the hands (UE) or feet (LE) to raise the body and reach a maximum height flight phase. A CJ begins in an upright raised position (i.e. extended elbows (UE) and knees (LE)) from which the athlete lowers quickly to a self-selected position of elbow (UE) and knee and ankle flexion (LE) followed immediately by explosive extensions of these joints to raise the body from the ground to a maximum height flight phase. Depending on the jumper's skill, the CJ uses an intermediate level of SSC. A DJ is usually performed from a raised surface or position where the athlete falls (i.e. drops) due to gravity to land on the hands or feet. The athlete then performs a rapid absorptive flexion followed by an explosive extension in the UE or LE joints, countering the impact load, and leading to a rise and maximum flight phase (Bobbert, Huijing, & Van Ingen Schenau, 1987a, 1987b). The three types of jumps described above embody different physiological and mechanical capacities of the athlete. The SSC is largely absent from a SJ, present but modest in a CJ, and dominant in a DJ (Bobbert, Gerritsen, Litjens, & Van Soest, 1996). Research and training approaches have emerged postulating that these types of jumps may allow specific diagnoses of explosive strength capacities in athletes (McNeal, Sands, & Shultz, 2007; Sands, McNeal, & Shultz, 1999).

Characterizing the potential differences in UE and LE jumping activities may assist practitioners in the intelligent prescription of training loads and evaluation methods of athletes who require UE and/or LE strength and power abilities. The extant literature on jumping is tilted heavily toward LE investigations, as literature reviews show (Baker, 1996; Hedrick & Anderson, 1996; Wathen, 1993). However, research on UE jumping is increasing rapidly (Freeman, Karpowicz, Gray, & McGill, 2006; Garcia-Masso et al., 2011; Koch, Riemann, & Davies, 2012; Mangine, Ratamess, Hoffman, Faigenbaum, Kang, & Chilakos 2008; Moore, Tankovich, Riemann, & Davies, 2012), and at least one study involving both UE and LE jumps has been conducted (Mangine, et al., 2008). A similar study of jump-types, as proposed here, was also performed on world level divers (Sands, McNeal, & Shultz, 1999).

Male gymnasts are an unusual population because of their reliance on UE and LE strength and power in training and performance. The purpose of this exploratory study was to characterize and compare UE and LE jump characteristics in three types of vertical jumps. The performance profiles created from this study, and the derivative information from jump-types, may provide information on the comparative capacities of UEs and LEs, and the relative use of SSC mechanisms by young highly trained male gymnasts. We hypothesized that statistical differences would be observed between the UE and LE, and that jump capabilities would show increased values in the order of static, countermovement, and drop jumps – mirroring the effective presence of the SSC.

METHODS

Twenty-one young male gymnasts (age: 15.1 ± 1.7 years, height: 159.7 ± 9.6 cm, body mass: 54.3 ± 11.0 kg) who participated in extensive gymnastics training (5 d/wk and 3-4 h/d) agreed to participate in this study. Every subject was a member of the U.S.A. Junior National Gymnastics Team. Testing occurred at the United States Olympic Training Center in Colorado Springs, CO during a national team training camp. Each athlete and their parents or guardians provided their written informed

assent or consent, respectively, prior to participation. This study was conducted under the requirements of the United States Olympic Committee with additional approval from the Institutional Review Board of East Tennessee State University.

A repeated measures design was used to test our hypotheses and determine the differences between UE and LE jumping and static, countermovement, and drop jumping conditions. Each participant completed a single testing session in which they performed two, single repetitions of both UE and LE static, countermovement, and drop jumps on a force platform.

A custom built force platform (61.0 cm x 61.0 cm x 11.2 cm) (Major, Sands, McNeal, Paine, & Kipp, 1998) sampling at 1,000 Hz was used to record the ground reaction forces produced during each LE and UE static, countermovement, and drop jump. The raw data from the force platform were stored in a computer and analyzed using custom software. No additional filtering or signal conditioning was used. The raw force-time data were then analyzed to calculate the variables of interest using previously established methods (Harman, 1995; Harman, Rosentstein, Frykman, Rosenstein, & Kraemer, 1991; Hatze, 1998; Semenick, 1990). Thirty-centimeter plyometric platforms (Power Systems, Inc., Knoxville, TN, USA) were used during the drop conditions for both LE and UE jumps. One box was used during the LE drop jump exercise, whereas two boxes were used during the UE drop jump exercise, one for each hand. During the drop conditions, the base of each box was positioned at the same height as the surface of the force platform.

Each athlete first completed their standard national team warm-up that consisted of various calisthenic exercises, walking, jogging, stretching, and basic tumbling skills. At the conclusion of their warm-up, athletes rotated in groups to each gymnastics event. The testing station was included in the event rotations. Upon reaching the testing station, athletes performed a self-selected number of practice repetitions for the SJ, CJ, and DJ tests to become familiar with each condition. The athletes were required to perform at least two practice repetitions of each test condition prior to testing. The lower extremity static jump (LSJ) required the athletes to squat to a knee angle of 90 degrees, remain in a static position, and without performing any extra countermovement, jump as high as possible. The lower extremity countermovement jump (LCJ) required the athletes to perform a countermovement to a self-selected knee, hip, and ankle flexion angle and then jump as high as possible. The lower extremity drop jump (LDJ) required the athletes to step off of a 30 cm plyometric box onto the force platform and immediately jump as high as possible, mimicking a gymnastics tumbling and vaulting takeoff. Each type of LE jump required the athletes to keep their hands on their hips at all times. If this posture was not maintained, the trial was repeated. Following the practice repetitions, each athlete performed two, single repetitions of the LSJ, followed by two, single repetitions of the LCJ and two, single repetitions of the LDJ. Athletes were given 1-2 min rest in between each repetition.

Upon completion of the LE jump conditions, athletes' body weights were measured with their hands on the force platform in a push-up position with the elbows extended. The athletes' effective UE mass in the push-up position was used within the scaling equations for the UE jumps. Next, the athletes performed practice repetitions of the UE static jump (USJ), countermovement jump (UCJ), and drop jump (UDJ). Like the LE jump conditions, athletes performed a self-selected number of practice repetitions, but were required to perform at least two practice repetitions for each variation. For each UE jump, the subject's feet were placed on a wood platform such that the feet were at the level of the force platform top-surface while their hands were placed on the force platform in a push-up position. The only exception of hand placement came during the UDJ, where the athletes started with one hand each on 30 cm plyometric

boxes. The USJ required the athlete to start in a lowered push-up position with the chest in contact with the force platform. From this position, athletes maximally pushed off the force platform to rise as high as possible achieving flight from the hands. Similar to the LSJ, the athlete received a countdown once they achieved the starting position, and then pushed off the platform as high as possible. The UCJ was performed starting in a standard push-up start position. Athletes then rapidly lowered themselves and then maximally pushed off the force platform achieving flight from the hands. The UDJ required the athletes to start with the arms horizontally abducted and one hand on each of the 30 cm plyometric boxes, adduct their arms to drop onto the force platform, and then maximally push off the force platform achieving flight from the hands. Following the practice repetitions, each athlete performed two, single repetitions of the USJ, followed by two, single repetitions of the UCJ, and two, single repetitions of the UDJ. Athletes again were provided with 1-2 min rest between each repetition. Figures 1-3 show examples of the force-time curves for a SJ, CJ, and DJ.

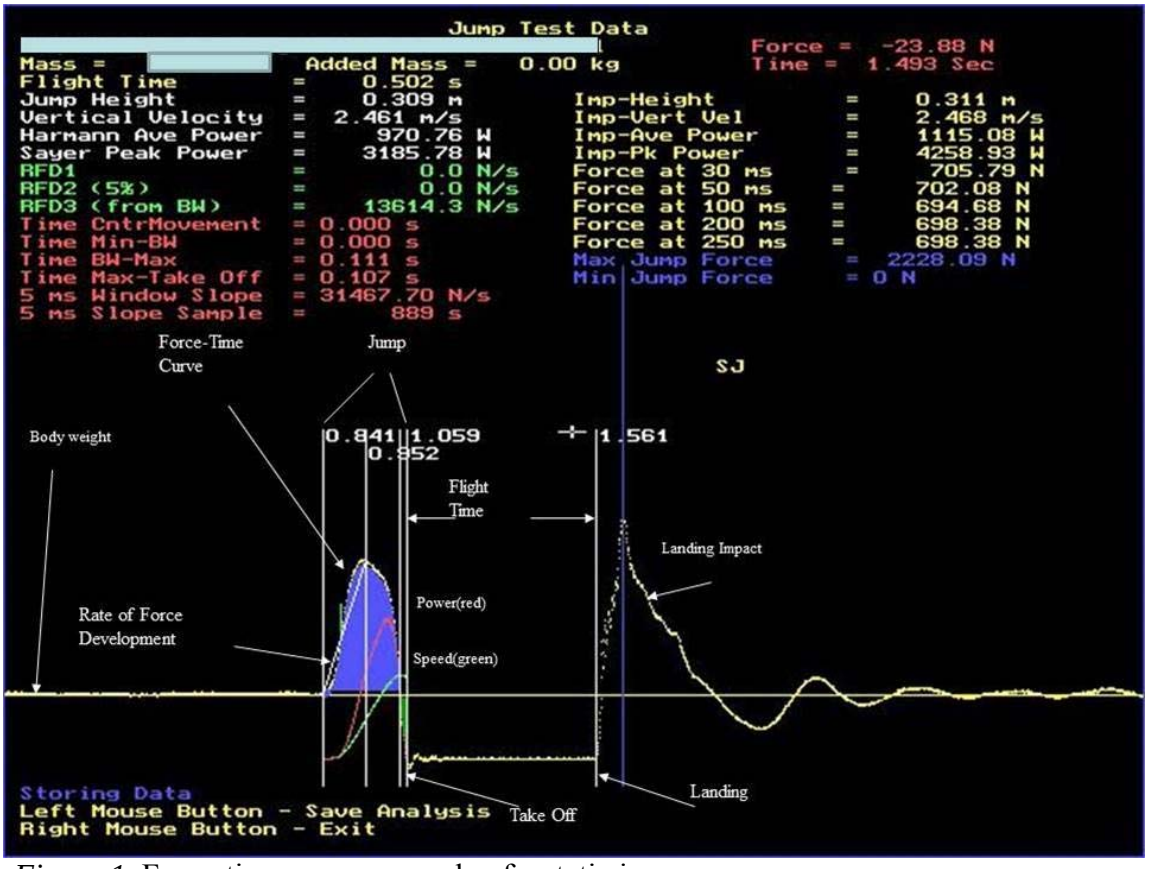

Figure 1. Force-time curve example of a static jump.

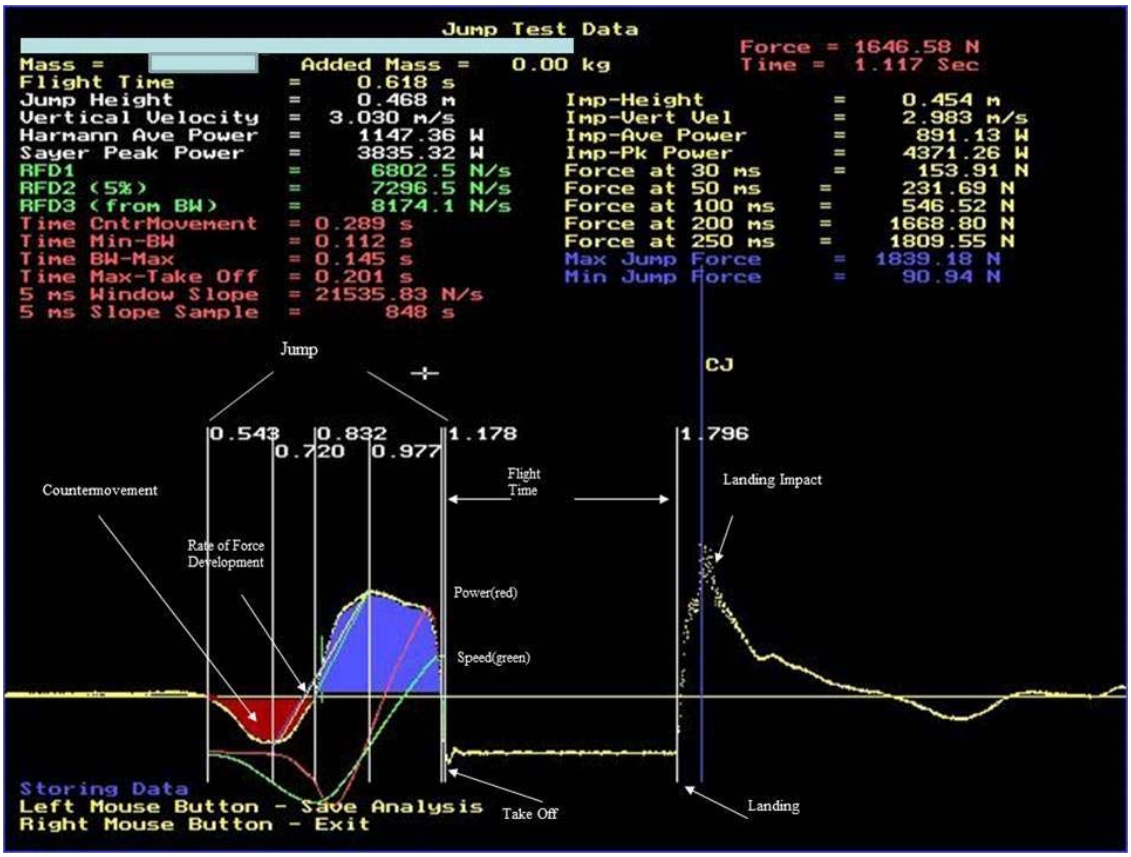

Figure 2. Force-time curve example of a countermovement jump.

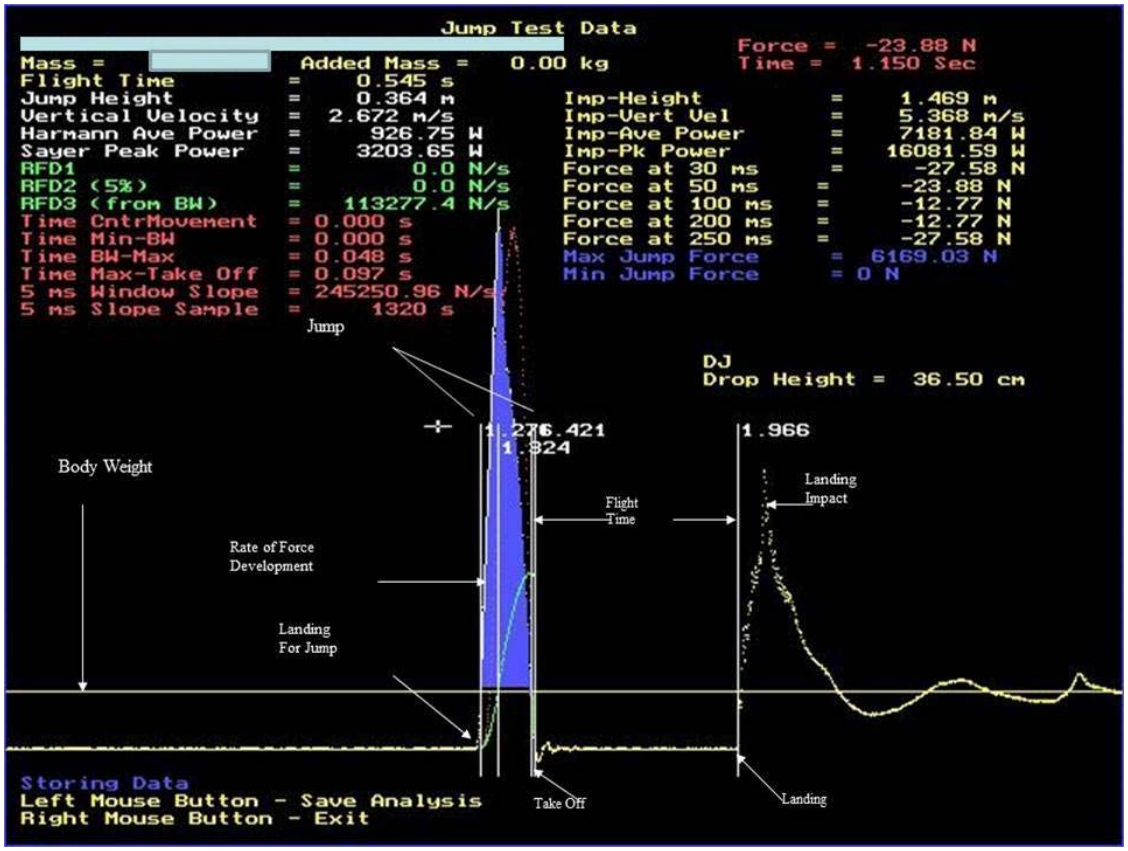

Figure 3. Force-time curve example of a drop jump.

The average of two trials for MXHT, RFD, and PF were used for further data analyses. The average of two trials of PP was used for further analyses for all jumps except the DJs. The lack of kinematics to confirm the transition from downward impact to upward jump on the UDJ and LDJ efforts did not permit power assessment. The goal of the LDJ technique was a 'bounce drop jump' that does not result in an identifiable countermovement from the force-time data alone. The UDJ instructions tried to achieve a 'near' bounce DJ, within safety limits, such as the type of UE impacts observed in tumbling and vaulting (McNeal, et al., 2007; Sands, 2014; Sands, Alumbaugh, McNeal, Murray, & Stone, 2014). All measured variables were compared between the jump and push-up movements (Henry, 1967).

Maximum jump heights were calculated from flight times produced during each jump type. Peak force and PP data were allometrically scaled using methods described by Auerbach et al. (2011) and Gayon (2000). Specific sample allometric scaling was adopted because of the youth and diminutive stature of young male gymnasts. We were concerned that the typical adult-based methods of allometric scaling would bias our results. Specifically, the natural logarithms for body mass, peak force, and peak power were calculated. Next, using regression equations, the slopes between body mass and peak force and body mass and peak power were calculated. Finally, the raw values of peak force and peak power were divided by the body mass of the subject raised to the slope found for each relationship. Using this approach, each variable includes a body mass that is raised to its own unique exponent, thus allometrically scaling each variable using its own unique relationship with either PF or PP. For the UE, the effective mass of the subject was measured while the subject was positioned in a standard push-up position with their hands on the force platform. For LE data, the entire body mass of the subject was used for allometric scaling.

A series of 2 (UE or LE) x 3 (SJ, CJ, DJ) repeated measures ANOVAs were used to analyze the data within this study. If the sphericity assumption was violated, Greenhouse-Geisser adjusted values were used. Pearson zero order product-moment correlation coefficients were used to examine the relationships between the relative gains or losses in output parameters between the upper and lower extremities. All statistical analyses were completed using SPSS 21 (IBM, New York, NY) and statistical significance was set at $p \leq 0.05$. Intraclass correlation coefficients, standard error of the measurement, minimum differences to be considered real, and paired-samples t-tests were calculated to assess the test-retest reliability of each variable using previously discussed methods (Weir, 2005) and are displayed in Table 1. Effect sizes (η^2_p) and statistical powers were calculated. Ninety-five percent confidence intervals were used for *post hoc* analyses.

RESULTS

Allometry

Calculation of the slope values for the relationships of the UE effective mass or entire body mass to each variable, as described above, showed that all values exceeded 1.0 (Table 2).

Upper versus Lower Extremities

Descriptive data for UE and LE performance measures are shown in Table 3. Statistical differences were found for all calculated variables: MXHT ($F_{1,20} = 235.36$, $p < 0.001$, $\eta^2_p = 0.92$), RFD ($F_{1,20} = 48.16$, $p < 0.001$, $\eta^2_p = 0.71$), PF ($F_{1,20} = 307.33$, $p < 0.001$, $\eta^2_p = 0.94$), PP ($F_{1,20} = 1551.43$, $p < 0.001$, $\eta^2_p = 0.99$).

No statistically significant relationships existed between the relative change in MXHT between the jump types of the upper and lower extremities for SJ-CJ ($p = 0.089$, r = 0.380), SJ-DJ ($p = 0.290$, r = 0.242), or CJ-DJ ($p = 0.839$, r = -0.047). Statistically significant relationships existed between the relative changes in RFD between jump types of the upper and lower extremities for

SJ-DJ ($p < 0.001$, r = 0.799) and for CJ-DJ ($p = 0.013$, r = 0.533), but not for SJ-CJ ($p = 0.992$, r = -0.002). There was statistically significant relationship between the relative change in PF between the upper and lower extremities for SJ-DJ ($p = 0.014$, r = 0.530), but not for SJ-CJ ($p = 0.465$, r = -0.169) or CJ-DJ ($p = 0.117$, r = 0.353). Finally, no statistically significant relationships existed between the relative change in PP between the jump types of the upper and lower extremities for SJ-CJ ($p = 0.324$, r = 0.226), SJ-DJ ($p = 0.808$, r = -0.056), or CJ-DJ ($p = 0.414$, r = -0.188).

Jump Types and Interactions

All calculated variables for jump-types and jump-type by UE and LE interactions were statistically different. Main effects for jump type were statistically different: MXHT ($F_{1,20} = 18.72$, $p < 0.001$, $\eta^2_p = 0.48$), RFD ($F_{1.01,20.09} = 46.73$, $p < 0.001$, $\eta^2_p = 0.70$), PF ($F_{1.15,22.97} = 308.71$, $p < 0.001$, $\eta^2_p = 0.94$), and PP ($F_{1.08,21.50} = 895.11$, $p < 0.001$, $\eta^2_p = 0.98$). Interaction effects (UE and LE by jump type) were found for MXHT ($F_{2,40} = 26.21$, $p < 0.001$, $\eta^2_p = 0.57$), RFD ($F_{1.01,20.14} = 45.75$, $p < 0.001$, $\eta^2_p = 0.70$), PF ($F_{1.27,25.44} = 17.76$, $p < 0.001$, $\eta^2_p = 0.47$), and PP ($F_{1.09,21.77} = 413.44$, $p < 0.001$, $\eta^2_p = 0.95$).

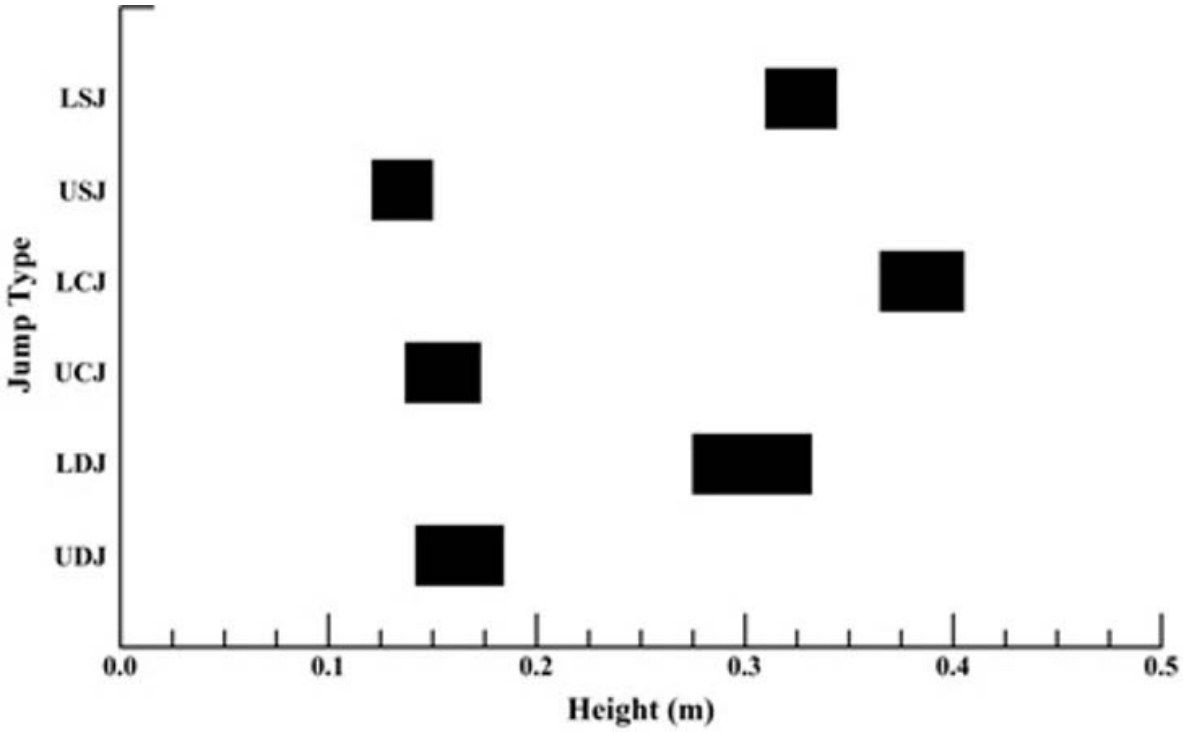

Figure 4. 95% confidence intervals for maximum jump height. USJ = upper extremity static jump; UCJ = upper extremity countermovement jump; UDJ = upper extremity drop jump; LSJ = lower extremity static jump; LCJ = lower extremity countermovement jump; LDJ = lower extremity drop jump.

Table
Test-retest reliability statistics for maximum jump height, rate of force development, peak force, and peak power.

	Max Heigh			
Exercise	ICC	SEM	MD	*p*
USJ	0.85	0.01	0.03	0.132
UCJ	0.86	0.01	0.04	0.001
UDJ	0.92	0.01	0.04	0.031
LSJ	0.83	0.02	0.05	0.062
LCJ	0.95	0.01	0.03	0.177
LDJ	0.96	0.01	0.03	0.019
	Rate of Force	Development		
	ICC	SEM	MD	*p*
USJ	0.93	498.10	1380.67	0.439
UCJ	0.91	532.51	1476.03	0.305
UDJ	0.82	449.00	1244.57	0.308
LSJ	0.91	1248.92	3461.83	0.660
LCJ	0.89	939.07	2602.97	0.424
LDJ	0.85	25903.12	71799.79	0.202
	Peak Force			
	ICC	SEM	MD	*p*
USJ	0.99	0.08	0.22	0.905
UCJ	0.99	0.17	0.47	0.195
UDJ	0.91	1.11	3.08	0.285
LSJ	0.98	0.27	0.74	0.250
LCJ	0.99	0.26	0.72	0.722
LDJ	0.94	1.89	5.23	0.617
	Peak Power			
	ICC	SEM	MD	*p*
USJ	0.97	0.08	0.24	0.172
UCJ	0.99	0.17	0.47	0.134
UDJ	0.99	0.64	1.76	0.127
LSJ	0.83	1.78	4.93	0.516
LCJ	0.99	0.24	0.67	0.154
LDJ	0.99	1.51	4.18	0.469

Notes: USJ = upper extremity static jump; UCJ = upper extremity countermovement jump; UDJ = upper extremity drop jump; LSJ = lower extremity static jump; LCJ = lower extremity countermovement jump; LDJ = lower extremity drop jump; ICC = intraclass correlation coefficient; SEM = standard error of the measurement; MD = minimum difference to be considered real; *p* = paired-samples t-test p-value between each trial

Table 2
Slopes used for allometric scaling of peak force and peak power.

Exercise	Allometric Scaling Slope	
	Peak Force (N/kg[a or c])	Peak Power (W/kg[b or d])
USJ	1.307[a]	1.774[b]
UCJ	1.233[a]	1.492[b]
UDJ	1.062[a]	1.291[b]
LSJ	1.128[c]	1.091[d]
LCJ	1.049[c]	1.150[d]
LDJ	1.187[c]	1.152[d]

Notes: USJ = upper extremity static jump; UCJ = upper extremity countermovement jump; UDJ = upper extremity drop jump; LSJ = lower extremity static jump; LCJ = lower extremity countermovement jump; LDJ = lower extremity drop jump

Table 3
Upper and lower extremity performance measures for static, countermovement, and drop jumps (Mean ± SD): n = 21.

Exercise	Max Height (m)	RFD (N/s)	Peak Force (N/kg[a or c])	Peak Power (W/kg[b or d])
USJ	0.14 ± 0.03	2632.22 ± 1882.65	6.4 ± 0.8[a]	1.82 ± 0.49[b]
UCJ	0.16 ± 0.04	3636.00 ± 1775.02	11.9 ± 1.7[a]	5.68 ± 1.70[b]
UDJ	0.16 ± 0.05	3636.95 ± 1058.31	23.5 ± 3.7[a]	22.96 ± 6.36[b]
LSJ	0.33 ± 0.04	6551.42 ± 4163.07	16.5 ± 1.9[c]	39.53 ± 4.31[d]
LCJ	0.38 ± 0.05	4255.02 ± 2831.40	20.4 ± 2.6[c]	29.55 ± 2.43[d]
LDJ	0.30 ± 0.06	103053.53 ± 66881.57	39.8 ± 7.7[c]	121.17 ± 15.07[d]

Notes: USJ = upper extremity static jump; UCJ = upper extremity countermovement jump; UDJ = upper extremity drop jump; LSJ = lower extremity static jump; LCJ = lower extremity countermovement jump; LDJ = lower extremity drop jump; RFD = rate of force development; a = upper extremity peak force scaling factor from Table 2; b = upper extremity peak power scaling factor from Table 2; c = lower extremity peak force scaling factor from Table 2; d = lower extremity peak power scaling factor from Table 2.

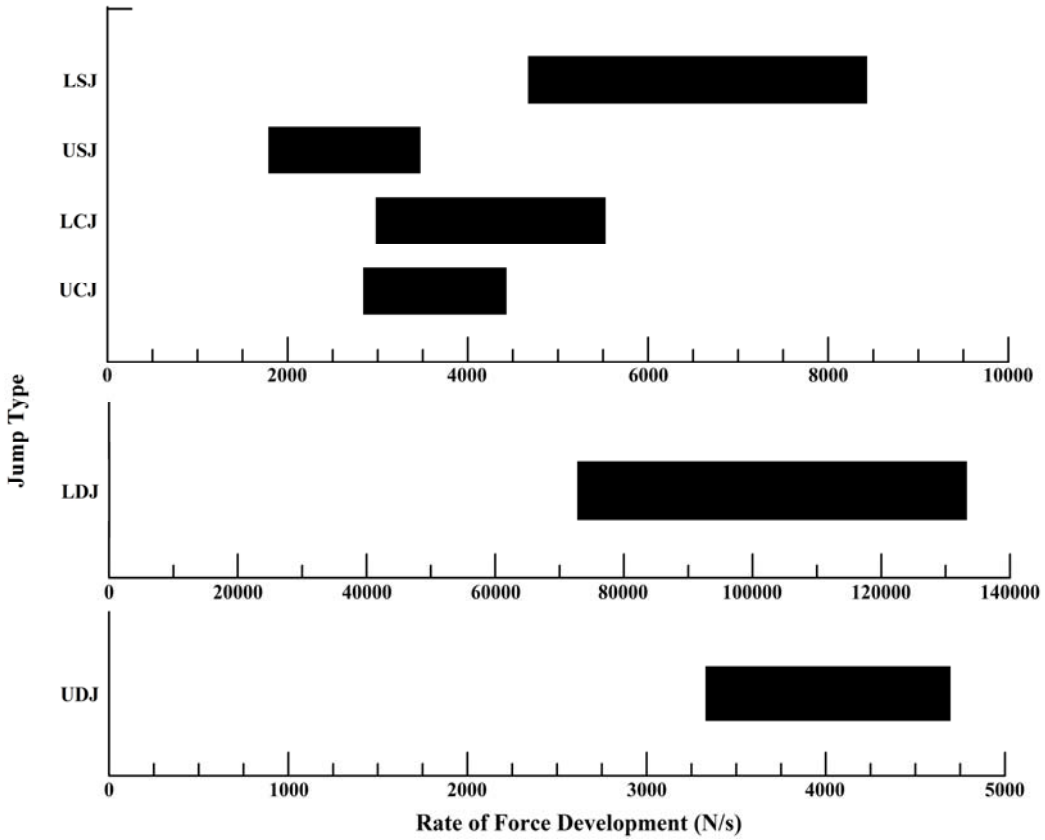

Figure 5. 95% confidence intervals for rate of force development. Note that the drop jump confidence intervals require a different scale and are shown separately at the bottom of the figure. USJ = upper extremity static jump; UCJ = upper extremity countermovement jump; UDJ = upper extremity drop jump; LSJ = lower extremity static jump; LCJ = lower extremity countermovement jump; LDJ = lower extremity drop jump.

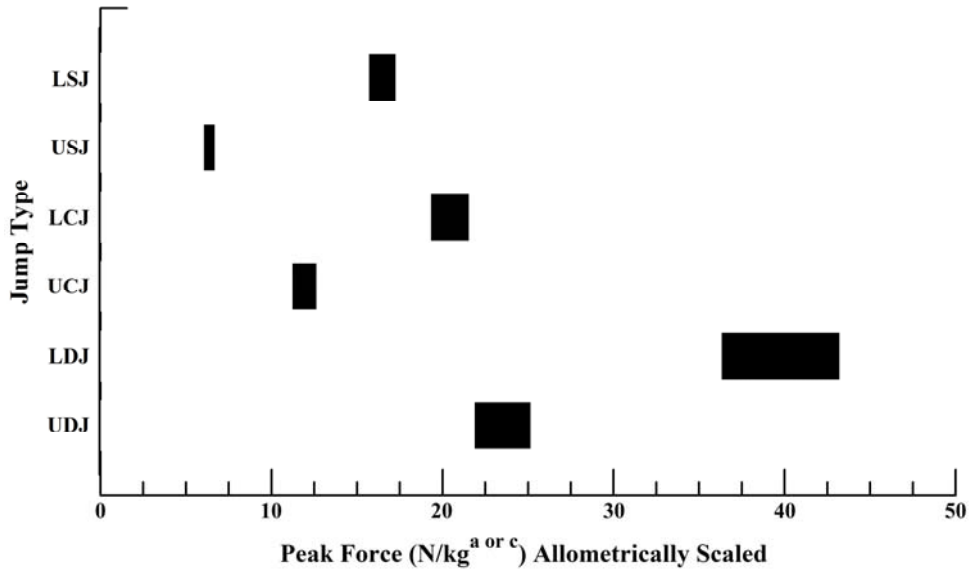

Figure 6. 95% confidence intervals for peak force allometrically scaled. USJ = upper extremity static jump; UCJ = upper extremity countermovement jump; UDJ = upper extremity drop jump; LSJ = lower extremity static jump; LCJ = lower extremity countermovement jump; LDJ = lower extremity drop jump; a or c = upper or lower extremity peak force scaling factor from Table 2, respectively.

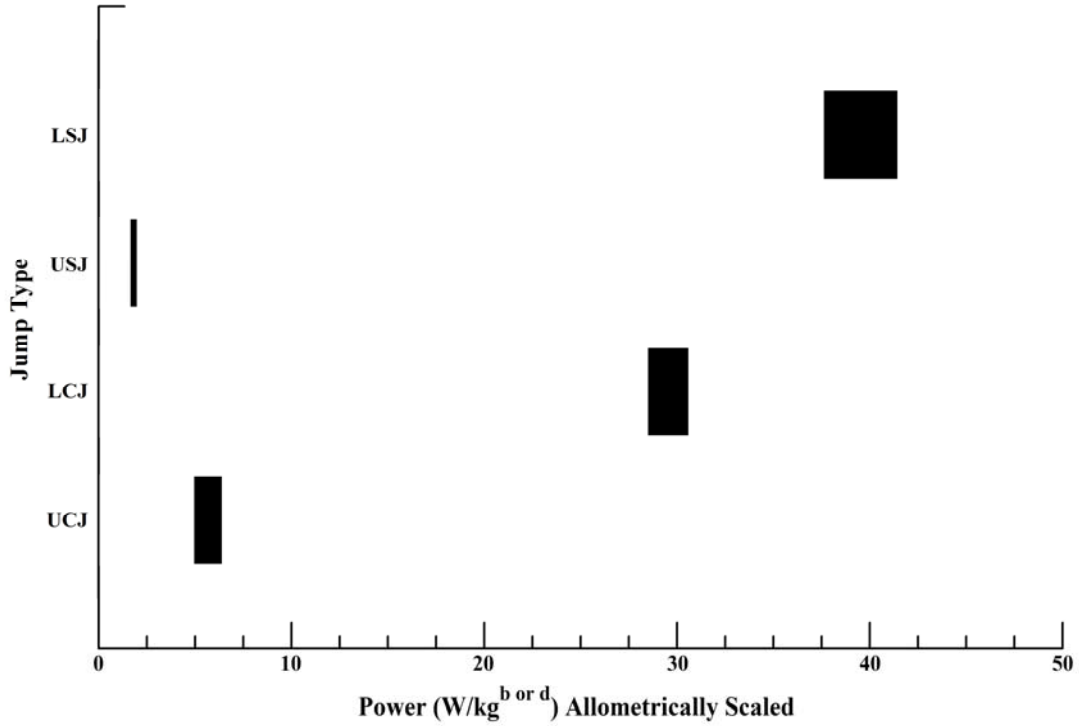

Figure 7. 95% confidence intervals for peak power allometrically scaled. Note that peak power was not calculated for the drop jumps. USJ = upper extremity static jump; UCJ = upper extremity countermovement jump; LSJ = lower extremity static jump; LCJ = lower extremity countermovement jump; b or d = upper or lower extremity peak power scaling factor from Table 2, respectively.

DISCUSSION

The reliability values displayed in Table 1 indicated that the trials data were stable. Table 2 shows the slopes or scaling exponent values for allometric scaling. Unique scaling exponent values were used because of the athletes' youth and the potential for mistaken assumptions using traditional scaling exponents such as 0.67 (Auerbach & Sylvester, 2011; Batterham, Tolfrey, & George, 1997). Table 2 shows that the scaling exponents were positive and greater than 1.0 for all variables. The scaling exponent values indicate that the variable increases more rapidly than body size, as defined by mass in these athletes. This information appears reasonable given the youth, selection to a high performance level national team, specific fitness, competitive success, and diminutive size of young male gymnasts (Carter, Ross, Aubry, Hebbelinck, & Borms, 1982; Dotan, Goldbout, & Bar-Or, 1980).

Our hypothesis that UE and LE jump variable values would differ was supported. Jump heights, PF, and PP all indicated a difference between UE and LE. However, RFD values showed little difference between the UCJ and the LCJ and were comparatively close to the USJ and LSJ, although the LSJ RFD reached greater magnitudes. The UDJ RFD values were close to both the UE and LE RFD values for SJs and CJs. Lower extremity efforts showed greater magnitudes in all variables except RFD in which the LCJ was similar to the UCJ. The relationships observed in comparisons of UE and LE variables may indicate that the UEs of these athletes had reached a performance ceiling in terms of RFD, while the LEs have a greater range of ability and/or adaptability regarding RFD. Of course, the LEs have considerably more muscle and larger joints to apply to rapid force production.

The allometrically scaled PF trended upward across the USJ, UCJ, and UDJ and the LSJ, LCJ, and LDJ. Interestingly, the only relationship between the upper and lower extremities that indicated a similar change in performance between jump types was the difference between the SJ and DJ. Allometrically scaled PP was not calculated for the UDJ and LDJ because of an inability to determine the transition from a downward direction of the impact to the upward direction of the jump. The USJ and UCJ followed our hypothesized trend of increasing performance while the LSJ and LCJ did not. The young gymnasts produced more power in the LSJ than the LCJ. The trends of these results indicate that the young gymnasts, while strong and explosive, do not appear to be well skilled in the use of the SSC. A comparable study using the same equipment and software with world and Olympic level divers (Sands, et al., 1999) showed some mixed results when comparing lower extremity SJ with CJ variables; however, the divers showed markedly improved performances in LDJ variables. Moreover, the divers generally performed in congruence with our stated hypotheses of performance magnitudes increasing from SJ to CJ to DJ. Gymnasts also differ from divers in the gymnast's general reticence to use weight training for conditioning, preferring to rely on body weight and repeated performance of gymnastics skills in a circuit-type format (Jemni, Sands, & Friemel, 2002; Sands, 2000).

In our study, the 95% confidence intervals showed that jump height of the LCJ was greater than the LSJ, but the LDJ was similar to the LSJ. Jump heights trended upward from USJ to UDJ, but did not demonstrate large differences. Additional analysis of the relationships between the relative gains or losses in MXHT revealed that the changes in performance between jump types were not similar between the upper and lower extremities. This may be due to several reasons including familiarity with the tasks, joint sequencing of each movement, and the amount of contributing musculature within the upper and lower extremities. Future research may consider performing an in-depth analysis that examines the differences between SJ-, CJ-, and DJ-type jumps between the upper and lower extremities.

The apparent inability of the young gymnasts to maximize their SSC actions, as demonstrated here, is paradoxical considering the powerful take-offs these athletes perform in tumbling and vaulting. The primary source of this paradox may be the reliance of gymnasts on jumping performances using soft mats and/or sprung surfaces (Arampatzis, 2002; Arampatzis, Bruggemann, & Klapsing, 2001). Jumping actions that involve landing on a steel plate may not share enough similarity with the specific jumping actions observed in gymnastics (Sands, 2014; Sands, et al., 2014), regardless of the extremities involved. Gymnasts jump and land using their LEs in LSJ, LCJ, and LDJ manners when tumbling and vaulting. The SJ variables were expected to be lower than the CJ variables. Countermovement jump variables were expected to be lower than DJ variables. The reasoning behind these assumptions was that gymnasts regularly and systematically train all types of jumps, but rely particularly heavily on the DJ-type of take-off for tumbling and vaulting. Common take-off foot contact durations in tumbling range from approximately 120 ms to 275 ms (Sands, 1984; Sands et al., 2013). As such, these take-off contact durations are somewhat longer than those desired by most SSC exercises and are performed on elastic spring surfaces such as the floor exercise spring floor and vault board. The longer durations of take-off foot contacts and systematic training on elastic surfaces may explain why these gymnasts were not as effective in DJs and the associated rapid SSC in this test context (Bobbert & van Zandwijk, 1999; Schmidtbleicher, 2002).

Gymnasts jump and land using their hands in USJ, UCJ, and UDJ manners when tumbling, vaulting, and during releases and re-grasps of the apparatuses. Gymnasts use a stretch-shortening-like action from the

hands particularly in tumbling and vaulting (Ferkolj, 2010; Penitente, Sands, McNeal, Smith, & Kimmel, 2010). Gymnasts' UEs suffer from similar injuries as seen in the LEs, both related to impact loading (Burt, Ducher, Naughton, Courteix, & Greene, 2013). However, there is no doubt that UE SSC actions are qualitatively and quantitatively different from the LE (Koch, et al., 2012; Li, et al., 2000; Mangine, et al., 2008). The results from this study showed that the UEs were less explosive than the LEs with the exception of DJs.

Children performing SSC exercise may exhibit modified and age/maturity-related muscle stiffness properties (Lloyd, Oliver, Hughes, & Williams, 2011b). Movement variability relative to the types of jumps has been shown in youngsters with vertical jump assessments involving SJs, CJs, and DJs (Meylan, Cronin, Oliver, Hughes, & McMaster, 2012). As children mature, the neuromuscular management of the SSC activities may shift to greater reliance on supra-spinal feed-forward mechanisms (Lloyd, Oliver, Hughes, & Williams, 2012). Others have postulated that young males may have similar SJs and CJs that follow adult-like patterns while SSC activities follow an alternative pattern (Lloyd, Oliver, Hughes, & Williams, 2011a). Stretch-shortening cycle behavior in CJs with an arm swing versus without showed that children exhibit about twice the movement variability of adults without an arm swing, but that athletes trained in jumping, such as basketball, do not exhibit the same movement variability (Gerodimos et al., 2008). This study prevented arm swing actions to ensure that the jumper's LE jump techniques were more reflective of LE actions. Athletes typically find static-type jump actions to be awkward. The role of maturation, training, jumping technique context, and other factors may contribute to the young gymnast's ability or inability to capitalize on the SSC during CJs and DJs.

CONCLUSIONS

Allometric scaling exponents greater than 1.0 existed for the junior male gymnast subjects within this study, indicating that variables increased more rapidly than body size. The allometric scaling approach used in the current study indicated that the exponent used for scaling was unique for each body portion and jump condition. This information is the first we have found showing this phenomenon. Coaches may need to increase their vigilance and understanding regarding determination of physical maturation via peak height velocity or other measures by including measures of strength and power fitness.

Young male gymnasts follow the premise partially that jumping ability should proceed from low to high via static-, countermovement-, and drop-types of UE and LE jumps by using progressively greater SSC skills and abilities. However, these gymnasts were unusual in that their ability to use the SSC may be attenuated due to physical maturation, use of softer take-off and landing surfaces, and lack of emphasis or access to weight training. The addition of a periodized resistance training program may benefit young male gymnasts in developing the necessary musculature needed to improve their UE and LE jumping ability and use of the SSC (Baker, 1996). It is suggested that the resistance training program should place an emphasis on developing general strength, especially with a younger population, before transitioning to more explosive type movements. The training stimulus (i.e. tumbling, vaulting, etc.) received by young gymnasts may be sufficient in training SSC movements and therefore additional plyometric volume may be unnecessary.

REFERENCES

Arampatzis, A. (2002). Interaction between elastic surfaces and the human body and its effect on the gymnastic performance. In S. Prassas & K. Gianikellis (Eds.), *Applied Proceedings: Gymnastics* (pp. 1-8). Caceres, Spain: International Society on Biomechanics in Sports, University of Extremadura.

Arampatzis, A., Bruggemann, G. P., & Klapsing, G. M. (2001). Leg stiffness and mechanical energetic processes during jumping on a sprung surface. *Med Sci Sports Exerc, 33*(6), 923-931.

Auerbach, B. M., & Sylvester, A. D. (2011). Allometry and apparent paradoxes in human limb proportions: Implications for scaling factors. *Am J Phys Anthropol, 144*(3), 382-391.

Baker, D. (1996). Improving vertical jump performance through general, special, and specific strength training: A brief review. *J Strength Cond Res, 10*(2), 131-136.

Batterham, A. M., Tolfrey, K., & George, K. P. (1997). Nevill's explanation of Kleiber's 0.75 mass exponent: an artifact of collinearity problems in least squares models? *J Appl Physiol, 82*(2), 693-697.

Bobbert, M. F., Gerritsen, K. G. M., Litjens, M. C. A., & Van Soest, A. J. (1996). Why is countermovement jump height greater than squat jump height? *Medicine and Science in Sports and Exercise, 28*(11), 1402-1412.

Bobbert, M. F., Huijing, P. A., & Van Ingen Schenau, G. J. (1987a). Drop jumping. I. The influence of jumping technique on the biomechanics of jumping. *Med Sci Sports Exerc, 19*(4), 332-338.

Bobbert, M. F., Huijing, P. A., & Van Ingen Schenau, G. J. (1987b). Drop Jumping. II. The influence of dropping height on the biomechanics of drop jumping. *Med Sci Sports Exerc, 19*(4), 339-346.

Bobbert, M. F., & van Zandwijk, J. P. (1999). Dynamics of force and muscle stimulation in human vertical jumping. *Med Sci Sports Exerc, 31*(2), 303-310.

Burt, L. A., Ducher, G., Naughton, G. A., Courteix, D., & Greene, D. A. (2013). Gymnastics participation is associated with skeletal benefits in the distal forearm: a 6-month study using peripheral Quantitative Computed Tomography. *J Musculoskelet Neuronal Interact, 13*(4), 395-404.

Carter, J. E. L., Ross, W. D., Aubry, S. P., Hebbelinck, M., & Borms, J. (1982). Anthropometry of Montreal Olympic Athletes. In E. Jokl (Ed.), *Physical structure of Olympic Athletes* (Vol. 16, pp. 25-52). Basel, Switzerland: Karger.

Dotan, R., Goldbout, U., & Bar-Or, O. (1980). Kinanthropometric parameters as predictors for the success of young female and male gymnasts (abstract). In M. Ostyn, G. Beunen & J. Simons (Eds.), *Kinanthropometry II* (9 ed., pp. 212-213). Baltimore, MD: University Park Press.

Ferkolj, M. (2010). A kinematic analysis of the handspring double salto forward tucked on a new style of vaulting table. *Sci Gymnastics J, 2*(1), 35-48.

Freeman, S., Karpowicz, A., Gray, J., & McGill, S. (2006). Quantifying muscle patterns and spine load during various forms of the push-up. *Med Sci Sports Exerc, 38*(3), 570-577.

Garcia-Masso, X., Colado, J. C., Gonzalez, L. M., Salva, P., Alves, J., Tella, V., et al. (2011). Myoelectric activation and kinetics of different plyometric push-up exercises. *J Strength Cond Res, 25*(7), 2040-2047.

Gayon, J. (2000). History of the concept of allometry. *Amer Zool, 40*, 748-758.

Gerodimos, V., Zafeiridis, A., Perkos, S., Dipla, K., Manou, V., & Kellis, S. (2008). The contribution of stretch-shortening cycle and arm-swing to vertical jumping performance in children, adolescents, and adult basketball players. *Pediatr Exerc Sci, 20*(4), 379-389.

Harman, E. A. (1995). The measurement of human mechanical power. In P. J. Maud & C. Foster (Eds.), *Physiological assessment of human fitness*

(pp. 87-113). Champaign, IL: Human Kinetics.

Harman, E. A., Rosentstein, M. T., Frykman, P. N., Rosenstein, R. M., & Kraemer, W. J. (1991). Estimation of human power output from vertical jump. *J Appl Sport Sci Res, 5*(3), 116-120.

Hatze, H. (1998). Validity and reliability of methods for testing vertical jumping performance. *Journal of Applied Biomechanics, 14*(2), 127-140.

Hedrick, A., & Anderson, J. C. (1996). The vertical jump: A review of the literature and a team case study. *Natl Strength Cond Assoc J, 18*(1), 7-12.

Henry, F. M. (1967). "Best" versus "average" individual scores. *Res Quart, 38*(2), 317-320.

Jemni, M., Sands, W., & Friemel, F. (2002). Etude de la recuperation entre les agres lors de quatre entrainements de gymnasttique masculine. *Exercise Physique Sportive, 57*, 57-61.

Knoll, K. (2002). Basic biomechanical relationships at push-off for handspring forward vaults. In K. E. Gianikellis (Ed.), *Scientific Proceedings of the XXth International Symposium on Biomechanics in Sports* (pp. 162). Caceres, Spain: Universidad de Extremadura, International Society of Biomechanics in Sports.

Koch, J., Riemann, B. L., & Davies, G. J. (2012). Ground reaction force patterns in plyometric push-ups. *J Strength Cond Res, 26*(8), 2220-2227.

Li, E., Sun, Y., & Ja, G. (2000). Biomechanical study of push-off technique for handspring and front salto vault. In Y. Hong & D. P. Johns (Eds.), *Proceedings of XVIII International Symposium on Biomechanics in Sports* (I ed., pp. 285-288). Hong Kong, China: The Chinese University of Hong Kong, International Society for Biomechanics in Sports.

Lloyd, R. S., Oliver, J. L., Hughes, M. G., & Williams, C. A. (2011a). The influence of chronological age on periods of accelerated adaptation of stretch-shortening cycle performance in pre and postpubescent boys. *J Strength Cond Res, 25*(7), 1889-1897.

Lloyd, R. S., Oliver, J. L., Hughes, M. G., & Williams, C. A. (2011b). Specificity of test selection for the appropriate assessment of different measures of stretch-shortening cycle function in children. *J Sports Med Phys Fitness, 51*(4), 595-602.

Lloyd, R. S., Oliver, J. L., Hughes, M. G., & Williams, C. A. (2012). Age-related differences in the neural regulation of stretch-shortening cycle activities in male youths during maximal and sub-maximal hopping. *J Electromyogr Kinesiol, 22*(1), 37-43.

Major, J. A., Sands, W. A., McNeal, J. R., Paine, D. D., & Kipp, R. (1998). Design, construction, and validation of a portable one-dimensional force platform. *J Strength Cond Res, 12*(1), 37-41.

Mangine, G. T., Ratamess, N. A., Hoffman, J. R., Faigenbaum, A. D., Kang, J., & Chilakos, A. (2008). The effects of combined ballistic and heavy resistance training on maximal lower- and upper-body strength in recreationally trained men. *J Strength Cond Res, 22*(1), 132-139.

McNeal, J. R., Sands, W. A., & Shultz, B. B. (2007). Muscle activation characteristics of tumbling take-offs. *Sports Biomech, 6*(3), 375-390.

Meylan, C. M., Cronin, J. B., Oliver, J. L., Hughes, M. G., & McMaster, D. T. (2012). The reliability of jump kinematics and kinetics in children of different maturity status. *J Strength Cond Res, 26*(4), 1015-1026.

Moore, L. H., Tankovich, M. J., Riemann, B. L., & Davies, G. J. (2012). Kinematic analysis of four plyometric push-up variations. *Int J Sport Physiol Perform, 5*(4), 334-343.

Penitente, G., Sands, W. A., McNeal, J., Smith, S. L., & Kimmel, W. (2010). Investigation of hand contact forces of female gymnasts performing a handspring vault. *Int J Sports Sci Eng, 4*(1), 015-024.

Sands, W. A. (1984). Aspects of the tumbling take off. *Technique, 4*(2), 16-23.

Sands, W. A. (2000). Olympic Preparation Camps 2000 Physical Abilities Testing. *Technique, 20(10)*, 6-19.

Sands, W. A. (2014). Interactions of the gymnast and spring floor. *Sports Performance and Tech, 1*(7), 29-33.

Sands, W. A., Alumbaugh, B., McNeal, J. R., Murray, S. R., & Stone, M. H. (2014). Comparison of floor exercise apparatus comparison of floor exercise apparatus spring-types on a gymnastics rearward tumbling take-off. *Science of Gymnastics Journal, 6*(2), 41-51.

Sands, W. A., Kimmel, W. R., McNeal, J. R., Smith, S. L., Penitente, G., Murray, S. R., et al. (2013). Kinematic and kinetic tumbling take-off comparisons of a spring-floor and an Air Floor(TM): A Pilot Study. *Sci Gymnastics J, 5*(3), 31-46.

Sands, W. A., Major, J. A., Irvin, R. C., Hauge Barber, L. S., Marcus, R. L., Paine, D. D., et al. (1994). Physical abilities profiles: U.S. Men's National Team. *Technique, 14*(2), 34-37.

Sands, W. A., McNeal, J. R., & Shultz, B. B. (1999). Kinetic and temporal patterns of three types of vertical jump among elite international divers. *Sports Med Train Rehab, 9*(2), 107-127.

Schmidtbleicher, D. (2002). Neuromuscular aspects of strength and strength training with respect to stretch-shortening-cycle typed movements. In K. E. Gianikellis, D. Schmidtbleicher, V. Baltzopoulos & V. M. Zatsiorsky (Eds.), *ISBS 2002 Applied Proceedings - Strength Training* (pp. 13-21). C ceres, Spain: University of Extremadura, C ceres, Spain, International Society of Biomechanics in Sports.

Semenick, D. (1990). The vertical jump. *Natl Strength Cond Assoc J, 12*(3), 68-69.

Wathen, D. (1993). Literature review: explosive/plyometric exercises. *Natl Strength Cond Assoc J, 15*(3), 17-19.

Weir, J. P. (2005). Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *J Strength Cond Res, 19*(1), 231-240.

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DIFFERENCES BETWEEN EXPERT AND NOVICE GYMNASTS PERFORMANCE OF A COUNTER MOVEMENT FORWARD IN FLIGHT ON UNEVEN BARS

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Original article

Abstract

This study investigated the different strategies exhibited by expert and novice gymnasts in counter movement forward in flight on uneven bars. Eleven gymnasts performed three trials connected with a kip to support. The gymnasts were divided into two groups according to their ability to connect: six able (termed as experts) versus five non-able (novices). The 3D motion data were collected at 250 Hz. Biomechanical parameters were computed at release (release state and angular momentum), during aerial phase (duration, minimum value of the moment of inertia) and at regrasp (total duration and rotation angle). Robustness of the release state was also compared. Significant differences were found between groups in the three phases. The novice gymnasts performed as robustly as expert gymnasts but less efficiently because they released the low bar before their centre of mass passed the horizontal, with a lower vertical velocity, resulting in a lower and shorter aerial phase. They also had a larger minimum moment of inertia in flight. Coaches could help novice gymnasts to decrease their dependency on their robust technique by improving the release angle. Exercises, which may allow novice gymnasts to exceed the threshold of a 90° rotation angle at release are suggested.

Keywords: *technique, expertise, counter movement forward in flight, kinematics.*

INTRODUCTION

Gymnasts can perform the same skill independently or as a part of a sequence. Additional constraints appear when the skill is performed as a part of a sequence. Indeed, the final body state of the first element (*i.e.*, the position, the configuration and their speed) must lead to the initial state of the following skill. A few adaptations are thus required in both the push-off and aerial phases of the first element to adjust the linear and angular momenta between the two elements (*i.e.*, during the connection phase; Hmed & Hassan, 2010; Sadowski, Boloban, Mastalerz, & Niznikowski, 2009). For example, Sadowski et al. (2009) found differences in body rotation angle at landing, and in hip flexion (at landing and in the last half revolution) when comparing a double backward layout somersault performed with stable landing or in combination with a whip somersault. Connecting acrobatic skills is a technical

development trend in gymnastics (Han, Xu, Dai, & Chang, 2008) and a characteristic of expertise. In particular, in bars routines, any break between two moves results in up to a 0.5 point deduction in competition, while connecting difficult elements awards additional points (FIG, 2013). Thus, coaches have to plan a technically possible progression, allowing gymnasts not only the opportunity to perform the skill but also to execute the skills in sequence in their routine. Previous researches focused on adaptations of landing to connect skills (Hmed & Hassan, 2010; Sadowski et al., 2009). Nevertheless to the best of our knowledge, the connection of skills on uneven bars has not been studied yet.

On the uneven bars and the high bar, among the elements that can be included in sequence in a routine are the release-regrasp elements. Combined with their preparatory giant circles, these elements have received attention due to the number of related injuries (Brüggemann, Cheetham, Alp, & Arampatzis, 1994; Gervais & Tally, 1993). When several techniques can be used to perform a skill, coaches are interested in identifying which technique is the most suitable for safety, success and connection. Previous studies have highlighted not only biomechanical factors of performance but also motor control aspects, such as the robustness of the technique, that affect both the kinematic variability among athletes (Hiley & Yeadon 2012; Yeadon & Brewin 2003) and the consideration of the consequences of failure (Bradshaw & Hume, 2012; Yeadon, 1999). Hiley and Yeadon (2003) showed that a scooped giant circle is a more robust dismount technique because the acceptable margin of error at release is 48% greater than in traditional techniques. In terms of failure consequences and connection problems, Kerwin, Irwin and Exell (2007) and Kerwin and Irwin (2010) compared inward and outward techniques of the Tkachev. The differences between the two techniques are due to the low bar, which represents a double geometric constraint in the outward technique. The gymnast has to avoid the bar in the giant circle not only before the Tkatchev but also after regrasping or if unexpectedly missing the high bar. With the inward technique, the angular momentum is larger, and the regrasp occurs earlier to facilitate connections (Kerwin et al., 2007). Thus, gymnasts do not use the same technique according to the consequences of a possible failure. Considering the effect of the technique on failure consequences, Yeadon (1999) discussed the dynamics at landing for different twisting somersault techniques. In contact twists, the angular momentum around the longitudinal axis is constant until the landing and could lead to greater ankle and knee injuries (Yeadon, 1993a). This is a disadvantage in comparison with the aerial twist technique (Yeadon, 1993b). Better understanding techniques from a biomechanical perspective can help coaches to identify which technique is the most suitable for safety, success and connection. This can be achieved by comparing experts and novices performing the same skill.

On the uneven bars, the "counter movement forward in flight" (Figure 1) is an element that requires reversing the direction of rotation twice when performed in combination with a kip to support. It involves a backward rotation around low bar, a first reversal of rotation around the body centre of mass shortly before grip release, a forward rotation in flight, and a second rotation reversal to swing backward around high bar. It belongs to the transition elements (*i.e.* flight elements between low and high bars). It is performed in approximately 70% of the routines at all levels of competition (Tordi, 2006). However, it is performed without deductions by the judges in only 30% of cases. Whereas advanced gymnasts execute the dual task of grasping the high bar while creating enough swing potential to link the counter movement forward in flight with a kip to support skill, beginners typically only perform the counter movement forward in flight as a catching task. Their technique can be observed as a derivative of the underswing dismount (Figure 2). At regrasp,

deductions are applied if the shoulder level is lower than the upper bar (0.3 point, in the FIG code of points, 2014; p. 51-52) and if the feet are passed the vertical position of the shoulders (0.1 point). Therefore experts **are expected to produce larger vertical** component of the centre of mass trajectory, and complete larger transversal rotation in flight to avoid such deductions. Moreover, a limited swing can lead to a lack of rhythm in the kip to support execution (0.1 point) or an additional swing (0.5 point). Thus, a proper understanding of the joint actions and centre of mass trajectory that ensure the counter movement forward in flight to kip to support connection without deductions is a requirement for gymnastics coaches.

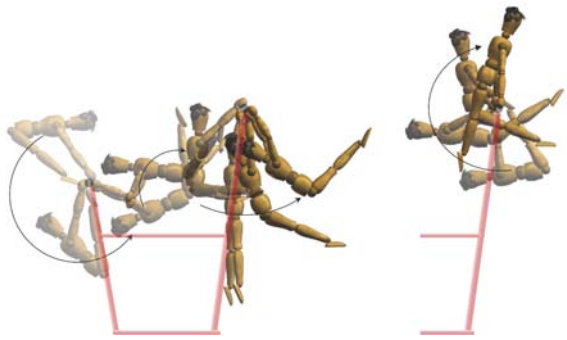

Figure 1. The counter-movement forward in flight on uneven bars in connection with a kip to support. Arrows indicate the rotation direction throughout the sequence.

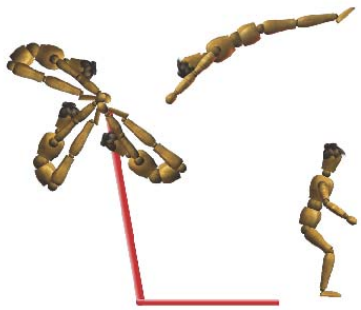

Figure 2. Toes on underswing dismount.

The purpose of the current study was to investigate control of counter movement forward in flight in expert and novice gymnasts. We hypothesised that expert gymnasts would perform better than novice gymnasts and succeed in the combination with a kip to support, by showing a more vertically oriented velocity at release and achieve a greater transversal rotation angle in flight thanks to adjustments of their moment of inertia and segment momenta. We also hypothesised that novice gymnasts would not show a higher variability of the biomechanical parameters at release, compared to expert gymnasts, since their technique would be robust and a derivative of the underswing dismount (Figure 2).

METHODS

Six expert national-level (13.7±2.9 years, 1.51±0.08 m, 42.5±10.1 kg) and five novice (20.5±2.3 years, 1.66±0.07 m, 56.1±6.6 kg) female gymnasts participated in this experiment. The inclusion criterion for the expert group was to be able to consistently perform the counter movement forward in flight in combination with a kip to support. The inclusion criteria for the novice group were specified as follows: (a) to have recently learned the counter movement forward in flight; (b) to be unable to connect with a kip to support; and (c) to be able to perform the kip to support independently. All participants, or their legal guardians, gave their informed consent in line with the guidelines set by the local ethics committee.

After warm up, all gymnasts were instructed to perform three repetitions of a counter movement forward in flight and kip to support continuously. Between trials, they had a rest period of self-chosen duration.

A 10-camera motion capture system (T-20 cameras, Vicon®, Oxford, UK) covering a 5 x 6 x 3.5 m^3 volume was sampled at 250 Hz to collect 3-D trajectories of markers placed on each participant. Thirty-five reflective markers defined fourteen segments in line with the anthropometric model of De Leva (1996): trunk, head, upper arms, forearms, hands, thighs, shanks, and feet, as detailed in Figure 3. The locations of each segment (chosen to minimize marker occlusions during the skill) are listed as the following

anatomical landmarks: forehead, chin, bilateral acromion process, lateral epicondyles of the humerus, ulnar styloid processes, second and fifth metacarpals heads, greater trochanters, lateral epicondyles of femurs, lateral malleoli of ankles, fifth metatarsal heads, tuber calcanei, forehead, chin, temples, spinous processes of C7, T5, T12, and posterior superior iliac spines. Eight additional markers were placed at the midpoints of the arms, forearms, thighs and shanks.

For all gymnasts, the bars were set at their maximum standard width (1.80 m).

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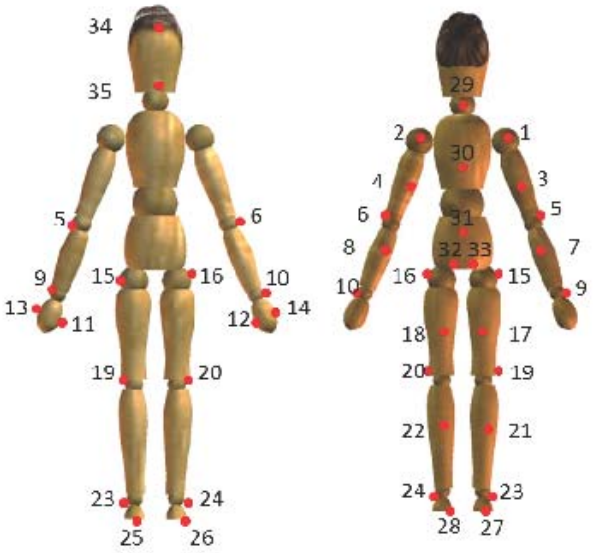

Figure 3. Set of 35 markers placed on the major processes of the right (1) and left humeri (2), posterior mid-arm (3, 4), lateral epicondyle of the right (5) and left humeri (6), posterior mid forearm (7, 8), right (9) and left (10) ulnar styloid processes, second (11, 12) and fifth metacarpals (13, 14), major trochanters (15, 16), posterior mid-thigh (17, 18), lateral epicondyles of femurs (19, 20), posterior mid-shank (21, 22), external malleolus (23, 24), fifth metatarsal (25, 26), tuber calcanei (27, 28), spinous processes of C7 (29), T5 (30), T12 (31), iliac spines postero-superior (32, 33), forehead (34) and chin (35).

This placement was chosen to minimise marker occlusions during the skill.

For analysis, the task was divided into three phases: (a) the release of the low bar phase, (b) the aerial phase, and (c) the regrasp of the high bar phase. Based on a frequency analysis, the position data were filtered with a zero-lag second-order Butterworth filter with a cut-off frequency of 6 Hz (Winter, 1990). In case of occultation of a marker, a spline function provided in the interpolation plug-in of the Vicon Nexus® software was used to complete the missing part of the trajectory of the marker. The joint angles were calculated according to ISB recommendations (Wu et al., 2002, 2005). A quasi-planar analysis was conducted since bilateral symmetry of movement was assumed. Hip and shoulder angle time histories were differentiated using a centred difference method to create angular velocity profiles. The anthropometric model of De Leva (1996) was combined with segment kinematics to calculate the body centre of mass, the body moment of inertia along the transverse (medial-lateral) axis, and the transverse component of the angular momentum with respect to centre of mass. Preliminary analysis revealed that the error percentage on the acceleration of body centre of mass in the airborne phase was estimated to be approximately 6%. To compare gymnasts of varying sizes, angular momentum and minimum moment of inertia in flight were normalized (Kerwin & Irwin, 2010). Therefore, both were divided by the theoretical maximum moment of inertia (when the gymnast hangs from the high bar in a straight position) and angular momentum was further divided by the potential of revolutions per second in the same posture

The release and regrasp times were manually determined based on mid-hand markers with respect to the markers on the bars and their displacement due to hand release and contact. The body rotation angle at release was evaluated in the sagittal plane as the angle between the global vertical axis passing through the low bar and the line from the low bar to the body centre of mass position at the instant of the low bar release

(Figure 4A). The angle of release was defined as the angle between the horizontal and the release velocity vector in the sagittal plane (Figure 4B). Computing the body rotation angle in flight and the release angle is of particular interest since these parameters determine both the height and range of the trajectory of the body centre of mass. The aerial phase duration, the position of the body mass centre at apex and the total rotation angle of the body during the aerial phase were computed. The rotation angle at regrasp was defined as the angle between the global vertical axis passing through the high bar and the line joining the centre of mass of the gymnast to the neutral bar position (Figure 4C). To assess the deduction at regrasp, the shoulder height relative to the high bar (Figure 4D) and the ankle antero-posterior position relative to the shoulders (Figure 4E) were reported.

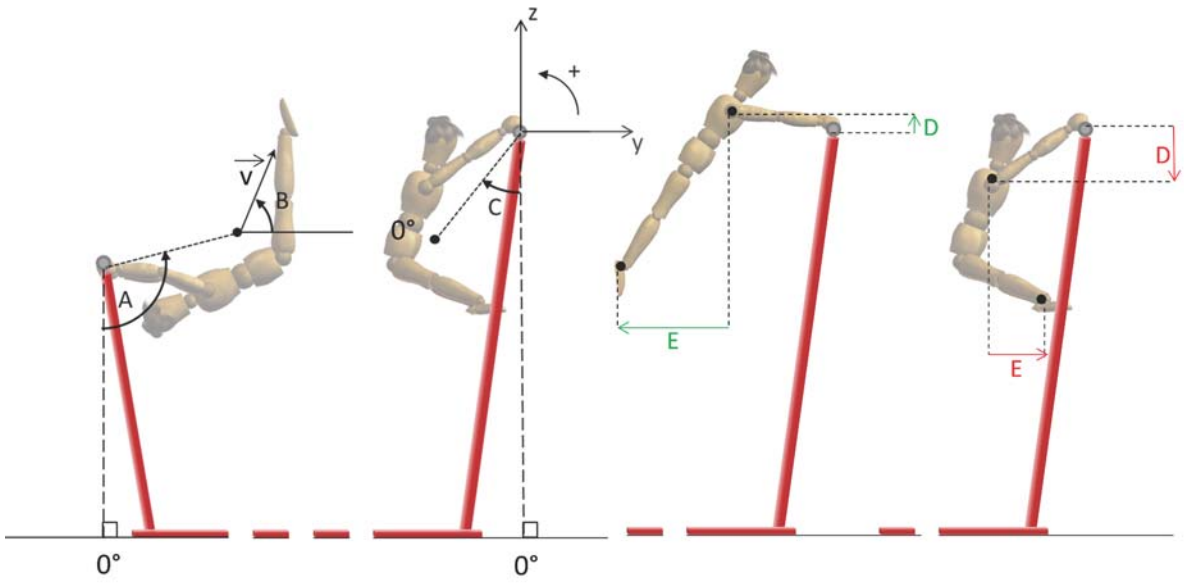

Figure 4. Definition of main angles, namely the rotation angle at release (A), angle of release (B) and rotation angle at regrasp (C). Deduction criteria: shoulders height *wrt* high bar (D) and ankle antero-posterior position *wrt* shoulders (E) are shown in the middle (no deduction) and on the right (deduction).

The mean values of the release parameters (the shoulder and hip flexion angles and velocities, the release angle, the body rotation angle, and the norm of release velocity), the normalised angular momentum, the minimum value of the transverse moment of inertia in flight, the total aerial phase duration, and the rotation angle at regrasp were calculated and compared using non-parametric Mann-Whitney U-tests. Afterwards, the effect size measure for non-parametric analysis was calculated, defined as $r=Z/\sqrt{N}$, where r represents the effect size, Z is derived from the conversion of the Mann-Whitney test and N is the total number of observations. This analysis considers r-values as: small effect size (r=0.10), medium effect size (r=0.30) or large effect size (r=0.50) (Field, 2005). To investigate whether the technique performed by the novice gymnasts is as robust as the technique of the experts despite their poorer experience, the intra-participant variability of the release state was investigated by determining the coefficients of variation of the release parameters. Mann-Whitney U-tests were used to compare the coefficients of variation between expert and novice groups. All statistical tests were performed (Statistica® Software 6.0, StatSoft, USA) with a significance level set at $\alpha=0.05$.

RESULTS

Low Bar Release

At release, neither the hip nor shoulder angles significantly differed between the two groups (p=0.07 and p=0.33, respectively; Table 1). However, the novice group showed a greater hip flexion velocity compared with the expert group (p<0.05). The expert group showed a larger angle of release (p<0.01) and a larger rotation angle (p<0.001). However, the release velocity norm (p=0.43) and the normalised transversal angular momentum (p=0.18) were similar between groups. In summary, expert gymnasts released the bar above horizontal with a larger vertical velocity than novice gymnasts. The coefficients of variation of the parameters at release (e.g., the hip and shoulder flexion and velocities, release angle, rotation angle at release and norm of release velocity) did not show any significant difference (all p>0.05) between the groups, as summarised in Table 2.

Table 1

Means and standard deviations for biomechanical and temporal variables at release, in flight and at regrasp. The last three columns are the between-group comparisons.

		Experts	Novices	U	*p*	*r*
Release	Shoulder flexion angle (°)	-32±7	-37±6	9	0.33	
	Hip flexion angle (°)	48±14	44±31	12	0.07	
	Shoulder flexion velocity (°/s)	554±323	451±185	10	0.43	
	Hip flexion velocity (°/s)	-159±100	-315±139	3*	0.03	0.66
	Release angle (°)	68±7	56±5	1*	0.00	0.77
	Rotation angle at release (°)	97±5	81±6	0*	0.01	0.82
	Norm of release velocity (m/s)	2.53±0.30	2.39±0.28	10	0.43	
	L_x (rev/s)	2.19±0.20	2.38±0.27	7	0.18	
Flight	Horizontal BCM position at apex (m)	0.91±0.20	1.09±0.08	6	0.12	
	Vertical BCM position at apex (m)	1.80±0.13	1.56±0.06	0*	0.00	0.82
	Total duration (ms)	440±46	365±14	0*	0.00	-0.82
	I_{min} (normalised)	0.47±0.06	0.60±0.08	3*	0.03	-0.66
Regrasp	Rotation angle at regrasp (°)	-39±10	-15±5	0*	0.00	0.82
	Shoulder height wrt high bar (cm)	-22±8	-46±5	2*	0.00	1.45
	Ankle antero-posterior position wrt shoulders (cm)	31±14	60±15	16*	0.00	-1.33
	Total rotation (°)	136±15	96±10	0*	0.00	0.82

Note: **(***) p<0.05. (L_x) corresponds to the normalised transversal angular momentum about the mass centre at release. (I_{min} normalised) is the normalised minimal value of the transverse moment of inertia. (BCM) is an acronym for body centre of mass, wrt is an acronym for with respect to.

Table 2
Means and standard deviations for coefficients of variation (dimensionless) with between-group comparison statistics.

	Experts	Novices	U	*p*
Shoulder flexion angle	0.12±0.05	0.12±0.06	11	0.84
Hip flexion angle	0.03±0.58	0.10±0.84	12	1.00
Shoulder flexion velocity	0.45±0.42	0.32±0.14	11	0.84
Hip flexion velocity	0.48±0.62	0.34±0.08	8	0.42
Release angle	0.07±0.04	0.06±0.03	11	0.84
Rotation angle at release	0.05±0.02	0.03±0.02	6	0.22
Norm of release velocity	0.06±0.03	0.07±0.03	7	0.31

Note: (*) p<0.05

Aerial Phase

The release state differences resulted in a higher centre of mass at the apex for the expert group in the aerial phase, (p<0.001). The expert group also spent significantly more time during the aerial phase (p=0.00). In addition, the expert gymnasts had a significantly smaller minimal value of the normalised transverse moment of inertia in flight compared with novice gymnasts (p<0.05).

High Bar Regrasp

At regrasp, expert gymnasts had a significantly larger rotation angle by 24° (p<0.001). Novice gymnasts had a lower shoulder height (p<0.001) and the average position of their feet was further ahead of the position of their shoulders compared with expert gymnasts (p<0.001). According to competition scoring guidelines, all gymnasts (excluding two in expert group) had a 0.3 point deduction for a lower shoulder height and a 0.1 point deduction for feet position beyond the vertical of the shoulders. The expert group had a larger total rotation (p<0.001).

In all cases, the effect sizes were greater than 0.5, indicating a “large” effect according to Field (2005).

DISCUSSION

Having the technical knowledge to make their gymnasts able to connect skills without deductions is a challenge for coaches. To fully understand the conditions allowing the connection of the counter movement forward in flight with a kip to support, we investigated kinematics of gymnasts able or not to successfully execute the sequence (expert and novice groups, respectively). The technique used by expert gymnasts allowed them to link the counter movement forward in flight to a kip to support thanks to a higher rotation angle at regrasp compared to novice gymnasts. This higher rotation angle at regrasp is the consequence of releasing the bar after the centre of mass passed the horizontal with a larger vertical velocity, and of a smaller minimum moment of inertia in flight.

Mechanical Requirements to Perform a Successful Connection

Between the groups, counter movement forward in flight techniques differed at take-off, in the aerial phase and at regrasp. Given their large effect sizes, the rotation angle at release, the angle of release and the minimal value of the inertia moment in flight afforded the most significant reasons why expert gymnasts succeeded and novice gymnasts did not succeed in connecting counter movement forward in flight with a kip to support. The expert gymnasts released the low bar above horizontal with a more vertically oriented velocity, resulting in longer flight duration and a higher parabola. In addition, they were able to further reduce their transverse inertia momentum in flight by larger hip flexion-abduction, which proportionally increased the angular velocities of their bodies. Their

greater backward rotation angles at release were compensated by longer flight durations and increase angular velocity due to more reduced moments of inertia. This accounts for the greater forward rotation angle at regrasp for a total rotation of 140° in flight. The higher measured values of the minimal moment of inertia in flight for the novice group could be due to their larger hip extension velocities at release. In fact, the optimal technique (Huchez, Haering, Holvoët, Barbier, & Begon, 2015) displayed transfer the angular momentum of lower limbs to the rest of the body by a strong hip flexion in the first part of the aerial phase. Gymnasts of novice group have to achieve a greater deceleration of the hip extension prior to bending the hips with less time in flight. This prevents them from optimally increasing their forward rotation by reducing their moments of inertia. Because both the release state and the minimal moment of inertia in flight differed between the two groups, future studies should investigate which of these parameters more significantly maximises the body rotation.

The release angle is an important factor affecting the connection success. A more vertically oriented release velocity allows the gymnast to increase flight time and, consequently, the forward rotation by the conservation of angular momentum in flight. Theoretically, this increase has an asymptotic value and is a function of the anthropometry of the gymnast. In effect, a horizontal component of the release velocity is required for forward travel and to be able to grasp the high bar. The failure of the novice gymnasts to perform the connection, with a rotation angle at regrasp two to three times lower than that of expert group, confirms that that a high rotation angle at regrasp is a guarantee for a successful connection (Gervais & Tally, 1993).

What makes the counter movement forward in flight high demanding for novice gymnasts are the short flight duration (0.44 s versus 0.80 to 0.92 in Jaeger, Gaylord or Pegan; Brüggeman et al., 1994; Cuk, 1995; Gervais & Tally, 1993) and the large angular momentum (up to 10 times higher than during the Tkatchev: 2.19 rev/s versus 0.22 rev/s in outward Tkatchev; Kerwin & Irwin, 2010).

Implications for Learning and Safety

Novice gymnasts did not show a higher variability than expert gymnasts in the release state, indicating that the preparatory underswing is a robust technique for novices (*i.e.,* a movement they are able to perform with consistency). However, this may be an obstacle towards the learning process of their training. The practice and use of the underswing dismount (Figure 2) during the early stages of their training may have a negative effect (termed "negative transfer"; Schmidt & Lee, 1999) on the counter movement forward in flight progression. Therefore, this technique should not be viewed as a pre-requisite in the learning progression.

The novice gymnasts may not achieve the appropriate release parameters because they favour a technique that minimises the chances and consequences of failure. Generally, when a gymnast fails a release and regrasp element, she falls on the bar or onto the mat. Thus, athletes have to develop techniques for reducing risks or minimising failure consequences. For example, in Kerwin and Irwin's study (2010), the risk of striking the low bar when failing a Tkachev led gymnasts to proceed at a lower velocity and angular momentum in the outward technique compared with the inward technique. In the counter movement forward in flight, the novice gymnasts had a short aerial phase and a large moment of inertia. This combination ensured a safe landing if they missed regrasping the bar. Because the counter movement forward in flight is among the first release and regrasp elements performed by novice gymnasts, their technique considerably reduced the failure consequences. Moreover, the increased horizontal velocity at release maximised the chance of catching the bar at the expense of body rotation.

Similarly, the expert technique reduced failure consequences. In elements with a forward rotation at regrasp, a body rotation

angle of approximately 45° (Gervais & Tally 1993, see Figure 1) allowed the gymnast to fall flat on the mat in the case of failure. A greater angle would increase the swing potential but would also increase the risk of injury due to an over-rotated landing on the mat. In this case, the most suitable technique for success and connection is not the safest. That can explain why in spite of differences in the techniques they used, both groups, and not only the novice one, adopted a strategy reducing the failure consequences.

LIMITATIONS

Four limitations of the present study need to be acknowledged. First, due to experimental constraints such as marker occlusions by chalk use, only a limited number of trials could be analysed. Second, though expert group was composed of national-level gymnasts, individual techniques could still be improved by maximising the regrasp angle (Huchez et al., 2015) and consistency criteria (e.g., Hiley & Yeadon, 2003; 2012). Nevertheless, measured parameters showed significant differences between the groups in the current study. Third, for future study, body height and body weight matched control should be recruited, to eliminate their potential effect on movement performance. Fourth, the results of this study highlighted differences between expert and novice gymnasts performing the same skill, but did not investigate how the coordination pattern of novice gymnasts could evolve towards that of expert gymnasts. To this end, future studies should assess phase lags involved when gymnasts with different expertise levels perform a counter movement forward in flight. Such issues could be investigated through training studies with multiple testing sessions.

Recommendations for coaches and judges

The differences found between novice and expert gymnasts performing the counter movement forward in flight can be useful for coaches and judges. Coaches could help novice gymnasts to decrease their dependency on the described robust technique by improving the release angle. Exercises in which gymnasts land in a seated posture on an increasingly taller pile of mats and instructions such as to aim for the high bar with their feet could be used. They could allow novice gymnasts to exceed the threshold of a 90° rotation angle at release. Indeed, the rotation angle at release was significantly higher in the expert group and quite systematically greater than 90° (only three trials were inferior to 90°). Releasing the low bar with a rotation angle greater than 90° would result in a more upward hip extension and consequently in a more vertically oriented release velocity. To allow a successful connection, such an improvement of the release angle should be accompanied by a progress in the reduction of the moment of inertia in flight.

Though expert gymnasts were able to link the two elements, they received the same deduction by judges as novice gymnasts because they regrasped the high bar when their shoulders were below the bar and their ankles were ahead of the horizontal position of the shoulders. Because the shoulders could be above the bar at a low regrasp angle, this parameter is not directly related to the swing potential and therefore to a smooth connection between the elements. Based on our mechanical analysis, the scoring guide should instead require a 45° rotation angle at regrasp with graduated deductions as the regrasp angle approaches the vertical.

CONCLUSION

The release angle and the rotation angle at release are key mechanical parameters to increase success of the counter movement forward in flight performed in combination with a kip to support. Expert gymnasts performed better than novice gymnasts because they released the low bar higher (their centre of mass above the horizontal) and with a larger vertical velocity. They also had a smaller minimum moment of inertia in flight and spent more time in flight.

REFERENCES

Bradshaw, E. J. & Hume, P. A. (2012). Biomechanical approaches to identify and quantify injury mechanisms and risks factors in women's artistic gymnastics. *Sports Biomechanics*, *11*(3), 324-341.

Brüggermann, G. - P., Cheetham, P. J., Alp, Y., & Arampatzis, D. (1994). Approach to a biomechanical profile of dismounts and release-regrasp skills of the high bar. *Journal of Applied Biomechanics*, 10, 291–312.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Routledge, Hillsdale, New Jersey.

Cuk, I. (1995). Kolman and Pegan saltos on the high bar. In T. Bauer (Ed.), *Proceedings-XIII International Symposium on Biomechanics in Sports*, (pp. 119-122), Lakehead University, Thunder Bay, Ontario, Canada.

De Leva, P. (1996) Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics*, *29*(9), 1223-1230.

Delignieres, D., Nourrit, D., Sioud, R., Leroyer, P., Zattara, M. & Micaleff, J. P. (1998). Preferred coordination modes in the first steps of the learning of a complex gymnastics skill. *Human Movement Science*, 17, 221-241.

Fédération Internationale de Gymnastique. (2014). WAG Help Desk. Lausanne: Fédération Internationale de Gymnastique. http://www.fedintgym.com/rules/files/wag/WAG%20Help%20Desk%20240114-e.pdf

Fédération Internationale de Gymnastique (FIG). (2013). Code de pointage: Gymnastique artistique féminine [Code of points: Artistic gymnastics for women]. Lausanne, Switzerland: FIG.

Field, A. (2005). Discovering statistics using SPSS. London: SAGE Publications.

Gervais, P. & Tally F. (1993). The beat swing and mechanical descriptors of three horizontal bar release-regrasp skills. *Journal of Applied Biomechanics*, 9, 66-83.

Han H., Xu G., Dai R. & Chang B. F. (2008). The Technique Feature of Women's Uneven Bar in the 40th World Gymnastic Championship. *Journal of Tianjin University of Sport.*

Hiley, M. J., & Yeadon, M. R. (2003). The margin for error when releasing the high bar for dismounts. *Journal of Biomechanics*, 36, 313–319.

Hiley, M. J., & Yeadon, M. R. (2012). Achieving consistent performance in a complex whole body movement: The Tkatchev on high bar. *Human Movement Science*, 31, 834–843.

Hmed, M. A. & Hassan, M. D. (2010). A comparative study of biomechanical variables to one of the single and sequential performances on the floor exercise device as a base to set aimed exercises. *World Journal of Sport Sciences 3*(5), 507-513.

Huchez, A., Haering, D., Holvoët, P., Barbier, F. & Begon, M. (2015). Local versus global optimal sports techniques in a group of athletes. *Computer Methods in Biomechanics and Biomedical Engineering 18*(8), 829-838.

Kerwin, D. G., & Irwin, G. (2010). Musculoskeletal work preceding the outward and inward Tkachev on uneven bar in artistic gymnastics. *Sports Biomechanics*, 9, 16–28.

Kerwin, D. G., Irwin, G. & Exell, T. (2007). Outward and inward Tkachevs on uneven parallel bars. In *Proceedings of XXVth International Symposium on Biomechanics in Sports*. Ouro Preto, Brazil, 427-430.

Newell, K. M., Kugler, P. N., van Emmerik, R. E. A., & McDonald, P. V. (1989). Search strategies and the acquisition of coordination. In S. A. Wallace (Ed.), Perspectives on the coordination of movement (pp. 85–122). Amsterdam, North Holland: Elsevier Science Publishers.

Sadowski, J., Boloban, W., Mastalerz, A. & Niznikowski, T. (2009). Velocities and joint angles during double backward stretched salto performed with stable

landing and in combination with tempo salto. *Biology of Sport*, *26*(1), 87-101.

Schmidt, R. A., & Lee, T. D. (1999). Motor control and learning. Champaign, IL: Human Kinetics.

Tordi, N. (2006). Envol de la barre inférieure à la barre supérieure [Flight from low bar to high bar]. *GYM'Technic*, No. 55.

Winter D.A. (1990). Biomechanics and motor control of human movement. New-York: Wiley.

Wu G., Siegler S., Allard P., Kirtley C., Leardini A., Rosenbaum D., … & Stokes I. (2002). ISB recommendation on definitions of joint coordinate system of various joints for the reporting of human joint motion—part I: ankle, hip, and spine. *Journal of Biomechanics 35*(4), 543-548.

Wu G., van der Helm F. C. T., Veeger H. E. J., Makhsous M., Van Roy P., Anglin C., … & Buchholz B. (2005). ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: shoulder, elbow, wrist and hand. *Journal of Biomechanics 38*(5), 981-992.

Yeadon, M. R., & Brewin, M. A. (2003). Optimised performance of the backward longswing on rings. *Journal of Biomechanics*, 36, 545–552.

Yeadon, M. R. (1993a). The biomechanics of twisting somersaults Part II: Contact twist. *Journal of Sports Sciences*, *11*(3), 199-208.

Yeadon, M. R. (1993b). The biomechanics of twisting somersaults Part III: Aerial twist. *Journal of Sports Sciences*, *11*(3), 209-218.

Yeadon, M. F. (1999). Learning how to twist fast. In *Proceedings of the XVII International Symposium on Biomechanics in Sports* (pp. 49-59).

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PROPOSED METHOD OF IDENTIFICATION OF TECHNICAL ERRORS IN ARTISTIC GYMNASTIC: CASE STUDY

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Original article

Abstract

The aim of this study was to identify technical errors in artistic gymnastics, with comparative kinematic analysis of two gymnasts of different levels of success. The sample for comparative kinematic analysis consisted of ten attempts basket to handstand performed without technical errors by top gymnast and ten attempts performed with technical error by the middle-class gymnast. Kinematic analysis was performed with the help of 3-D video system for the APAS kinematic analysis, using a model with 17 points and 15 segments. Statistical significance of obtained mean differences between the two groups of attempts was determined using t-test for independent samples. Obtained results indicated that attempts performed flawlessly have significant greater speed of center of body gravity, point of hips and peak of feet; center of gravity of body is further away from the axis of rotation, and position of hang under is achieved with a greater angle in shoulder joint, and smaller in the hip joint; phase of front swing in hang under is realized with higher extension speed in hip joint and with expressed anti – flexion in the shoulder joint. All the above stated contributes to leave bars much later and again reach for with stretched arms, and thus there were no errors in the execution. Obtained information about the differences in performing between top gymnast and middle class gymnast have contributed to the identification of technical errors during execution and represents very important step in detection and elimination of them, generally in artistic gymnastic, not only for the specified element.

Keywords: *artistic gymnastics, kinematic analysis, identification, technical errors.*

INTRODUCTION

Researches in the field of kinematic analysis of a certain kind of movement are becoming more and more frequent in artistic gymnastics; particularly as the obtained information enables more rational and economical instruction and acquisition of the analyzed movement (Brueggmann, Cheetam & Arampatzis, 1994; Takei, 1998; Yeadon & Brewin, 2003; Hiley & Yeadon, 2007; Heng, 2007; Hanin & Hanina 2009, etc).

The apparatus which offers all competitors equal possibility of achieving top results is parallel bars. Success on this

apparatus largely depends on knowing all the details of complex technique elements, therefore many research papers are focused on this feature. However, very few research papers deals with kinematic analysis of the parallel bars elements. Linge, Hallingstad and Solberg (2006) dealt with the modeling of the parallel bars in Men's Artistic Gymnastics. Prassas & Ariel (2005) dealt with the kinematics of giant swings and (Prassas, 1994) back toss on the parallel bars, as well as Tsuchiya, Murata, Fukunaga (2004) who dealt with the kinetic analysis of the same element. The double back salto dismount from the parallel bars was researched by Gervais & Dunn (2003). Additionally, there were many research papers which dealt with the comparative study of two similar elements. Kolar E., Kolar K. A., & Stuhec (2001) conducted comparative analysis of selected biomechanic characteristics between a support backward swing and support swing for the 1 1/4 straddle-piked forward salto on the parallel bars. Furthermore, there are research papers which concentrate on the examining of the new elements. A detailed study of this kind was carried out by Cuk (1996), with the aim of determining the procedure used to prepare a new exercise, from the initial idea to its realization.

Basket to handstand on Parallel Bars (Figure 1) belongs to the category of difficult elements which are very interesting for further research.

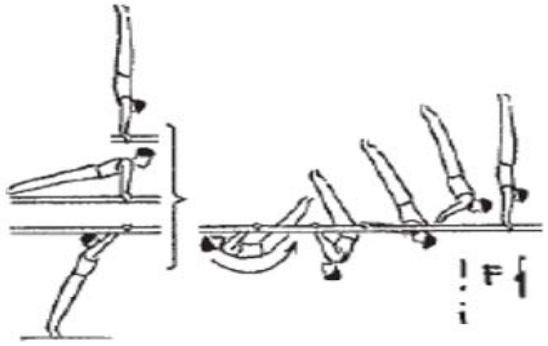

Figure 1. Basket to handstand on Parallel Bars (FIG, 2013).

This is the element which can be classified as an element belonging to "D" difficulty group, and which, by its specific aspect, belongs to IV group of elements on parallel bars (underswings). The above named element has become so popular that it's performed in all European and World championship finals, as well as in the Olympic Games. There is no top competitor on parallel bars who does not perform basket to handstand as integral part of his exercise. The reason of high popularity of basket to handstand is not only obtaining points for difficulty (difficulty values – D score – 0.40 points) and fulfilling a specific requirement (element groups – underswings – 0.50 points). The other important reason is that this element is highly perspective, since it has the possibility of advancing into more complex elements in the same structure group (Basket with 1/2 and 1/1 turn to handstand, Basket with immed. straddle cut to support, Basket with inlocation – el grip and hop to handstand – Cucherat, Basket to one rail handstand – Chiarlo).

The technique shown in the Code of Points (FIG, 2013) closely resembles to backward clear circle to handstand as performed on the high bar (Figure 1). During this technique, the gymnast maintains the hip flexion angle throughout most of the circle, in particular while he is below the bars (Figure 1). It has been recommended that this technique is used during the initial stages of learning the felge (Davis, 2005), probably because it is less demanding for the young gymnasts. However, the technique used by many senior gymnasts more closely resembles a "stoop stalder" (Davis, 2005). As the gymnast passes beneath the bars, a deep pike position (large hip flexion angle) is adopted, from which he rapidly extends passing through release and into the final handstand position.

The aim of this research is to establish a method of identifying technical errors in gymnastics at the example of basket from handstand to handstand. Research should find in which phases and kinematic parameters is reflected difference between the two groups of attempt basket to handstand, different in final performance and determine the phase and kinematic

parameters that differentiate attempts without technical errors and attempts with great technical fault basket to handstand.

METHODS

The sample consisted of two athletes with different success on parallel bars: top and average gymnast. Top gymnast is the Slovenian national team member, a multiple medal winner at the parallel bars at World and European championships since 2000, as well as a multiple winner of the World Cup on the same apparatus. In all official competitions since 2001 till today, competitor, in his competitive part of exercises on the parallel bars, successfully performed the exercise with the help of which leads to the identification of technical errors - basket to handstand. The average gymnast is Serbian national team member in artistic gymnastics, champion of Serbia on parallel bars, but has no significant results in international competitions on this apparatus. In 2010 competitor has started training analyzed exercise, but due to large technical errors in execution is not yet included in his exercise on parallel bars. Both gymnasts have similar morphological characteristics (Table 1):

Table 1
Morphological characteristics of gymnasts.

Longitudinal dimension	*Top gymnast*	*Average gymnast*
Body height	*1.65 m*	*1.64 m*
Head	*0.21 m*	*0.22 m*
Trunk	*0.59 m*	*0.61 m*
Legs + foot	*1.09 m*	*1.08 m*
Hand	*0.54 m*	*0.56 m*
Transversal dimensions		
Width of hips	*0.31 m*	*0.29 m*
Shoulder width	*0.45 m*	*0.43 m*
Body weight	*63 kg*	*63 kg*

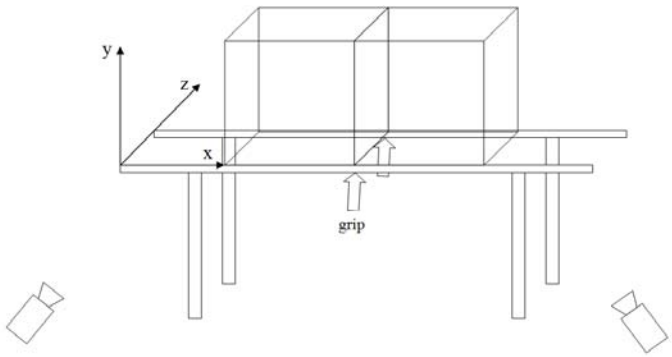

Figure 2. Space calibration.

Gymnasts performed basket to handstand at the training. All attempts were recorded with the help of two synchronized cameras DVCAM - Sony - □ SR - 300 PK, with a frequency of 50 Hz. Before recording, and for precise space calibration, two reference frames were videotaped ($1m^3$), which were positioned in the middle of the Parallel bars (Figure 2).

For research purposes, there were ten attempts rated as successful (without technical errors) performed by the top gymnasts and ten rated as unsuccessful attempts (with a large error) executed by the average gymnast. Criteria for successful and

unsuccessful execution were assessments of three brevet judges.

In order to determine the kinematic parameters and represent kinograms, Ariel Performance 3D video system was used for kinematic analysis (APAS). As part of the kinematic analysis, digitization of the 15 – segment model of competitors was conducted. As a performed element had features of a two-dimensional motion, there was no significant movement along the "z" axis.

For the purpose of the research, the positions and trajectories of the referential points on the "x" and "y" axes were analyzed (the body centre of gravity, TXBCG, TYBCG), the velocity of the referential points (the body centre of gravity – VEBCG, the tip of the right foot VEFOO, the centre of the right shoulder joint – VESHO and the centre of the right hip joint – VEHIP), the goniometric characteristics: the angle (the right hip joint – ANHIP, the right shoulder joint – ANSHO, the trunk and x-axis – ANTUX, the legs and x-axis – ANLEX) and the angular velocity (the right hip joint – AVHIP, the right shoulder joint – AVSHO).

For the purposes of this research, with expert analysis form research of Velickovic et all. (2011), for each phase were selected following time sequence:

a) Phase one: 0.12s, 0.26s, 0.36s, 0.44s,
b) Phase two: 0.56s, 0.66s, 0.78s, 0.84s, 0.86s, 0.92s, 1.02s, 1.08s, 1.16s,
c) Phase three: 1.30s, 1.36s, 1.38s, 1.44s, 1.52s,
d) Phase four: 1.54s, 1.58s, 1.64s, 1.72s, 1.84s.

With the intention to better and more accurately describe the movement, selected were four to five positions – time sequences (for a second phase nine), with the aim to cover beginning, middle and completion of phase. In phases where movement was slower was selected fewer positions – sequences, and in phases where movement was faster was selected more positions (Velickovic et all, 2011).

The value of one parameter in one sequence of all distinguished efforts represents one variable, and the encoding is as follows in table 2.

Table 2
The value of one parameter in one sequence of all distinguished efforts represents one variable, and the encoding.

The first two letters represent the parameter	The next three letters represent a point, segment or joint	The numbers at the end of the code indicate the time sequence
TX – trajectories on the x axis	BCG – the body centre of gravity	012 – 0,12s
TY – trajectories on the y axis	FOO – the foot	.
VE – velocity	HIP – the hip	.
AN – the angle	SHO – the shoulder	102 – 1,02s
AV – the angular velocity	ANHIP – hip joint	
	ANSHO – shoulder joint	
	TUX – trunk in relation to the x-axis	
	LEX – legs in relation to the x-axis	

Example: AVSHO012 – the angular velocity shoulder in 0.12 sec.

The obtained parameters of motion (kinematic and goniometric characteristics) were further analyzed using descriptive and

comparative statistics, measures of central tendency and dispersion of results: Mean – MEAN, standard deviation – STD, standard error of the mean – STD ERROR.

T – test for independent samples – was applied to determine the mean differences of analyzed kinematic parameters (significant positions) between 10 attempts of top and 10 attempts of average gymnast. Statistical analysis was performed by software package SPSS v 20 for Windows.

RESULTS

The values of the arithmetic means between 10 attempts of all analyzed parameters of movement for all the observed time sequences are shown in graphs.

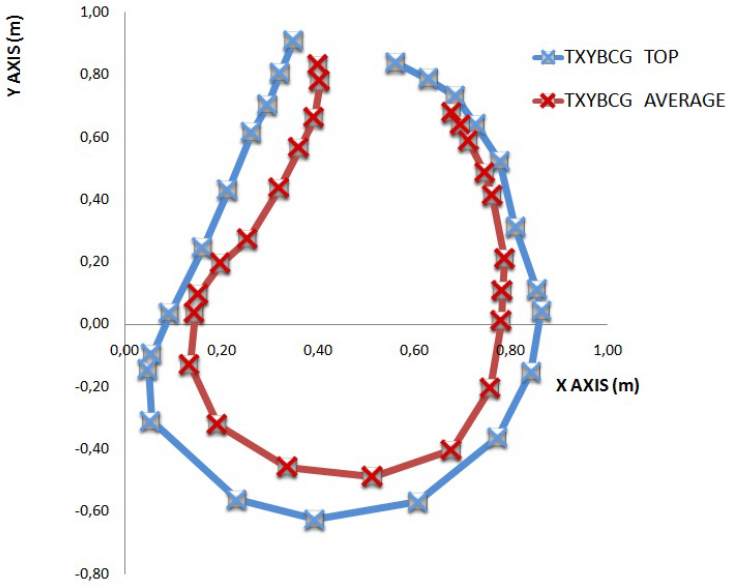

Figure 3. Trajectory of the center of gravity of the body in the "xy" axis – means.

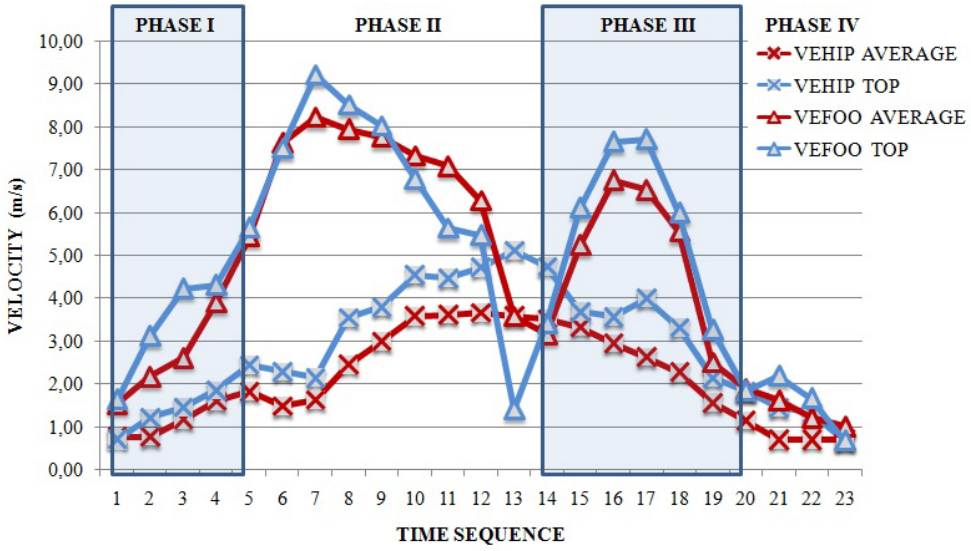

Figure 4. The velocity of the hips and feet – means.

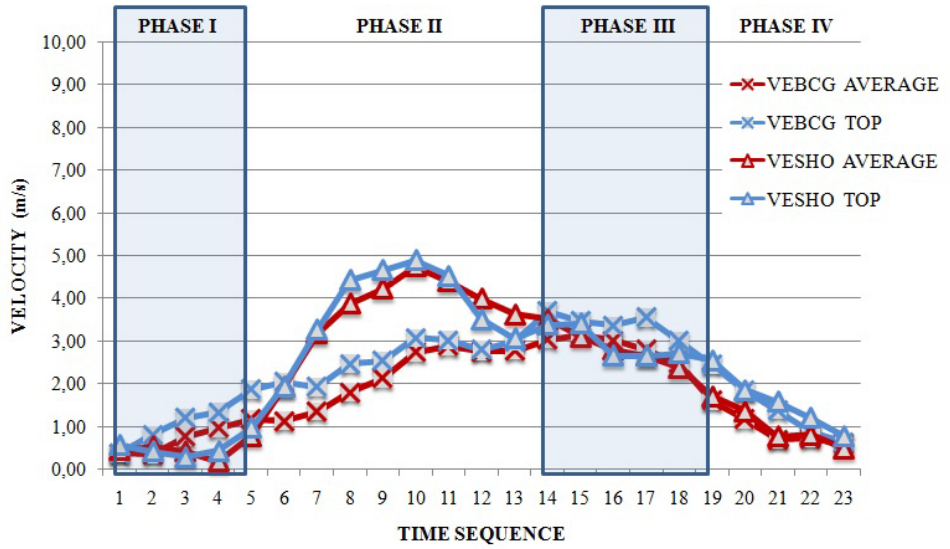

Figure 5. Velocity of gravity of the body and shoulders – means.

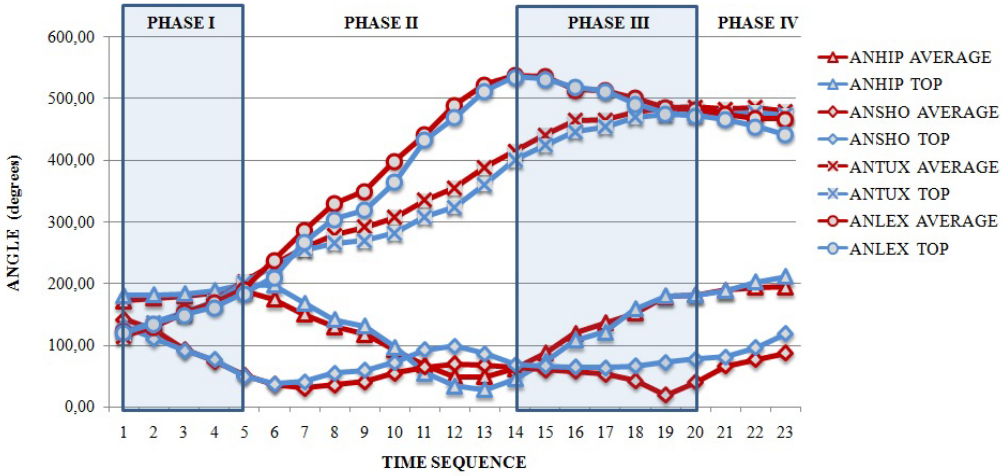

Figure 6. Referent angles – means.

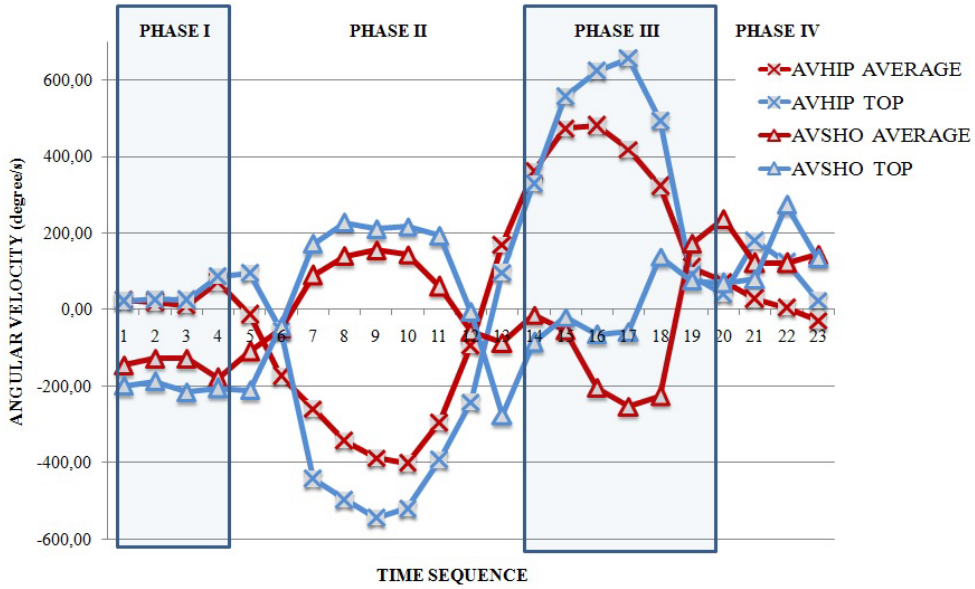

Figure 7. Angular velocities in referent angles – means.

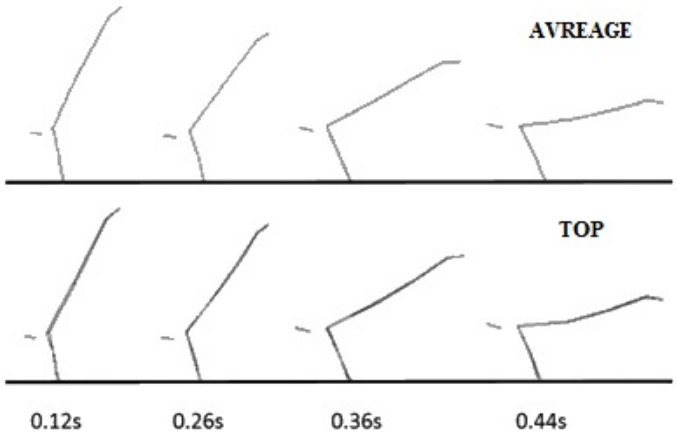

Figure 8. Phase one basket to handstand.

Table 3
Statistical significance of the T – test between successful and unsuccessful attempts – Phase I.

		PARAMETERS – PHASE I											
		TXBC	TYBC	VEBC	VESH	VEHIP	VEFO	AVSH	ANTU	ANHIP	ANLE	AVSH	AVHIP
		G	G	G	O		O	O	X		X	O	
TIME SEQUENCES	2	0 .00	0 .00	0 .29	0 .20	0 .59	0 .14	0 .19	0 .09	0 .08	0 .00	0 .99	0 .41
	4	0 .00	0 .00	0 .00	0 .06	0 .00	0 .00	0 .07	0 .00	0 .00	0 .02	0 .02	0 .47
	6	0 .00	0 .00	0 .00	0 .18	0 .00	0 .00	0 .06	0 .00	0 .00	0 .00	0 .00	0 .61
	4	0 .00	0 .00	0 .00	0 .09	0 .00	0 .00	0 .06	0 .01	0 .00	0 .00	0 .00	0 .74

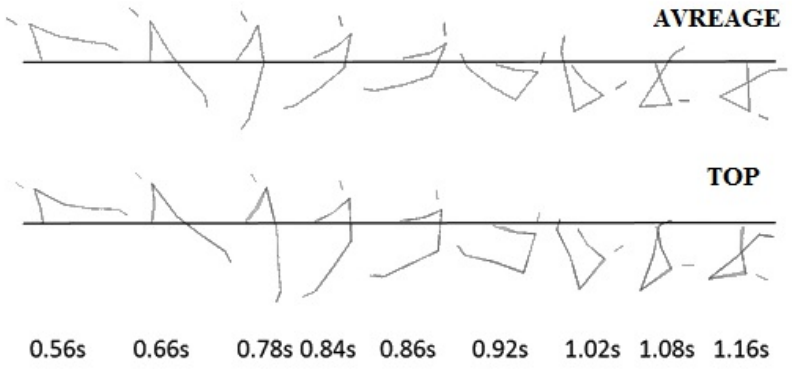

Figure 9. Second phase basket to handstand.

The first phase is shown on Figure 8. By visual inspection of image, differences in the shown sequences are not visible.

Reviewing figures 3 – 7 and table 2 reveals the following:

a) Trajectory of the center of body gravity has a slightly higher trajectory and is nearer to the center of rotation at the top gymnast (Figure 8 – Phase I), statistically

significant (TXBCG and TYBCG – Table 2);

b) The top of the feet, hips and body center of gravity at top gymnast achieved greater speed (Figures 4 and 5), significantly in the last three time sequences (VEFOO, VEHIP, VEBCG – Table 1). Point of shoulders almost equally slow down with both gymnasts and the differences were not statistically significant (VESHO – Table 3);

c) Differences in the shoulder joint angles are about 4^O and not statistically significant (Figure 6), but the angular velocity of retro flexion (Figure 7) have significantly higher values with top gymnast (AVSHO – Table 3). The angle of the hip joint (ANHIP), as well as the position of the trunk and legs in relation to the x-axis (ANTUX, ANLEX) have significantly higher values at top gymnasts (greater hyperextension - Table 3). The angular velocity of extension in this joint (ANHIP) is close to zero values with both gymnasts and have no statistically significant differences.

By visual examination of Figure 9 we can observe that a top gymnast, after losing balanced position (ts from 0.78s to 1.02s), is significantly moving away from the axis of rotation (higher angle in the shoulder joint, the hip point is more moved back). Also, at the end of the fall (ts 1.24s), top gymnast achieves greater flexion in the hip joint.

Review of the figures 3 – 7 and table 3 notes next:

a) Body center of gravity is moving on wider path with top gymnast (forming larger semicircle – Figure 4) during the whole second phase (mostly significant - Table 3);

b) Body center of gravity and hip point achieves greater velocity with top gymnast during whole second phase. All values are statistically significant (Table 4), and the difference between speed of BCG ranges from 0.1 to 0.7 m/s and hip velocity from 0.4 to 1.4 m/s in favor of top gymnast. Foot peak velocity has higher values until the point of entry into antigravity phase (ts 0.78s), after which these values are higher with the average gymnast. The velocity of the shoulder after leaving the support surface (ts 0.66 s) is higher with the top gymnast. After descending of this point below the bars (after ts 1.02) speed has greater values with the average gymnast;

c) The angle of the shoulder joint (Figure 6) and move of ante flexion is much more pronounced and consistently has larger values with top gymnast. These values are statistically significant from the moment of exit point of the shoulder from support surface (loss of balance) to the beginning of ante flexion in the shoulder joint. Movement of ante flexion lasts until descent of the shoulder point below the bars (ts 1.08s). From this time sequence finds the movement of retro flexion, which is also significantly faster with the top gymnast. At the end of this phase angle of the shoulder joint is significantly higher with the top gymnast.

d) Observing the hip joint, there is a pronounced *"kurbet"* (rapid hyperextension in order to achieve faster flexion that follows the further movement) was ascertained in a time sequence from 0.56 to 0.66s. In the first part of the second phase angle of the hip joint is higher with top gymnast. The descent of shoulder point below the bars (ts 1.02s) begins with much higher angular velocity of flexion in the joint (Figure 7) and the achievement of significantly higher flexion (Figure 6) with the top gymnast. A top gymnast achieves significantly greater flexion in the hip joint as it passes through the lower vertical (ts 1.24s). Flexion is approximately 30^O compared to the approximate 55^O with average gymnast. Trunk and legs throughout this phase squint smaller angle with the x axis with top gymnast.

Table 4
The statistical significances of T – test – Phase II.

		PARAMETERS – PHASE II											
		TXBCG	TYBCG	VEBCG	VESHO	VEHIP	VEFOO	AVSHO	ANTUX	ANHIP	ANLEX	AVSHO	AVHIP
TIME SEQUENCES	5 6	0 .00	0 .60	0 .00	0 .71	0 .00	0 .00	0 .73	0 .02	0 .00	0 .00	0 .00	0 .00
	6 6	0 .00	0 .00	0 .00	0 .45	0 .00	0 .36	0 .13	0 .83	0 .00	0 .00	0 .00	0 .10
	7 8	0 .00	0 .00	0 .00	0 .04	0 .00	0 .00	0 .00	0 .02	0 .00	0 .00	0 .00	0 .00
	8 6	0 .00	0 .00	0 .00	0 .00	0 .00	0 .05	0 .00	0 .00	0 .63	0 .00	0 .00	0 .00
	9 2	0 .00	0 .00	0 .00	0 .15	0 .00	0 .00	0 .00	0 .00	0 .00	0 .08	0 .08	0 .00
	1 02	0 .33	0 .00	0 .03	0 .05	0 .00	0 .00	0 .00	0 .00	0 .00	0 .01	0 .00	0 .02
	1 08	0 .61	0 .00	0 .04	0 .03	0 .00	0 .86	0 .00	0 .00	0 .00	0 .00	0 .09	0 .00
	1 16	0 .22	0 .00	0 .03	0 .00	0 .00	0 .00	0 .00	0 .00	0 .00	0 .26	0 .00	0 .40
	1 24	0 .35	0 .30	0 .00	0 .95	0 .00	0 .67	0 .27	0 .00	0 .00	0 .07	0 .01	0 .00

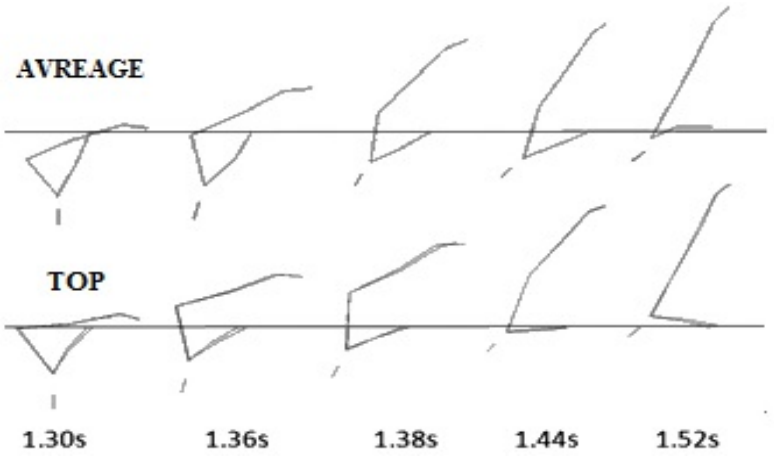

Figure 10. Third phase basket to handstand.

Visual inspection of Figure 10 shows that the average gymnast reaches the full extension of the hip joint much earlier and leaves the bars much earlier (ts 1.52s shoulders are below the bars).Review of the figures 3 – 7 and table 4 notes next:

a) BCG trajectory still has a wider path with top gymnast. Mentioned differences were not statistically significant, except the TYBCG in the last two sequences, when the height of the BCG has larger values with the top gymnast;

b) The values of velocities of all the reference points are higher with top gymnast, mostly statistically significant (except for the point of the shoulder);

c) After entering the third phase angle of the shoulder joint continues to move at an accelerated retro flexion with average gymnast almost to the end of phase. The value of the angle is reduced to 20^{O}. At this stage ante flexion in the mentioned joint is not recorded. With the top gymnast the reverse mode of the shoulder joint reveals – a movement of accelerated ante flexion. Mentioned differences are mostly statistically significant (Table 5);

d) The angle of the hip joint has similar trend with both gymnasts – accelerated extension, just as this action is much more prominent with the top gymnast (statistically significant);

e) The angle of the trunk in relation to the x-axis still has significantly smaller values with the top gymnast.

Table 5
The statistical significances of T – test – Phase III.

		PARAMETERS – PHASE III											
		TXBC	TYBC	VEBC	VESH	VEHI	VEFO	AVSH	ANTU	ANHI	ANLE	AVSH	AVHI
		G	G	G	O	P	O	O	X	P	X	O	P
TIME SEQUENCES	30	.44	.150	.00	.02	.00	.04	.98	.00	.00	.31	.01	.00
	36	.77	.70	.00	.48	.00	.00	.02	.00	.00	.13	.00	.00
	38	.77	.14	.00	.76	.00	.00	.00	.00	.00	.04	.00	.00
	44	.13	.00	.00	.15	.00	.00	.00	.03	.61	.61	.00	.00
	52	.06	.01	.00	.00	.00	.00	.00	.00	.66	.31	.28	.07

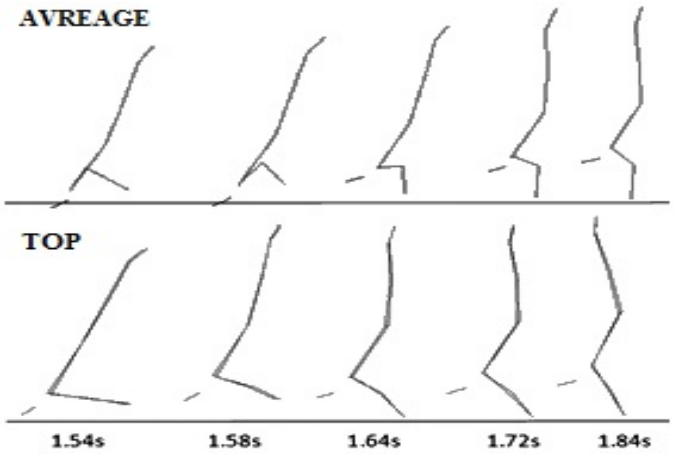

Figure 11. Fourth phase basket to handstand.

Viewing figure 11, with the average gymnast can be seen distinct convulsion of hands after leaving the bars, and at reaching bars at lower height with bent arms.

Review of the figures 3 – 7 and table 6 notes next:

a) Significantly higher and further path (relative to the grip) BCG with the top gymnast;

b) Speed of reference points, especially in without support phase (significantly) higher for the top gymnast;

c) The angle of the shoulder joint has consistently larger values with the top gymnast. With the average gymnast at the beginning of the phase without support registers retroflexion with the elbow joint bent very much, in order to begin anteflexion of shoulder and extension of the elbow joint when the gymnast reaches the bars;

d) A statistically significant extension in the hip joint at the end of the movement in favor of larger values with the top gymnast.

Table 5
The statistical significances of T – test – Phase IV.

		PARAMETERS – PHASE IV											
		TXBCG	TYBCG	VEBCG	VESHO	VEHIP	VEFOO	AVSHO	ANTUX	ANHIP	ANLEX	AVSHO	AVHIP
TIME SEQUENCES	58	0 .00	0 .00	0 .00	0 .00	0 .00	0 .00	0 .00	0 .01	0 .47	0 .20	0 .00	0 .89
	64	0 .00	0 .00	0 .00	0 .00	0 .00	0 .00	0 .16	0 .03	0 .32	0 .22	0 .20	0 .00
	72	0 .00	0 .00	0 .23	0 .00	0 .00	0 .00	0 .01	0 .05	0 .00	0 .01	0 .06	0 .00
	84	0 .00	0 .00	0 .10	0 .28	0 .20	0 .01	0 .00	0 .10	0 .00	0 .00	0 .80	0 .77

DISCUSSION

The first phase of the movement is characterized by significantly faster drop of the top gymnast, concluded on the basis of the speed of the center of gravity points of the body, hip and foot peaks and the angular velocity of retroflexion in the shoulder joint. Also the position for performing of the so-called *„kurbet“* in the stage of fall is much better because statistically significant greater hyperextension in the hip joint was indentified.

In phase II drop with top gymnast continues faster, which was concluded on the basis of speed point of BCG, hip and shoulder. Balanced position is faster lost and BCG moves away from the axis of rotation, which is aided by the more pronounced *„kurbet“* performed while the gymnast is still in support phase.

Entering the antigravity phase values of velocity point BCG, hip and shoulders are falling due to the effects of gravity, but they still have larger values with top gymnast.

The reason lies in better preconditions with top gymnast. The lower level of kinetic energy, forces to leave the bars in the final amplitude of the pendulum, which is below the level of reaching the bars by the point of the shoulder. Unlike the previous, top gymnast, amplitude of the pendulum and level of kinetic energy, increases with effective operations in previous phase (already mentioned), then with accelerated extension in hip joint (during the entire Phase III) and with accelerated anteflexion in the shoulder joint.

How will the IV phase be performed, whether with thrust on bent or stretched arms towards the handstand, depends on the

preconditions acquired in the previous phases which has already been mentioned.

A top gymnast acts stronger and on longer path, achieves greater kinetic energy with the effect, primarily of external forces in phase II and internal forces in the III phase, so that the result is much higher trajectory of the center of body gravity in unsupport phase (IV). The re-grip of bars will be in a much higher position, which allows to perform actual movement without error, without delay, and on stretched arms. The evaluation of the movement is done only in the fourth phase, when we can conclude errors such as bent arms and pronounced delay in completion of the movement. Exactly this is noted with the average gymnast – leaving the bars with extremely bent arms, and re-griping bars in the lower position of BCG with extremely bent arms.

CONCLUSION

Determining the cause of bad performance, is significantly easier way in the planning and programming process of removing the errors and working on further improvement of the analyzed movement. With method of identification we can significantly contribute not only in elimination of technical errors, but also to more successful training of new elements, and can be applied to a large number of elements in artistic gymnastic. This would significantly reduce the number of errors in the training of new elements when the gymnast is still in the phase of wide irradiation and generalizations, and later would be, if there is a need, much easier to identify and eliminate technical errors during the execution.

In future researches could be done an analysis of the variability of kinematic parameters of different performing styles of basket to handstand. It could also be conducted research which would determine the difference in the amount of produced energy between successful and unsuccessful execution and execution between average and top gymnasts for the mentioned element. By this researches we could reach the kinematic parameters wich represent the ideal performance technique of basket to handstand.

REFERENCES

Brüeggmann, G.P., Cheetam, P., & Arampatzis, D. (1994). Approach to a Biomechanical Profile of Dismounts and Release – Regrasp Skills of the High Bar. *Olympic Scientific Projects, Journal of Applied Biomechanics, 10*(3), 291-312.

Čuk, I. (1996). The development and analysis of a new gymnastics exercise – drop shoot with a forward somersault tucked from the parallel bars (Unpublished Doctoral dissertation or master's thesis). *University of Ljubljana, Faculty of Sport, Slovenia, Ljubljana.*

Davis, J. (2005). Under somersaults on parallel bars. *Gym Craft*, *14*, 6–7.

Gervais, P. & Dunn, J. (2003). The double back salto dismount from the parallel bars. *Sports Biomechanics*, *2*(1): 85-101.

Hanin, Y. & Hanina, M. (2009). Optimization of Performance in Top-Level Athletes: An Action – Focused Coping Approach. *International Journal of Sports Science and Coaching, 4*(1), 47-91.

Heng, T. (2007). Kinematical descriptors of circles of short pommel horse in men's artistic gymnastics. *Journal of Biomechanics*, *40,* S741.

Hiley, M. & Yeadon, M. (2007). Optimization of Backward Giant Circle Technique on the Asymmetric Bars. *Journal of Applied Biomechanics*, *23*(4), 300-308.

International Gymnastics Federation. (2013). *Code of points for men's artistic gymnastics.*

Kolar, E., Andlovic-Kolar, K., & Stuhec, S. (2002). Comparative analysis of selected Biomechanics characteristics between a support backward swing and support swing for the 1 – 1/4 straddle – piked forward salto on the parallel bars. *Sports Biomechanics*, *1*(1), 69 – 78.

Linge, S., Hallingstad, O., & Solberg, F. (2006). Modeling the parallel bars in

men's artistic gymnastics. *Human Movement Science*, *25*, 221-237.

Prassas, S. (1994). Technique analysis of the back toss on the parallel bars performed by elite gymnasts. *12 International Symposium on Biomechanics in Sports*, 249-251.

Prassas, S. & Ariel, G. (2005). Kinematics of giant swings on the parallel bars. *23 International Symposium on Biomechanics in Sports*, 953-955.

Takei, Y. (1998). Three – Dimensional Analysis of Handspring With Full Turn Vault: Deterministic Model, Coaches' Beliefs, and Judges' Scores. *Journal of Applied Biomechanics, 14*(2), 190-210.

Tsuchiya, J., Murata, K., & Fukunaga, T. (2004). Kinetic analysis of backward giant swing on parallel bars. *International Journal of Sport and Health Science, 2*(1), 211-221.

Veličković, S., Kolar, E., Kugovnik, O., Petković, D., Petković, E., Bubanj, S., Bubanj, R., & Stanković, R. (2011). The kinematic model of the basket to handstand on the parallel bars. *Facta Universitatis: Series Physical Education And Sport*, *9*(1), 55 – 68.

Yeadon, M. & Brewin, M. (2003). Optimal performance of the backward long swing on rings. *Journal of Biomechanics, 36*, 542-552.

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GYMNASTICS DISPOSITIONS AND SKILLS: A CASE STUDY LISTENING TO THE VOICES OF TEACHERS

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Original article

Abstract

Faced with the problem of the gradual disappearance of gymnastics in the Spanish curriculum, the aim of this research is to analyse the thinking and experiences of a group of physical education teachers as regards the teaching of gymnastics skills. More specifically, this research investigates teachers' views on their initial physical education at the university, and their perceptions of difficulties they experienced at the beginning of their professional lives. The methodology employed is qualitative using Aquad 7 program to support the interpretative process. The findings show that the participants considered that their initial physical teacher education curriculum did not give them the procedural knowledge necessary to carry out their gymnastic teaching effectively. As regards the beginning of their careers as teachers, although a group of participants stated that they had implemented educational gymnastics satisfactorily, two groups put forward a negative vision. Of these, one group taught gymnastics but did not feel fully prepared to do so, which made them anxious and insecure, and the other group did not teach gymnastics at all because they lacked the necessary conditions and resources. The results suggest that initial teacher education should be receptive to the initial teacher's needs and constraints in the gymnastic field.

Keywords**:** *initial physical teacher education, gymnastic, novice teachers, reflective professional practice.*

INTRODUCTION

The aim of initial teacher education, in all subjects, is to prepare students for their future professional lives. However, many authors have highlighted the gap between theoretical studies at university and their applicability in the professional world (Cochran-Smith & Lytle, 1999; Zeichner, 2010). Novice teachers have some problems in adapting to the constant changes and demands of the educational context that occur in a society in which knowledge is advancing at a vertiginous speed (Bauman, 2000). This may lead teachers to abandon the teaching of some important educational learning contents, as they do not feel fully prepared (Lloyd & Sullivan, 2012). Our study has focused on gymnastics as it forms part of the curriculum of physical education, which is not divorced from this reality.

Research carried out by Sloan (2007), in England, stresses that gymnastics is the subject in the physical education curriculum that is taught least and about which teachers appear most insecure. In Spain, gymnastics

has a very limited presence in secondary school curriculums (Decree-Law No. 112/2007 of 20 July, Valencian Community), no higher than 1.2%. At university studies, for example, there are 240 ECTS in the Sports and physical education curriculum but there is only 6 ECTS for learning gymnastics (2.5%) in the majority of universities. Throughout the Spanish education system, the marginalisation of gymnastics is well known by professionals in the field. For example, when our physical education students at university do the practice credits in schools they are reporting us in the practicum memoire that they never observe gymnastics being taught in schools, during the last decade at least. Additionally, Physical Education in Spanish schools has not the same consideration that Maths or Language, probably because is not a Pisa evaluation subject. The Physical Education curriculum, in Spain, is a quite open curriculum and this openness gave teachers liberty to choose learning contents and skills. Normally, teachers' dispositions influence election, the available resources, and also the students' predisposition, mainly in Secondary educations.

The benefits of learning gymnastics must be considered in order to assess the implications of its loss from National Educational Reform in 1970 (Law 14/1970) when new teachers have a university accreditation. Gymnastics has played an essential role in physical education for developing skills such as resistance, flexibility, agility, coordination and the kinaesthetic sense (Dowdell, 2013). It contributes to balanced physical skills with personal and social competences (Rikard & Banville, 2006). Dowdell and Holt (2005) suggest that teamwork, and planning skills, could be also encouraged by doing gymnastics, as well as dedication and constancy, and this can benefit pupils in diverse aspects of their life. The aforementioned educational values of gymnastics mean the convenience of include this learning alongside others physical education subjects (Kovač & Novak, 2001).

Now that an open curriculum, offer the opportunity to include gymnastic learning in schools, the aim of the research was to identify teachers' skills and dispositions to gymnastics to find the causes behind the scarce presence. We have looked at the professional thinking and reflections of a sample of physical education teachers in the Valencian Community (Spain), to bring together their cognitive and emotional thinking (Deglau & O'Sullivan, 2006). The analysis is based on the biographies of the participants, their experiences as learners during their university studies, and on their initial experiences as newly qualified teachers. The identification of their problems and needs could contribute to a proposal for initial physical teacher education studies that give more attention to gymnastic learning.

The development of gymnastics teaching skills: from theory to practice

When developing teaching skills, two essential factors come together: learning acquired through initial teacher education at university and the practical experience of teaching in schools (Korthagen, Loughran, & Russell, 2006). Darling-Hammond and Bransford (2005), Feiman-Nemser (2001) and Hargreaves (2000) accentuate that novice teachers perceive frequently their initial studies to be inadequate when beginning their teaching career.

There is a long history of research into reflection processes as a key part of initial education of teachers (Tsangaridou, 2005). From Dewey (1933) and Schön (1987), authors as Calderhead (1996), Griffiths (2000), Cordingley (2009), and many others have argued that collaboration is often necessary in order that knowledge might be reinforced with the support of an expert teacher. This perspective of professional reflection, when is developed in a community of practice could facilitate change and innovation (Edwards & Nicoll, 2006); when professionals are capable of questioning and sharing experiences with

others, there is greater potential for the improvement of practices (Korthagen, 2010; Money, Kirby, Parry, Hesford, & Mooney, 2009). Additionally, and in line with research into teacher education carried out by Price and Valli (2005), Darling-Hammond (2010), Lieberman (2010) it is also necessary to view research on the teaching of gymnastics skills from a perspective of reflection that relate knowledge and practice (Dowdell, 2010).

The values of professional experience must be validated by shared reflections in school context (Glass & Rud, 2012) but also as Cochran-Smith and Lytle (2009) suggest knowledge generated by teachers in the classroom can be corroborated and revised – critically– with knowledge validated by research. The reflective model of professional development for physical education teachers had major potential (Money et al, 2009; Sinelnikov, 2009; Williams & Kentel, 2013).

This study is part of a research, in which also we inquired others questions (Ávalos, Martínez, & Merma, 2014). The teachers' reflection and vision will allow us to explore how academic education influences their initial professional dispositions and skills to teach gymnastic. This could allow us to address the initial education of future professionals of this discipline more effectively and rethink teachers' professional learning. The following research questions were posed:

1) How do participants believe that initial physical learning at university has prepared them for teaching gymnastics skills?

2) How do participants perceive their initial teaching of gymnastics at schools?

METHOD

The qualitative focus used for this narrative research is adequate for analysing professional thinking and teachers' perceptions. Clandinin, Cave and Cave (2011) maintain that narrative research is a thinking process, which is carried out taking into account its contextual nature. The interrelation between teachers and their educational context offers the possibility of attributing meaning to experiences (Andrews, Sclater, Squire, & Treacher, 2000; Latta & Kim, 2009). Consequently, narrative research is a very useful tool for investigating teaching practice (Coulter & Smith, 2009), and the results could allow the improvement of traditional practices, enriching knowledge and teaching action from the experiences of others (Cochran-Smith & Lytle, 2009; Stylianou, Kulinna, Cothran, & Kwon, 2013). In the field of physical education, narrative research has proved itself to be a useful methodological tool, which can provide a deeper interpretation of the educational context (Garrett, 2006).

The study was carried out with a sample of volunteers. The centre for In-service Teacher Education (CEFIRE) in Alicante (Spain) provided a list of physical education teachers that agreed to take part in the research.

The sample is representative, given that included teachers with extensive experience (20 teachers with more than 16 years in teaching and 15 teachers who have between 15 and 5 years' experience) and teachers with little experience (15 teachers with fewer than 4 years' experience). This difference in the number of years spent in teaching gives a multiple vision of physical teaching.

The research instrument employed was semi-structured interviews, which is frequently used for educational research (Coulter & Smith, 2009; Denzin & Lincoln, 2000).

Meetings with the participating teachers were organised by telephone and email. The interviews were carried out individually in the teachers' own school and the questions focused on teachers' university studies and their experiences teaching gymnastics skills at the beginning of their career.

After collecting the data, the corresponding analysis was carried out using the inductive method, based on the identification and categorization of the text

units extracted from the participants' narratives. The information was processed using the qualitative computer software AQUAD 7 (Huber, 2012), which allowed us to categorise and organise the information in codes and subcodes to interpret participants' critical thinking. The data were analysed following the model suggested by Miles and Huberman (1994).

The first step consisted in analysing the interviews in order to identify possible relationships between the research questions and the emergent concepts from the participants' narratives. Then, in order to validate the codes and categories, a process of triangulation was carried out. Three researchers from the Department of Education of the University of Alicante intervened in the discussion of codes. In this way the codification map was obtained from the emerging themes of the narratives.

The first theme, identify the participants opinions on adequacy of physical university studies for the learning and teaching of gymnastics. The second deals with the participants' opinions on experiences in teaching gymnastics at the beginning of their careers as secondary education teachers.

RESULTS

The results are presented in codes and subcodes related to the two emerging themes. The results are presented in tables shown the absolute frequencies (AF) and the percentage of absolute frequency (%AF), where AF is the total number of a code in the narratives, and the %AF is related to the total absolute frequency of the codes (AF.100/total AF).

Theme I: Perception of initial teacher learning in gymnastics skills

Knowing teachers' opinions as regards their initial teacher training in gymnastics has allowed us to determine the different learning experiences of the participants. Positive, negative, and non-existent experiences in learning gymnastics emerge in this theme. As shown in Table 1, a significant number of participants affirmed that their initial teacher education in gymnastics was non-existent or unsatisfactory (58.60%), and other group said they had had positive learning experiences during their university studies (41.40%).

Table 1
Perceptions of initial physical learning in gymnastics skills.

CODES	AF	%AF
1. Learning experience:		
1.1. Satisfactory experience	147	41.40%
1.2. No training and unsatisfactory experience	208	58.60%
Total	355	100%

Table 1.1
Unsatisfactory experiences in university education: causal factors.

SUBCODES	AF	%AF
Negative personal disposition	61	29.32%
Inadequate teacher and methodology	116	55.76%
Insufficient means and resources	5	2.40%
No training	26	12.50%
Total	208	100%

Table 1.2
Satisfaction with initial studies: causal factors.

SUBCODES	AF	%FA
Positive personal disposition	52	35.37%
Adequate teacher and methodology	84	57.14%
Sufficient means and resources	11	7.48%
Total	147	100%

Table 2
Teachers' perceptions of teaching gymnastics as beginning of teachers.

CODES	AF	%FA
2. Experience in teaching gymnastics		
2.1. Satisfactory experience in teaching gymnastics	87	47.02%
2.2. Non-experience and unsatisfactory experience in teaching gymnastics	98	52.97%
Total	185	100%

Table 2.1
Satisfactory experiences of teaching gymnastics as beginning of teachers.

SUBCODES	AF	%AF
Favourable disposition to teach	35	40.22%
Favourable disposition of pupils	22	25.28%
Favourable working conditions and environment	30	34.48%
Total	87	100%

Table 2.2
Unsatisfactory experiences and non-experiences of teaching gymnastics as beginning of teachers.

SUBCODES	AF	%AF
Unsatisfactory experiences:		
Lack of disposition to teach	28	28.57%
Lack of disposition of pupils	14	14.28%
Non-experiences:		
Lack of academic training	11	11.22%
Inadequate conditions and lack of resources	45	45.91%
Total	98	100%

1.1. Dissatisfaction with initial studies

There are different reasons behind the dissatisfaction cited by the participants (Table 1.1.). The inadequate methodology used by university teachers (55.76%) was the main reason for dissatisfaction. The participants claimed that the activities were complex and technically demanding, and

methods were not very appropriate for secondary schools. Participants expressed this view as follows:

We only did very complicate floor exercises such as back flips and things like that. I remember we had to keep a record for every class. I could say we had very few classes and they were not easy to apply in schools (Nov. 002).

At university, my training was obsolete, insufficient, and poor. It wasn't adapted to the real world I later found in schools. Furthermore, the teacher didn't know how to teach and had many doubts...the truth is I learnt very little (Ava.005).

Others participants express that negative personal disposition towards the subject (29.32%), was due to past experiences or to a lack of affinity for gymnastics:

I hadn't had very good experiences during my previous training. So I didn't have the confidence. In addition I wasn't very good at gymnastics and so my only aim was to pass the subject (Nov.009).

Also, a small group of participants claimed they have never had any specific training in gymnastics (12.50%) and this is the cause of their dissatisfaction.

When I did my degree, gymnastics was not included in the subjects of team sports and individual sports (Nov. 012).

I remember studying all types of sports, but I don't remember studying gymnastics skills (Exp. 006).

A lack of means and resources does not appear to be an important reason for dissatisfaction (2.40%).

1.2. Satisfaction with initial studies

On the other hand, from the satisfactory narratives a 57.14% value the adequate teacher and/or teaching methodology (Table 1.2):

The teacher educator gave a theoretical introduction and then we moved on to the practical part. Sometimes we worked in groups, some of us were observers and had to make notes so we could realise what mistakes we had made. I value this methodology very positively as it enriched my learning (Exp.019).

The quality of the resources (7.48%) is the reasons for satisfaction with the least presence.

Theme II: Perceptions of teaching gymnastics as beginning teachers

In this theme, we look at the initial professional experiences of physical education teachers when teach gymnastics and the reasons behind the experiences they describe. A significant number of participants perceived that their initial teaching in gymnastics was unsatisfactory (52.97%). We include here the group dissatisfied because were not able to teach gymnastics:

I have never taught gymnastics skills in Secondary School because I don't like them. In addition, I didn't know how to teach them, I think they are dangerous. And I haven't been trained how to teach the skills in a way which is more fun for pupils (Ava. 011).

Another problem is pupils who are very frightened. They arrive with a note from their parents saying they mustn't take part in gymnastics classes. These parents are unconsciously preventing their children from experimenting with and learning gymnastics skills (Exp. 020).

In contrast, a 47.02% of narratives express positive teaching experiences. These positive or negative opinions can be explained by personal attitude, working conditions and environment, and the disposition of pupils to learn gymnastics skills.

2.1. Satisfactory perceptions

Table 2.1 shows that the teaching of gymnastics skills at the beginning of the participants' careers was satisfactory. This indicates that these teachers wanted to teach gymnastics (40.22%).

When I began work, I immediately started teaching these skills because I enjoyed it. I gave my classes in the way I was taught to at university (Exp.003).

Some participants (34.48%) affirm that their work conditions are ideal, as they have the possibility of sharing experiences and knowledge about this area with colleagues, and they enjoy suitable facilities, resources and timetables.

During the first two years, I didn't do anything. Then in 2003 I began teaching and started doing acro-gymnastics sessions. A colleague with more experience in teaching, and who also taught this type of gymnastics a lot, gave me the information necessary. Thanks to him, I was able to teach this and it went pretty well (Nov.007).

Finally, a 25.28% reflects a good pupil acceptance of gymnastics learning.

2.2. Unsatisfactory perceptions

Table 2.2 shows the reasons for teachers' unsatisfactory experiences of teaching gymnastics that we have presented in Table 2 (52.97%). These feelings of dissatisfaction arise from their negative personal dispositions to teach these skills (28.57%), due to lack of self-confidence, no feeling of affinity towards gymnastics, or fear that pupils might injure themselves.

I eliminated exercises that could be dangerous for my pupils for fear they might injure themselves: for example the backward summersault which could cause neck injuries, or vaulting over the horse. Either of these can cause problems with parents, school authorities...I try to avoid conflicts and include other activities (Nov. 002).

When I began to give classes, I worked with a colleague who did teach these skills. As the sessions progressed, things became more complicated and I was a little frightened. I didn't feel confident. I even injured myself (Ava.009).

In second place, to a lesser extent, the participants state that some pupils are unwilling to do gymnastics (14.28%) due to their lack of ability or previous negative experiences.

In the beginning, in a Secondary School, I produced a didactic unit around gymnastics skills. We did very basic things: forward and backward somersaults, cartwheels, and some handstands. From the start, there were some girls and boys who had problems doing these exercises. So I had to give them much more simple exercises. And they couldn't do them either (Ava.010).

When I wanted to include these exercises in class, there were pupils who were terrified of the vault, plinth and trampoline because they had fallen or hurt themselves…when they were younger (Exp. 004).

Others reasons given by the participants for not teaching gymnastics skills at the beginning of their careers are fundamentally inadequate working conditions (45.91%), mainly lack of resources or infrastructures; also, a lack of teacher training in this field (11.22%). Thus, they did not feel capable of teaching these skills at the beginning of their career.

Inadequate working conditions and resources, and a lack of academic training are reflected in the following narrative:

Another problem is the lack of adequate resources and infrastructure, which is an obstacle for the carrying out of these types of activities (Nov.012).

When I began work, my school didn't have a gym, and so I couldn't teach gymnastics (Exp. 010).

The truth is that I haven't worked with jumps and "those kinds of things", with plinths... This is because I haven't been trained well enough (Exp. 011).

In summary, the perception of satisfaction at the beginning of teachers' careers is mainly due to the personal affinity teachers have towards gymnastics skills, and also the existence of favourable working conditions. In addition, as regards unsatisfactory experiences or the absence of experience in teaching gymnastics, the results reveal that lack of training and the subsequent insecurity contributed to difficult beginnings. Furthermore, the results confirm the findings of previous research, such as that carried out by Dunkin (1990), and Hodkinson and Taylor (2002), which also determined problems experienced during this initial stage, as

these related to the pupils themselves and the resources available.

DISCUSION

Duran, McCarthy, Graesser and McNamara (2007), and Hughes, Pennington and Makris (2012) have made important contributions to the interpretation of evidence taken from narratives, focusing on the credibility of findings. These authors maintain that the illustration of conclusions with examples, relevant counter-examples, alternative interpretations of the evidence or reference to the limitations and conflictive evidence give greater credibility to research. Likewise, a detailed description of the results permits readers to evaluate if their experience is consistent with the study. After analysing the information, the results have allowed us to answer the research questions with the conviction that we can make a valid contribution to research in this field.

First research question

Analysis of the first emerging theme reveals that more than half of the participants do not value their initial preparation very highly, including in these results the percentage of narratives that affirm dissatisfaction because they haven't received gymnastics learning at all. These findings coincide with the results of studies (Cochran-Smith, 2005; Korthagen, 2010) that reveal the limited influence of initial teacher education on teaching, principally at the beginning of teaching life. The participants' criticism of their university studies is based on the inadequate methodology used for teaching how to teach gymnastics skills, their university teachers' lack of preparation, and their own negative disposition towards this specific area. These criticisms could mean that the methodological focus of gymnastics does not correspond with the secondary education classrooms, and furthermore the new and last modalities of gymnastics as acrobatic gymnastics, aerobic gymnastics, trampoline gymnastics and gymnastics for all aren't learned at university. Due to these, some participants that would teach gymnastic express that were not able to apply academic knowledge in their professional practice. This leads them to discredit the initial learning. For example, there is only one narrative, which underlines the importance of a reference model in the university stage:

I worked in a way that was very similar to what I had seen during my teacher placement period (Exp.010).

Second research question

The second theme shows that although many participants had a positive disposition towards teaching gymnastics at the beginning of their career, others show a resistance and have never included these practices in their teaching. In addition, a third group, who did gymnastics in their teaching, were dissatisfied with the experience.

The participants motivated to teach gymnastics at the beginning of their career stated that their personal disposition was good, that the context conditions were positive and that pupils responded satisfactorily to gymnastics. We should also highlight that in some cases, but not many, in which teachers pointed out the influence of shared experiences with their colleagues.

In my second or third year I worked with three teachers and we taught gymnastics skills. We produced a joint sequenced programme. I think we did it quite well (Exp.014).

In the past, I gave classes with a colleague who is a mini trampoline expert, and he gave me the confidence I needed (Exp.013).

In the category in which initial teaching education is not valued, participants attribute their difficulties to two causes: dissatisfaction with their initial teaching of these skills, that don't help them to overcome their lack of confidence and a negative view of their own aptitudes for teaching this discipline. The strong sense of insecurity teachers experienced was especially due to their fear of the injuries

that could be incurred while doing gymnastics.

I think these skills are very useful, but as "I'm so clumsy!"... It wasn't difficult for me to give the classes because what we did was very basic, but I didn't try to do complicated gymnastics activities, and so I left it there. Now it would be impossible for me to teach this (Exp.013).

I've been giving classes in Secondary Schools for many years. I don't teach gymnastics because I don't trust the pupils. They aren't very responsible, are immature and do stupid things (Exp.015).

Another problem is the youngsters' rejection of these activities, as they know they can't do them well (Nov.001).

In some narratives, this negative self-concept was attributed to the inadequacy of their specific university training:

My university training, as well as being obsolete, I would describe it as inadequate and poor as it was not adapted to the real world which I later found myself in. So, I had no alternative but to teach myself through experience and trial and error (Ava.006).

Teachers blame also the sometime negative disposition of pupils. They claim that pupils displayed a clear resistance to learning these skills, together with a lack of the necessary basic motor skills, often caused by early negative experiences.

It is very difficult as there are pupils in class who have refused to do gymnastics in class ever since they were small because they hurt themselves once and became frightened of gymnastics. These pupils don't want to do anything in class (Ava.005).

Pupils sometimes go to secondary education affected by experiences that made them feel ridiculous, frightened or frustrated. As Nunomura, Okade and Carrara (2012) affirm, "many pupils are naturally highly motivated when they begin but this feeling can be quashed by negative sports experiences" (p. 33). A more collaborative model may reduce pupils' fears of ridicule, failure and frustration that a competitive one. Participants confess that during their beginnings they did not know how to respond to this situation effectively.

Finally, another category has emerged, teachers who did not dare implement the teaching of gymnastics skills. These teachers relate similar reasons to those mentioned by teachers who had a negative experience of gymnastics teaching at the beginning of their career, which totally annulled their teaching capacity. A lot of narratives coincide with Lasky's affirmations (2005) that a lack of good working conditions and resources and the inability to produce a good curriculum design interfere with teachers' capacity to obtain good practices:

At the beginning of my teaching career, in the schools where I worked, there were no facilities, until 93-94 when I did have a gymnasium and could teach gymnastics skills (Exp.009).

The truth is that when I began, I didn't teach gymnastics skills because my university training in this area was not very good (Exp. 015).

Darling-Hammond (2010) argues that the countries recognized as having the best education systems –Finland, Korea and Singapore– are known to invest a great deal in teacher education. From results, we can conclude that resources and working conditions in gymnastics must be improved, given that participants clearly found that sport facilities, and prevention and safety measures in Spain does not meet their needs.

In short, teachers are aware of aspects which have restricted their teaching of gymnastics skills: a lack of specific knowledge resulting in limitations at the beginning of their teaching career. Adequate university education could be the key to overcoming these limitations (Hadar & Brody, 2012; Vescio, Roos, & Adams, 2008). Change towards less individualistic and more collaborative learning could favour more innovative and creative pedagogic practice in the future (Armour, Makopoulou, & Chambers, 2012; O'Sullivan & Deglau, 2006) and in addition could reinforce shared knowledge. Furthermore, teaching difficulties and

insecurities at the beginning of teachers' careers could be solved more easily in schools which function as communities of practice and are spaces of participative reflection (Zeichner, 1994). Teachers' sharing of their insecurities would facilitate the finding of alternatives and solutions, especially where there are novice teachers and teachers with extensive work experience in the same centre. Shared professional knowledge, as stressed by Whitcomb, Borko and Liston (2009), could bring about a great change in gymnastics education, especially if teachers are capable of employing a reflective approach.

CONCLUSIONS

The relevance of initial teacher education for initial professional action in schools

It is evident from this study that the participants gave little relevance to their university gymnastic program and school conditions for teaching. The findings force us to reflect on the real value of initial learning or school environment when teachers simply remember having to overcome the obstacles of. For many researchers, authentic professional induction occurs through practical experience (Borko, 2004; Hargreaves, 2000) and in the relationships between new and expert teachers. Teachers learn by breaking the silence that currently exists and communicating with each other.

Korthagen (2010), amongst other authors, has argued that university studies in education are often swept away by real work environment. There have been many studies, such as those of Feiman-Nemser (2001), Korthagen (2010) and Zeichner (2012), into the phenomenon of the shock of teaching when novice teachers arrive in the classroom and, in general, researchers conclude that the impact of initial teacher education on teaching in practice tends to be minimum (Cochran-Smith, 2005). Immersion in the real world of teaching is the clue. Teaching always takes place in a particular context, and thus theoretical knowledge must take into account different experiences in diverse contexts. Korthagen (2010) suggests using experiences is a challenge and oblige us to reconstruct our theories (Whitcomb, Borko, & Liston, 2009). In addition, given the nature of distributed knowledge, learning with colleagues allows an active dialogue to take place within the educational community. Other studies, like those by Price and Valli (2005), underline the need for teacher trainees to be immersed in practical experiences in changing contexts. In this way, they will be better able to understand the complexities of learning how to teach. Lieberman and Miller (2007), and Lieberman (2010) also agree that teacher training should be based on teaching practice in schools and on authentic classroom problems. Likewise, Macdonald and McCuaig (2012), Lampert et al. (2013), and McDonald, Kazemi and Schneider (2013) propose new pedagogies based on appropriate practices.

The relevance of reflection, shared experiences and support of expert teachers

Glass and Rud (2012), in particular, synthesize the concept of reflection as a construction of meaning. As a counterpoint to routine experience, reflection involves linking personal experience with thought inspired by other experts; it deepens personal experience and relates it to other experiences and knowledge (Cordingley, 2009). Here it is understood to be a rigorous form of thinking, a systematic and disciplined procedure (Capel, Hayes, Katene, & Velija, 2011) which involves a considerable degree of curiosity. Clearly, ours results don't showed great focus on reflexion. Then, something must be done in initial teacher education.

Could be reflection, as the attempt to connect individual experience and necessities with the community of practice, has to be an instrument of learning (Greenwood and Levin, 2003). In the teaching of gymnastics, we believe that the concept of reflection put forward by Glass and Rud (2012) is of particular interest. They claim reflection is both an individual

and collaborative process. From this perspective, in both initial and professional development for gymnastics teachers shared reflective practice is of great relevance as Money et al. (2009) suggested.

For Flores and Day (2006), becoming a good teacher is a complex task, and this process takes place in a specific context and requires the interaction between a variety of perspectives and practices of the different members of the educational community. Thus, they conclude that in teachers' personal and professional histories, there is a strong interrelation between their thinking and the characteristics of their place of work and its limitations. In summary, could be initial teacher education have little repercussion due to the fact that they do not take into account specific contexts and offer few opportunities to reflect on a range of different cultural contexts.

REFERENCES

Andrews, M., Sclater S. D., Squire, C., & Treacher, A. (2000). *Lines of narrative: psychosocial perspectives*. Oxon: Routledge.

Armour, K. M, Markopoulou, K., & Chambers, F. (2012). Progression in physical education teachers' career-long professional learning conceptual and practical concerns. *European Physical Education Review, 18*(1), 62–77.

Ávalos, Martínez, & Merma (2014). Inconsistencies in the curriculum design of educational gymnastics: case study. *Science of Gymnastics Journal*, *6*(3), 23–37.

Bauman, Z. (2000). *Liquid modernity.* Cambridge: Polity Press.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher, 33*(8), 3–15.

Calderhead, J. (1996). Teachers: Beliefs and knowledge. In D. C. Berliner, & R. C. Calffee (Eds.), *Handbook Education Psychology* (pp.709–725). New York: Macmillan.

Capel, S., Hayes, S., Katene, W., & Velija, P. (2011). The interaction of factors which influence secondary student physical education teacher's knowledge and development as teachers. *European Physical Education Review, 17*(2), 183–201.

Clandinin, D. J., Cave, M., & Cave, A. (2011). Narrative reflective practice in medical education form residents: Composing shifting identities. *Advances in Medical Education and Practice, 2*, 1–7.

Cochran-Smith, M. (2005). Teacher educators as researchers: multiple perspectives. *Teaching and Teacher Education, 21*(2), 219–225.

Cochran-Smith, M., & Lytle, S. L. (1999). Relationships of knowledge and practice: Teacher learning in communities. In A. Iran-Nejad, & P. D. Pearson (Eds.), *Review of Research in Education* (pp. 249–306) Vol. 24. Washington, DC: AERA.

Cochran-Smith, M., & Lytle, S. L. (2009). *Inquiry as stance. Practitioner research for the next generation.* New York: Teachers College Press.

Cordingley, P. (2009). Using research and evidence as a lever for change at classroom level. In *American Educational Research Associations Annual Meeting*. San Diego, USA, 13–17 April 2009.

Coulter, C. A., & Smith, M. (2009). Discourse on narrative research. *Educational Research, 38*(8), 577–590.

Darling-Hammond, L. (2010). *The flat world and education. How America's commitment to equity will determine our future*. New York: Teachers College Press.

Darling-Hammond, L., & Bransford, J. (2005). *Preparing teachers for a changing world: what teachers should learn and be able to do.* San Francisco: Jossey-Bass.

Decree-Law Nº. 112/2007 of 20 July, Valencian Community, Spain. Secondary Education curriculum in the Valencian Community (2007/9717) to the area of Physical Education.

Deglau, D., & O'Sullivan, M. (2006). Chapter 3: The Effects of a long-term professional development program on the beliefs and practices of experienced teachers [Monograph]. *Journal of Teaching in Physical Education, 25*, 379–396.

Denzin, N. K., & Lincoln, Y. (2000). *Handbook of qualitative research*. Londres: Sage.

Dewey, J. (1933). *How we thing: a restatement of the relation of reflective thinking to the educative process.* Boston: D. C. Heath.

Dowdell, T. (2010). Characteristics of effective gymnastics coaching. *Science of Gymnastics Journal*, *2*(1), 15–24.

Dowdell, T. (2013). Benefits of gymnastics participation for school age children. *Education, 16,* 1–17.

Dowdell, T., & Holt, J. (2005). *Coaching women's gymnastics vol. 1. Systems for success.* Brisbane: Self-Published.

Dunkin, M. (1990). The induction of academics staff to a university: process and product. *Higher Education, 20*(1), 46–47.

Duran, N. D., McCarthy, P. M., Graesser, A. C., & McNamara, D. S. (2007). Using temporal cohesion to predict temporal coherence in narrative and expository texts. *Behavior Research Methods, 39*, 212–223.

Edwards, R., & Nicoll, K. (2006). Expertise, competence and reflection in the rhetoric of professional development. *British Educational Research Journal, 32*(1), 115–131.

Feiman-Nemser, S. (2001). From preparation to practice: Designing a continuum to strengthen and sustain teaching. *Teachers College Record, 103*(6), 1013–1055.

Flores, M. A., & Day, C. (2006). Contexts which shape and reshape new teachers' identities: A multi-perspective study. *Teaching and Teacher Education, 22*(2), 219–232.

Garrett, R. (2006). Critical storytelling as a teaching strategy in physical education teacher education. *European Physical Education Review, 12*(3), 339–360.

Glass, G. V., & Rud, A. G. (2012). The struggle between individualism and communitarianism: The pressure of population, prejudice, and the purse. *Review of Research in Education, 36,* 95–112.

Greenwood, D., & Levin, M. (2003). Reconstructing the relationships between universities and society through action research. In N. Denzin, & Y. Lincoln (Eds.), *The Landscape of Qualitative Research* (pp. 131–166). Thousand Oaks: Sage.

Griffiths, V. (2000). The reflective dimension in teacher education. *International Journal of Educational Research, 33*(5), 539–555.

Hadar, LL., & Brody, D. L. (2012). The interaction between group processes and personal professional trajectories in a professional development community for teacher educators. *Journal of Teacher Education, 64*(2), 45–61.

Hargreaves, A. (2000). Mixed emotions: teachers' perceptions of their interactions with students. *Teaching and Teacher Education, 16*(8), 811–826.

Hodkinson, S., & Taylor, A. (2002). Initiation rites: The case of new university lecturers. *Innovations in Education and Teaching International, 39*(4), 256–264.

Huber, G. L. (2012). *AQUAD 7. Manual for the analisis of qualitative data.* Tübingen: Ingeborg Huber Verlag.

Hughes, S., Pennington, J. L., & Makris, S. (2012). Translating autoethnography across the AERA standards: Toward understanding autoethnographic scholarship as empirical research. *Educational Research, 41*(6), 209–219.

Korthagen, F. (2010). La práctica, la teoría y la persona en la formación del profesorado. *Revista Interuniversitaria de Formación del Profesorado, 68*(24), 83–101.

Korthagen, F., Loughran, J., & Russell, T. (2006). Developing fundamental principles for teacher education programs and practices. *Teaching and Teacher Education, 22*(8), 1020–1041.

Kovač, M., & Novak, D. (2001). *Učni načrt za osnovno šolo*. *Športna vzgoja.* [Primary school curriculum. Physical Education]. Ljubljana: Zavod RS za Šolstvo.

Lampert, M., Franke, M. L., Kazemi, E., Ghousseini, H., Turrou, A. C., Beasley, H., Cunard, A., & Crowe, K. (2013). Keeping it complex: using rehearsals to

support novice teacher learning of ambitious teaching. *Journal of Teacher Education, 64*(3), 226–243.

Lasky, S. (2005). A sociocultural approach to understanding teacher identity, agency and professional vulnerability in a context of secondary school reform. *Teaching and Teacher Education, 21*(8), 899–916.

Latta, M. M., & Kim, J. H. (2009). Narrative inquiry invites professional development: Educators claim the creative space of praxis. *The Journal of Educational Research, 103*(2), 137–148.

Law 14/1970, of 4 August, General Education of Education Reform (Spain). *BOE* 6 of August of 1970, 212. Retrieved from http://www.boe.es/aeboe/consultas/bases_datos/doc.php?id=BOE-A-1970-852

Lieberman, A. (2010). Teachers, learners, leaders: joining practice, policy and research. *Educational Leadership, 15*(67), 1–11.

Lieberman, A., & Miller, L. (2007). Transforming professional development: Understanding and organizing learning communities. In W. D. Hawley (Ed.), *The keys to effective schools: educational reform as continuous improvement* (pp. 99–116). Thousand Oaks: Corwin Press.

Lloyd, M. E., & Sullivan, A. (2012). Leaving the profession: The context behind one quality teacher's professional burn out. *Teacher Education Quarterly, 39*(4), 139–162.

Macdonald, D., & McCuaig, L. (2012). Research principles and practices: Paving the research journey. In D. Armour, & D. Macdonald (Eds.), *Research Methods in Physical Education and Young Sport* (pp. 16–28). London: Routledge.

McDonald, M., Kazemi, E., & Schneider, S. (2013). Core practices and pedagogies of teacher education. A call for a common language and collective activity. *Journal of Teacher Education, 20*(10), 1–9.

Miles, B., & Huberman, A. M. (1994). *Qualitative data analisis*. London: Sage.

Money, J., Kirby, G., Parry, G., Hesford, R., & Mooney, C. (2009). Gymnastics: Collaborative CPD- what has the impact been on pupils' learning? *CTEL Journal Innovations in Practice, 1*(2), 29–40.

Nunomura, M., Okade, Y., & Carrara, P. (2012). How much artistic gymnastics coaches know about their gymnasts' motivation. *Science of Gymnastics Journal, 4*(2), 27–37.

O'Sullivan, M., & Deglau, D. (2006). Chapter 7: Principles of professional development [Monograph]. *Journal of Teaching in Physical Education, 25*, 441–449.

Price, J. N., & Valli, L. (2005). Preservice teachers becoming agents of change: Pedagogical implications for action research. *Journal of Teacher Education, 56*(1), 57–72.

Rikard, L., & Banville, D. (2006). High school student attitudes about physical education. *Sport, Education and Society, 11*, 385–400.

Schön, D. A. (1987). *Educating the reflective practitioner: toward a new design for teaching and learning*. San Francisco: The Jossey-Bass Education Series.

Sinelnikov, O. A. (2009). Sport education for teachers: Professional development when introducing a novel curriculum model. *European Physical Education Review, 15*(1), 91– 114.

Sloan, S. (2007). An investigation into the perceived level of personal subject knowledge and competence of a group of pre-service physical education teachers towards the teaching of secondary school gymnastics. *European Physical Education Review, 13*(1), 57–80.

Stylianou, M., Kulinna, P. H., Cothran, D., & Kwon, J. Y. (2013). Physical education teachers' metaphors of teaching and learning. *Journal of Teaching in Physical Education, 32*, 22–45.

Tsangaridou, N. (2005). Classroom teachers' reflections on teaching physical education. *Journal of Teaching in Physical Education, 24*(1), 24–50.

Vescio, V., Roos, D., & Adams, A. (2008). A review of research on the impact

of professional learning communities on teaching practice and student learning. *Teaching and Teacher Education, 24*, 80–91.

Whitcomb, J., Borko, H., & Liston, D. (2009). Growing talent. Promising professional development models and practices. *Journal of Teacher Education, 60*(3), 207–212.

Williams, K., & Kentel, J. A. (2013). Risky pedagogy: Reconceptualizing gymnastics education through collaborative inquiry in an Irish Primary School. *Asian Journal of Exercise and Sports Science, 10*(2), 60–76.

Zeichner, K. (1994). Research on teacher thinking and different views of reflective practice in teaching and teacher education. In I. Carlgren, G. Handal, & S. Vaage (Eds.), *Teachers' minds and actions: research on teachers' thinking and practice* (pp. 9–27). London: Falmer Press.

Zeichner, K. (2010). Rethinking the connections between campus courses and field experiences in college-and university-based teacher education. *Journal of Teacher Education, 61*(1-2), 89–99.

Zeichner, K. (2012). The turn once again toward practice-based teacher education. *Journal of Teacher Education, 63*(5), 376–382.

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PARTICIPATION OF THE PAN-AMERICAN GYMNASTICS UNION IN THE 2011 WORLD GYMNAESTRADA

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Original article

Abstract

This paper focuses on the World Gymnaestrada (WG), the largest international Gymnastics for All festival, organized by the International Gymnastics Federation (FIG). The aim was to analyze the participation of the National Federation members of the Pan-American Gymnastics Union (PAGU) in the 14th edition of the WG, held in Lausanne, Switzerland, in 2011. The data collection was made by a semi-structured questionnaire with eight of heads of delegation of the eleven participating American national federation. The results highlight the largest delegations were Brazil, Canada and the USA, respectively, countries which also traditionally participate in this festival. The participants were majority female (74,5%) and the performance were strongly influenced by Artistic and Rhythmic gymnastics disciplines, as well as Dance. PAGU participation has increased in compare with past editions of the WG, ranking it as second in terms of continent with the largest number of participants (6,64%). Although the participation is strongly related to the economic factors, considering all the WG editions held in Europe. We conclude that non-competitive gymnastics still treat secondarily for most PAGU Member Federations, since they are focus on competitive gymnastics disciplines and especially on their national teams.

Keywords**:** *general gymnastics; gymnastics for all; North America; Central America; South America; gymnastics festival.*

INTRODUCTION

The development of sports federation management represents a key aspect in the practice of Gymnastics for All (GfA) in the Americas. Thus, obtaining and analyzing data on the teams that practice GfA and that participated in the 2011 edition of the World Gymnaestrada (WG) is the first step to be taken to understand, contextualize and support the development of GfA in this continent. This has motivated the authors to conduct this study, whose aim is to analyze the profile of delegations of the PAGU

member federations that participated in the 2011 WG.

About Gymnastics for All and World Gymnaestrada

GfA is one of the seven disciplines of the International Gymnastics Federation (FIG) – and the only non-competitive discipline –, whose main principles are: participation, pleasure, joy and promoting the health of its practitioners (Wichmann, 2015). According to FIG definition (2009, p.3):

Gymnastics for All offers aesthetic experiences in movement for participants and spectators while providing the opportunity to focus on items that are of particular interest in a national and cultural context.

GfA brings back the roots of gymnastics: fun and leisure (Fiorin-Fuglsang & Paoliello, 2008), as opposed to the disciplinary and methodical character that gymnastics has assumed over time (Soares, 1998). Therefore, it combines the historical and cultural origins of gymnastics with the development of lifelong values through the practice of exercises (Soares, 1994; Vigarelo, 2003). In fact, in the past two decades some Brazilian authors (Perez-Gallardo & Souza, 1995; Paoliello *et al*., 2014) have proposed concepts and methodologies that emphasized GfA as a major enabler of human development (Maturana & Resepka, 1995; Ayoub, 2011; Paoliello *et al*., 2014). Thus, in a pedagogical perspective, GfA can be described as

An expression of body language that combines various interpretations of gymnastics (Natural, Standardized, Artistic, Rhythmic, Aerobics, etc) and blends them with other practices (Dance, Folklore, Games, Theatre, Mimicry, etc.), in a free and creative way, according to the characteristics of the social group, promoting social interaction among participants. (Perez-Gallardo & Souza, 1995, p. 292).

One of the most appealing features of GfA is to encourage a playful, educational and socially enriching practice that can contribute to health promotion and fitness. It is a practice that allows highlighting cultural and identity aspects of each group, region or country in a free and creative way. These characteristics fundamentally set GfA apart from other gymnastics disciplines under the aegis of FIG, making it so valuable to many practitioners (Russel, 2014).

World Gymnaestrada (WG), which literally means "gymnastics on the road" or "gymnastics road" (FIG, 2009), is held every four years and gathers thousands of gymnasts from several countries from all over the world, with performances that show great technical, aesthetics and material diversity. Since its creation in 1953, this festival has been one of the key contributors to the widespread practice of gymnastics, turning FIG into the first international federation to propose sports practice in competitive and non-competitive settings and to foster the lifelong values developed in each setting (Mechbach & Waneberg, 2011).

Overall, the FIG principles that govern the practice of GfA and, consequently, of the WG are, namely: fun, associated with the pleasure of the physical practice and with the playful aspects of gymnastics; fitness, related to the impact on the gymnast's physical health; fundamentals, represented by the basic gymnastics skills; friendship, as a means to promote social interaction and interchange of experiences in the context of gymnastics (FIG, 2010). By practicing GfA, people may experience these principles at any point in their lives, regardless of age or background (Mechbach & Waneberg, 2011; Hartmann, 2012).

Additionally, the WG has become an important opportunity for personal and professional development, a strong instrument that fosters voluntary cooperative work and dialogue among national federations that are FIG members (FIG, 2009).

A brief analysis (Table 1) reveals a growing trend in the number of participating countries and gymnasts:

Table 1

Participation in World Gymnaestrada (1953-2011)

Year	Number of Countries	Participants
1953	14	5000
1957	17	6000
1961	16	10000
1965	26	15600
1969	28	9600
1975	19	10500
1982	22	14200
1987	26	17300
1991	30	18400
1995	34	19200
1999	37	20800
2003	45	21600
2007	53	22000
2011	55	19000

* Adapted from FIG (2015).

Participation in World Gymnaestrada (1953-2011)

It can be noted that the number of participants has increased approximately by 400% between 1953 and 2011 editions of the festival (around six decades), and such growth was proportionally similar in the number of FIG member federations, which increased from 14 to 55. Among other aspects, this significant growth can be explained by FIG's greater incentive to the practice of GfA and by improvements in the organization of continental unions and national federations and committees. It seems that GfA is moving in the opposite direction of the neoliberal thinking, which overrates performance inside or outside the sports arena (Ehrenberg, 1991; Lash, 1999; Silva, 1999; Bracht, 2005; Ortega, 2008), as well as competition (Ayoub, 2011). Therefore, GfA seems to be better understood if we link it to the concept of Sports for All and, as a consequence, of democratization of sports and leisure (Toledo & Silva, 2013).

In alignment with this trend, the participation of PAGU member federations in the WG has significantly increased in the last editions of the festival. The first participation of PAGU member Federations was in the second edition of the WG in Zagreb (1957), when two countries attended (FIG, 2015). Ever since, the continent has been represented in all WG editions, reaching a total of 11 Member Federations in 2011 (Schwirtz, 2006), as depicted in the figure below:

Participation of PAGU Member Federations in the WG

Among PAGU member federations, Brazil and Canada had the highest attendance rate, having participated in 13 WG editions (Schwirtz, 2006). Gómez (2014) analyzed some aspects related to the development of GfA in the American continent, as Paoliello (2014) did for South America, showing a gradual increase in participation in the WG, especially after the 1999 edition, when it reached 11 federations (of the 23 affiliates of PAGU/FIG) in 2011. For Russel (2014, p.15), "Traditionally these forms of gymnastics were practiced mainly in Europe, but there is now a large following in Asia and increasingly in Africa and the Americas." International experiences have shown to be sources of learning (Hartmann, 2010). Gradually, groups have developed innovative and unique GfA proposals (training programs, projects, festivals), which are aligned with specific national and continental needs aiming at their development (with varying levels in each American gymnastics federations). The Asian Gymnaestrada, a festival promoted by the Asian Gymnastics Union (AGU), is a good example of this sort of expansion beyond the borders of Europe.

Nevertheless, despite this increase in the practice of GfA, the analysis of this

social phenomenon is still taking its first steps from a scientific standpoint, challenging gymnastics researchers to include non-competitive gymnastics modalities in their projects.

Notes on the 14th World Gymnaestrada

The 2011 edition of the WG was held in Lausanne, Switzerland, with the main theme "*Meet the magic!*". It involved five years of planning and around 4,000 volunteers (FIG, 2011). The official program included an opening ceremony, small and large group performances, an educational forum, conferences, national evenings, FIG Gala performances and the closing ceremony. In parallel to these events, there were group performances throughout the city, as well as shows and parties (FIG, 2011). In the 2011 edition, following WG's tradition (Mechbach & Waneberg, 2011), participants were accommodated in 70 schools in Lausanne and in other 14 cities in the region.

The festival was attended by 19,087 gymnasts from a wide range of age groups, representing 54 Member Federations (FIG, 2011) with the following regional distribution:

Number of National Federations that participated in the 14th WG by continent

It can be noted that the participation of European federations (27 countries, accounting for 50% of all) was numerically the same as the sum of all other countries from the other four continents (27). This dominance is explained by the long-standing tradition of gymnastics in Europe, especially in Central European and Nordic countries (Langlade & Langlade, 1986; Neumann, 1987; Soares, 1998; Hobsbawn & Ranger, 1983). It should also be stressed that no WG edition has ever been conducted outside Europe, which reinforces this hegemony.

Year	1957	1961	1965	1969	1975	1982	1987	1991	1995	1999	2003	2007	2011
Country/ Edition	2nd	3rd	4th	5 th	6 th	7 th	8 th	9 th	10 th	11 th	12 th	13 th	14 th
Argentina				x	x								x
Brazil	x	x	x	x	x	x	x	x	x	x	x	x	x
Canada	x	x	x	x	x	x	x	x	x	x	x	x	x
Chile					x						x	x	x
Cuba										x			
Ecuador											x		
United States									x	x	x	x	x
Guatemala												x	x
Honduras											x	x	x
Mexico										x	x	x	x
Trinidad and Tobago										x	x	x	x
Uruguay													x
Venezuela											x	x	x

Figure 1. Participation of PAGU Member Federations in the World Gymnaestrada. Adapted from FIG (2011).

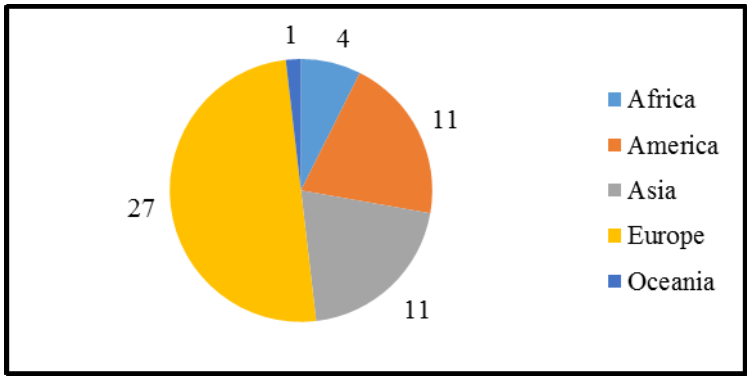

Figure 2. Number of National Federations that participated in the 14th WG by continent

METHODS

The increase in participation of PAGU member countries in the WG (Figure 1), the lack of systematic analyses of this topic and the importance of fostering the development of GfA in the American continent has motivated the authors to conduct this research study.

The survey was conducted during the 14th WG, between July 10-16, 2011, as part of a project that involved 12 Brazilian investigators from the Gymnastics Research Group from the Faculty of Physical Education of University of Campinas (UNICAMP) in Brazil (GPG, 2015).

It included an exploratory data collection (Thomas, Nelson & Silverman, 2011) from a face-to-face survey conducted with four subject during the 2011 WG, and other 4 surveys were sent by e-mail, since it was not possible to have a face-to-face interview during the event. Out of the 11 heads of delegation invited to take the survey, eight have replied (72.7%). The survey was taken by heads of delegation of the following countries: Argentina, Brazil, Canada, Chile, Mexico, Trinidad and Tobago, United States and Venezuela. The survey was translated into the three official languages of the countries that participated in the survey (English, Spanish and Portuguese), in order to minimize communication issues.

Six categories were previously defined for data analysis: 1 - "Composition of delegations from the Americas"; 2 – "Disciplines that are most influential in the routines performed at the WG"; 3 - "Types of participants"; 4 - "Group selection system to represent the national delegation"; 5 - "Investment and Funding strategies"; 6 - "Distribution of GfA Programs". These categories have been chosen because they allow the identification of several aspects, from group composition and their routines to how gymnastics federations operate and groups participate in international events such as the WG. It is important to highlight that this information complements the research scope that is already addressed by the GPG, in the sense that it provides input to public policies that promote GfA in Brazil. This paper presents the results of the first two categories, since they provide data that comprises general aspects of the participant groups. This information characterizes the population that was investigated and allows for reflections on the development of GfA in the American continent. Such information is also interesting to the federations that are currently responsible for GfA management, thus contributing to expand the participation of American federations in the WG.

Descriptive statistics were used to analyze the data, which is presented graphically (in tables and charts), with the corresponding reflections and proposals described in a written text.

This research study presents the following limitations: failing to collect data

from 100% of the population studied (11 national PAGU member federations that participated in the 2011 WG); lack of detailed information in the answers of some surveys; some heads of delegation took a long time to respond to the survey.

RESULTS & DISCUSSION

1 – COMPOSITION OF DELEGATIONS

The delegations of the eight PAGU National Federations that participated in this research totaled 1,875 people, with 1,263 gymnasts (9.82% of the total number of WG participants) and 612 people among team supporters[1], managers and team leaders (Figure 3).

WG participants from PAGU Member Federations that participated in the survey

The substantial participation of Brazil, Canada and also the United States reinforces the trend that had already been observed in previous editions, thus confirming that these federations have the highest participation rate in the WG and the longest tradition in GfA among PAGU member countries.

Brazil was the national federation with the largest delegation. Several factors played a role in such a high number of participants, namely:

- regular attendance in previous WG editions; local events that promote GfA, such as the International Forum of General Gymnastics (FIGG) that has been conducted since 2001 and that is considered the largest GfA-centric scientific event in the Americas and one of the largest in the world;

- a significant number of scientific papers and educational books (Paoliello, 2008; Santos & Santos, 1999; Ayoub, 2011; Pinto, 2013; Toledo & Silva, 2013), such as academic dissertations;

- a growing number of initiatives that encourage the practice of non-competitive gymnastics in various educational settings, like a national program sponsored by the Ministry of Sports called "*Segundo Tempo*" (Barbosa-Rinaldi & Teixeira, 2011). This public program offers sports and physical activities to children after or before their regular school hours[2].

Composition of PAGU Member Federations that participated in the survey in the 14th WG

Gymnasts account for approximately 70% of the total number of participants, while 10% are team leaders and 20% are team supporters (footnote 1). Unlike other international sports events, particularly high performance competitions, participants are from a wide range of age groups ranging from children to elderly gymnasts, as usually observed in gymnastics festivals (Neumann, 1987), providing supporters the opportunity of getting involved in the day-to-day routine of the delegation, as a delegate does.

The number of female participants is considerably higher than the number of male participants in all delegation roles (gymnasts, team leaders and supporters). This could be related to the high predominance of GfA participants that are former gymnasts of competitive disciplines, mainly Artistic Gymnastics and Rhythmic Gymnastics, which traditionally have more female practitioners.

Interestingly, these data indicate a new trend that has been observed for quite some time in the practice of gymnastics, which historically was a sport mainly practiced by men (Knijnik, 2010). The authors highlight that this sport is usually seen as intimidating by society (media, family members and friends), which hinders or prevents children from choosing disciplines that are not

[1] In this paper, the term "team supporters" is generically used to include both chaperones, who supervise underage gymnasts, and supporters, i.e., people with no other role apart from providing assistance as required by their manager (not a gymnast, coach, manager or chaperone).

[2] For more information: http://portal.esporte.gov.br/snee/segundotempo/ (website in Portuguese).

strictly related to the expected gender behavior. This is rather evident in Latin American countries, where there still seems to be prejudice against the participation of male gymnasts, as that commonly encountered towards dance.

The predominance of female participants walks hand-in-hand with what is observed in National Federations of long tradition in GfA, such as Finland (Laine, 2006) and Japan (Soares *et al*., 2015), suggesting that it is not a unique feature of American National Federations.

The presence of supporters, including managers of the participant organizations, chaperones and spouses who, in addition to attending the festival, also take the opportunity to enjoy the so-called "Sports Tourism" (Wichmann, 2015).

The number of teams in each delegation is directly related to the size of the delegation. For example, Trinidad and Tobago and Venezuela have just one team each, which indicates that GfA is not a predominant discipline in those countries. On the other hand, gymnastics in Mexico is clearly expanding, as shown by their growing number of participants since the 2003 WG edition.

We would like to highlight that there was a predominance of group performances in all delegations surveyed and absence of large group performances. Conversely, countries that do not have a long tradition in the practice of gymnastics tend to concentrate their participation in group performances. Interestingly, countries like Brazil and Canada – the largest delegations from the Americas – do not have any teams enrolled in large group performance, which may suggest another problem: the difficulties in bringing together smaller groups because of the large geographical distances between them, as well as the high costs involved to attend a WG conducted in Europe.

Another interesting point was raised in the survey by Argentina. Although many gymnastics team leaders are willing to develop GfA in Argentina and despite the existence of several teams, their participation in the WG is small and irregular. In 1969, a group of team leaders participated in the WG, but only in 2011 the country was represented again in the WG – this time with two teams (one university team and another dance team), with a delegation composed of 30 members. It can be noted that progress was slim in over four decades.

The composition of gymnastics teams varies greatly. The United States delegation was composed of teams from private clubs, municipal associations and sport organizations like Young Men's Christian Association (YMCA) and Sokol (Banjak, 1993), while in other National Federations, school and university teams are more predominant.

Another relevant aspect is that the Canadian delegation includes a medical team, which shows an important institutional concern with the health monitoring of their delegation members. No other PAGU Member Federation has informed to have an official Medical team as part of their delegation.

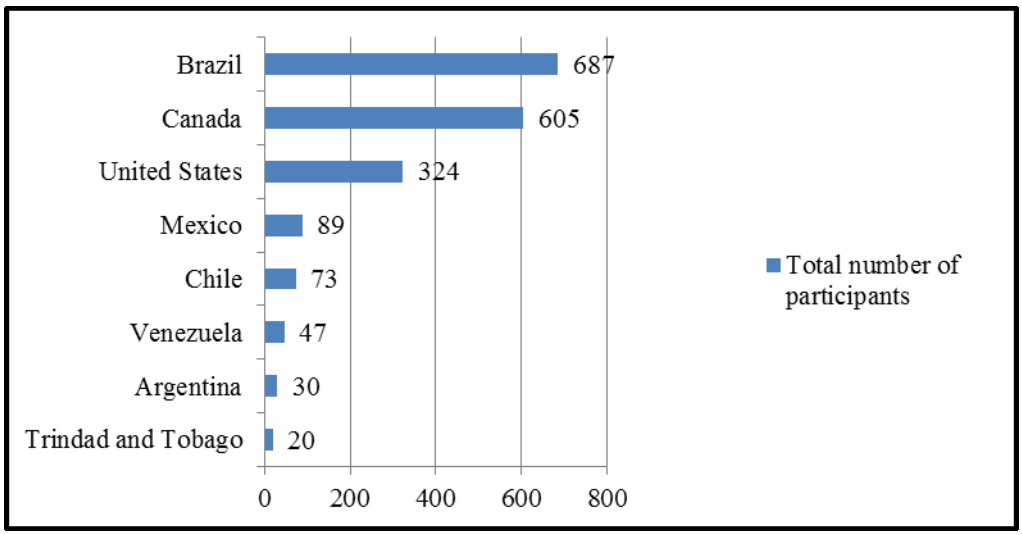

Figure 3. WG participants from PAGU Member Federations that participated in the survey

Table 2.
Composition of PAGU Member Federations that participated in the survey in the 14th WG

Category/ Country	Argentina	Brazil	Canada	Chile	Mexico	Trindad and Tobago	Venezuela	United States	Total
Groups number	2	23	22	1	3	1	1	*	53
Gymnasts number	28	499	374	54	52	16	39	201	1263
Male	7	72	11	10	15	5	0	*	120
Female	21	427	363	44	37	11	39	*	942
Coaches number	2	57	29	1	9	2	2	28	130
Male	0	*	1	0	3	1	2	*	7
Female	2	*	28	1	6	1	0	*	38
Team supporters number	0	102	27	13	28	2	6	95	273
Male	0	*	1	2	11	2	3	*	19
Female	0	*	26	11	17	0	3	*	57

Note: * No information.

Table 3.
Gymnastic disciplines and other practices on the performances

Disciplines/Country	Argentina	Brazil	Canada	Chile	Mexico	Trinidad and Tobago	Venezuela	United States	Total
Gymnastics for All	X	X			X	X	X	X	6
Artistic Gymnastics	X	X	X	X	X			X	6
Rhythmic Gymnastics	X	X	X					X	4
Acrobatic		X						X	2
Aerobic		X							1
Trampoline		X							1
Dance	X	X			X	X	X		5

2 – GYMNASTICS DISCIPLINES THAT ARE MOST INFLUENTIAL IN THE ROUTINES PERFORMED AT THE WG

As stated in the WG regulations (FIG, 2009), routines can be inspired by the core elements of several gymnastics disciplines, as well as by elements of Dance and many other sports and cultural forms of expression. In fact, the routines performed at the WG show great variety and "freedom" as permitted by the WG regulations. The table below shows these influences clearly:

Gymnastic disciplines and other practices on the performances

Table 3 clearly shows the wide range of disciplines that influence teams in each performance - Brazil is the country with more diversity. Overall, Artistic and Rhythmic Gymnastics and Dance are the most influential disciplines in our sample, probably because these are consolidated practices in most countries.

Chile had only one participating team and reported only one influential discipline (AG). Although it had the highest number of teams (22), Canada listed only two gymnastics disciplines as influential to their teams (AG and RG). The authors do not claim to say that these data represent the actual scenario of gymnastics diversity in these countries, since several factors affect the participation of groups in the WG, such as economic status, public and federal policies, interest in festivals like this, among others.

Among the gymnastics disciplines inquired in the survey, GfA and AG were mentioned by 75% of delegation leaders, followed by RG in 50% of the answers. Other disciplines like Acrobatic Gymnastics (AcroG), Aerobic (AeroG) and Trampoline were mentioned by 25%, 12.5% and 12.5% of respondents, respectively. The fact that GfA was mentioned as the main influential discipline shows consistency with the WG proposal. The influence of the basic AG movements, ranked as influential in the same percentage as GfA, shows that many teams still use core AG elements to develop their routines. It is worth noting that AG was the first discipline to be included in the Olympic Games (FIG, 2015) and it is the most popular gymnastics discipline in many American countries today. In the specific

case of Brazil, AG has grown significantly in the past two decades, and it is the most popular and media-covered gymnastics discipline.

Along the same lines, RG was the second gymnastics discipline to be added to the Olympic Games in 1984 with individual competition and in 1996 with group competition (Laffranchi, 2001). Similarly, these discipline regulations establish the use of gymnastics elements (jumps/leaps, rotations, balances) and hand-held apparatus, characteristics also found in GfA. RG uses low-cost apparatus that can be easily adapted and stored, differently from AG. Consequently, its practice is more affordable (Toledo, Tsukamoto & Gouveia, 2009). Some children's games of the American culture use similar apparatus, like balls, which are still often used in many countries, as well as "hula hoops" (Brazil) and ropes (Brazil, USA), making the RG practice easier in several settings.

On the other hand, disciplines like Acrobatic Gymnastics and Aerobic Gymnastics are not included as disciplines in the Olympic Games and do not have a long-standing tradition in most countries. The authors believe the low rate of answers that mention these disciplines (Table 3) is an interesting paradox, since they share significant artistic elements that cause higher visual impact, an important feature in events such as the WG. In addition to these factors, it is easy to start practicing these modalities, which can involve various numbers of participants and do not require specific apparatus, thus being more economical, which is a positive aspect for many developing countries.

Although it is an Olympic discipline since 2000, Trampoline was mentioned only by a few respondents of the questionnaire, which can be explained by the low tradition of this discipline in the majority of PAGU Member Federations surveyed. Trampoline is not a widespread practice in those countries, due to the high cost of apparatus, difficulties to find skilled professionals to coach gymnasts and, also because their practitioners usually see it as a leisure practice rather than a competitive discipline.

Last but not the least, Dance was extensively mentioned by the survey respondents, in 62.5% of the surveys. Although it is not a gymnastics discipline, it can greatly contribute to the choreographic and artistic elements of a routine (Santos & Santos, 2001; Sborquia & Neira 2008; Scarabelim & Toledo, 2015) and it is crucial to most gymnastics sports. It is worth saying that some groups also add local/regional cultural elements to their routines, such as typical local dances. It was also observed that some groups define themselves as dance groups and their participation in this festival is allowed by the WG regulations (FIG, 2009).

Finally, we know that other disciplines are also listed in the WG program, such as *TeamGym*, Aesthetic Group Gymnastics, Male RG, but since those disciplines were not included in the survey, they were not analyzed.

We can also identify that PAGU member federations use less large-sized apparatus (parallel bars, flying rings, for example) in the performances. This could be related to the fact that PAGU member federations lack the gymnastics tradition and the availability of large-sized apparatus when compared to countries in Central Europe (Germany, Switzerland, among others).

CONCLUSIONS

It was observed that the attendance of PAGU member federations in the WG has increased over the years. This increase was accompanied by a growth in the number of National Federations and participants in those delegations.

Brazil and Canada were the leaders in terms of number of participants in the 14th edition of the WG, which may be directly related to their regular and traditional participation in the WG, as well as how the practice of GfA has spread in these countries (as indicated by research studies, scientific and performance events,

institutional initiatives, and so on). The United States and Mexico have also increased their participation in the WG over the years.

Considering the gender, participants were predominantly female (74.5%), possibly because of historical and cultural aspects related to the gymnastics practice that region. Such predominance is also observed in the most of European National Federations and in the WG itself, as indicated by Laine (2006), for example, in Nordic countries, which reinforces the idea of a global trend.

Disciplines like AG and RG, as well as Dance, were among the top aesthetic and movement references used in the creation of performances.

The authors believe that the number of national federations as well as the number of gymnasts is not significant, especially if we consider the potential number of participants in this continent, given the number of federations enrolled in FIG and the population density of the region. The low participation rate seems to be related to insufficient financial incentives to non-competitive gymnastics, lack of GfA development policies driven by national federations, by the public and/or private sector (Paoliello *et al*, 2014).

Last, but not the least, the participation of PAGU has contributed to the increase of diversity of cultures and experiences in the American continent, in the sense advocated by Wichmann (2013:64). We believe that the opportunities for cultural sharing and interchange through a well-structured dialogue and collective initiatives (of groups and funding organizations that foster the development of gymnastics) can be beneficial to bring those groups together and it is crucial for the development of GfA in our continent.

Despite the limitations of this research study, the data presented can help GfA managers in the Americas to expand the participation of groups in the WG and, above all, to streamline access and support the widespread practice of GfA in their countries. National federations should definitely ask for team leaders and managers for their input in order to better understand the barriers to the growth and maintenance of GfA.

We hope that this research study can motivate and inspire other investigators to further study GfA, as well as the contribution of non-competitive sports to contemporary society.

REFERENCES

Ayoub, E. (2011). *Ginástica Geral e Educação Física Escolar*. (3rd. ed). Campinas: Editora Unicamp.

Banjak, S. J. (1993). *Sokol – Gymnastic Manual – New & Revised Version*. USA: The Slovak Gymnastic Union Sokol.

Barbosa-Rinaldi, I.P., & Teixeira, R. T. S. (2011). Ginástica Geral. In: Oliveira, A. A. B. *et al.* (Org.). *Ensinando e aprendendo esportes no programa segundo* tempo (v. 2), Maringá, Eduem, pp. 17-50.

Bracht, V. Sociologia crítica do esporte: uma introdução. 3ª Ed. Ijuí, Rio Grande do Sul: Editora Unijuí, 2005.

Ehrenberg, Alain. Le culte de la performance**.** Paris: Hachette Littératures, 1991.

Fédération Internationale de Gymnastique, FIG (2009). *World Gymnaestrada Regulation Manual*. Retrieved April 27, 2015, from http://www.fig-gymnastics.com/site/rules/disciplines/gfa.

Fédération Internationale de Gymnastique, FIG (2010). *Foundations of Gymnastic Course Manual*. [Brochure]. FIG: Author.

Fédération Internationale de Gymnastique, FIG. (2011). *WG-2011 Guide*. [Brochure]. FIG: Author.

Fédération Internationale de Gymnastique, *FIG*. (2015) Retrieved April 27, 2015, from http://www.fig-gymnastics.com/site/page/view?id=384.

Fiorin-Fuglsang, C.M. & Paoliello, E. (2008). Possíveis relações entre a Ginástica Geral e o lazer. In: Paoliello, E. (Org.). *Ginástica Geral: experiências e reflexões.* São Paulo: Phorte.

Gómez, C. (2014). La Gimnasia para Todos en el continente americano. *Anais do VII Fórum Internacional de Ginástica Geral*. Campinas, SP: SESC Campinas e FEF/UNICAMP, pp.65-69.

Grupo de Pesquisa em Ginástica, GPG. (n.d.) Retrieved April 27, 2015, from http://www.fef.unicamp.br/fef/posgraduacao/gruposdepesquisa/gpg/apresentacao.

Hartmann, H. (2010). Policies and strategies for developing General Gymnastics. *Anais do V Fórum Internacional de Ginástica Geral*. Campinas, SP: SESC Campinas e FEF/UNICAMP, pp. 27-32.

Hartmann, H. (2012). Lifelong learning and education in General Gymnastics. *Anais do VI Fórum Internacional de Ginástica Geral*. Campinas, SP: SESC Campinas e FEF/UNICAMP, pp. 68-74.

Hobsbawn, E., & Ranger, T. (1983). *The inventation of Tradition***.** Cambridge: University Press, Cambridge.

Knijik, J.D. (2010). Gênero, um debate que não quer calar. In: Knijnik, J.D. (Org). *Gênero e Esporte: masculinidades e feminilidades.* Rio de Janeiro, RJ: Apicuri.

Lasch, Christopher. La cultura del narcisismo. Bercelona: Andrés Bello, 1999.

Laffranchi, B. (2001). *Treinamento desportivo aplicado à ginástica rítmica*. Londrina,PR: UNOPAR.

Laine, L. (2006). The Finnish Play Movement: Nationalism, Citizenship and Women's Resistance. *Junctures,* v. 7, pp. 25-40, 206.

Langlade, A., & Langlade, N. R. (1986). *Teoría general de la gimnasia*. (2 Ed). Buenos Aires: Editorial Stadium.

Maturana, H., & Resepka, S. N. de. (1995). *Formacion Humana y capacitacion*. Santiago: Dolmen.

Mechbach, J., & Waneberg, P.L. (2011). The World Gymnaestrada – a Non-competitive event. The concept "Gymnastics for All" from the perspective of Ling Gymnastics. *Scandinavian Sport Studies Forum,* (v. 2), pp. 99-118.

Neumann, H. (1987). *Deutsche Turnfeste* – Spiegelbild der deutschen turnbewegung. Wiesbaden: Limpert.

Ortega, F. O corpo incerto – corporeidade, tecnologias médicas e cultura contemporânea. Rio de Janeiro: Garamond, 2008.

Paoliello, E. (Org.). (2008). *Ginástica geral: experiências e reflexões*. São Paulo: Phorte.

Paoliello, E. (2014). A Ginástica Geral na América do Sul. *Anais do VII Fórum Internacional de Ginástica Geral*. Campinas, SP: SESC Campinas e FEF/UNICAMP, pp. 51-55

Paoliello, E., Toledo, E., Ayoub, E., Bortoleto, M.A.C. & Graner, L.S.P. (2014). *Grupo Ginástico Unicamp: 25 anos.* Campinas, SP: Editora da Unicamp.

Perez-Gallardo, J. S., & Souza, E. P. M. (1995). La experiencia del Grupo Ginástico Unicamp en Dinamarca. In: *Anais do Congresso Latino*. Foz do Iguaçu: pp. 292-298.

Pinto, L. G. S. (2013). *O processo de ensino-aprendizagem da ginástica na "minha escola"***.** Dissertação de mestrado em Educação. Universidade Estadual de Campinas, Campinas, Brasil.

Russel, K. (2014). Gymnastics challenges – a view form 50 years of coaching and teaching. In: Schiavon, L.M. *et al.* (Orgs.). *High Performance Gymnastics.* Hildesheim: Arete-Verlag.

Santos, J.C.E., & Santos, N.G.M. (1999). *História da Ginástica Geral no Brasil.* Rio de Janeiro: Fontoura.

Santos, J.C.E., & Santos, N.G.M. (2001). *Ginástica Geral: elaboração de coreografias e organização de festivais.* Jundiaí: Fontoura.

Scarabelim, M.L., & Toledo, E. (2015). *Proposta de criação de uma ficha analítica de composições coreográficas na Ginástica para Todos*: primeiros ensaios. Conexões (v. 13, special edition), pp. 181-196.

Sborquia, S. P., & Neira, M.G. (2008). As Danças Folclóricas e Populares no Currículo da Educação Física: possibilidades e desafios. *Motrivivência*, (31), 79-98.

Schwirtz, K. (2006). *History of general gymnastics: development and importance of general gymnastics within the Fédération*

Internationale de Gymnastique. Moutier: Fédération Internationale de Gymnastique.

Silva, A. M. Elementos para compreender a modernidade do corpo numa sociedade racional. In: SOARES, C. L. (org). Corpo e Educação. Campinas: Centro de Estudos Educação e Sociedade - CEDES, 1999. Coleção CADERNOS CEDES, no. 48.

Soares, C. L. (1994). *Educação Física: Raízes Europeias e Brasil*. (2nd. ed.). Campinas: Autores Associados.

Soares, C. L**.** (1998). *Imagens da educação no corpo**:** estudo a partir da ginástica francesa no século XIX***.*** Campinas: Autores Associados.

Soares, D. B., Bortoleto, M. A. C., Ayoub, E., Paoliello, E., & Carbinatto, M. V. (2015). Festival Nacional de Ginástica do Japão: Panorama geral e tipologia das composições coreográficas. Conexões (v. 13, special edition), pp. 127-143.

Thomas, J. R., Nelson, J. K., & Silverman, S. J. (2011). *Research Methods in Physical Activity*. (6th. ed., ebook). United States: Human Kinetics.

Toledo, E. (2007). Ginástica de grande área: algumas abordagens e reflexões de sua manifestação no Brasil. *Anais do IV Fórum Internacional de Ginástica Geral*. Campinas, SP: SESC Campinas e FEF/UNICAMP, pp.38-43.

Toledo, E., Tsukamoto, M. H. C., & Gouveia, C.H. (2009). Fundamentos da Ginástica Geral. In: Nunomura, M., & Tsukamoto, M. H. C. (orgs). *Fundamentos das Ginásticas*. Jundiaí-SP: Fontoura.

Toledo, E., & Silva, P. C. C. (Org.). (2013). *Democratizando o ensino da ginástica: estudos e exemplos de sua implantação em diferentes contextos sociais.* Várzea Grande-SP: Fontoura.

Vigarello, G. (2003). A invenção da ginástica no século XIX: movimentos novos, corpos novos. *Revista Brasileira de Ciência e Esporte*. Campinas, (v. 25, n. 1), pp. 9-20.

Wichmann, A. (2013). The historical roots of the Gymnaestrada: National gymnastics festivals in nineteenth-century Europe. In: Merkel, U (Org). *Power, politics and Internation Events*: Socio-cultural analyses of festivals and spectacles. United States: Routledge.

Wichmann, A. (2015). Diversity versus Unity: A Comparative Analysis of the Complex Roots of the World Gymnaestrada. *The International Journal of the History of Sport*, (32, 4).

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TECHNICAL CONTENT OF ELITE RHYTHMIC GYMNASTICS

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Original article

Abstract

The primary aim of this study was to analyse all technical elements used in the Rhythmic Gymnastics Kiev World Championship 2013, and identify the Structural characteristics of the technical content of elite Rhythmic Gymnastics individual routines. The data has been collected from the difficulty forms concerning 288 individual routines. To allow the comparison between gymnasts with different levels the individual routines were clustered into 3 subgroups according to their final ranking competition. Body difficulty elements were organized, according to the composition requirements stated in the RG Code of Points (FIG, 2012). Non-parametric tests - Kruskal-Wallis, Mann-Whitney and Friedman test were applied to determine whether there were significant differences between groups. As main results we can point out that in general the rhythmic gymnasts used similar body difficulties with limited variety. The highest valued elements are Dynamic Elements with Rotation and throw (DER) and rotations and these represent 50% of the total value of the routine. Concerning the dance steps and mastery, no differences were found between the routines of gymnasts place in the three parts of the ranking. The routines had differences in the composition pattern between the gymnasts according to the final ranking of the gymnasts in following items: (i) on the number of rotations of flat foot or other part of the body, Fouetté rotations and Mixed Difficulties; (ii) on the value of jumps, rotations, DER and Mixed Difficulties.

Keywords**:** *body difficulty, individual routines, evaluation, rhythmic gymnastics.*

INTRODUCTION

The main reason for the success in RG competition is the capacity to perform the exercise, with high level body elements and apparatus technic, with perfect execution, in harmony with the character and rhythm of the music, respecting the principle of originality and diversity. This is a guarantee of an exciting high performance sport to watch.

The rules which guide the routines composition can also have influence in the gymnasts' performance (Massidda, 2012).

The limited variety on the choice in difficulty elements makes the routine composition boring and puts in risk its artistic value (Ávila, 2012a).

The skilful interaction between the gymnast and the apparatus and the increase difficulty elements in the routines composition are the development in RG (Lebre, 2011).

The analysis of these factors can, according to Ávila, (2012b), influence the developmental programs for the practice and the experimental designs used in the scientific research in RG. The knowledge can also contribute to preview and characterize the effort requirements allowing improvements in the gymnasts' preparation to the competition readiness (Ferreirinha, 2009).

Ferreirinha (2009) refers that to determine the training models it is important to know the characteristics competition routines for high level gymnasts including the details concerning the specificity of their components.

Is, than, fundamental to analyse the development tendencies for the sport in general and to identify specificities of each component as we propose to do with the structural characteristics of the difficulty elements including the diversity and variety in the routines.

The routines composition is not stable concerning their content because they have to be adapted to changes done in the Code of Points (CoP) every Olympic cycle.

An individual RG routine is composed by a series of body and apparatus elements linked in a specific way which we call difficulty elements (D). On the present Olympic cycle, the content of and individual RG routine should respect the specific requirements that are common to the routines of all 4 apparatus: jumps/leaps, balances, rotations, apparatus mastery, dance steps and dynamic elements with rotation and throw (DER) (FIG, 2012).

The value of each difficulty element is from 0.10 points to 1.50 points or more, which may be absolutely determinant in the final score obtained in competition. The inclusion of complex abilities in the routines is essential to have a high score (Massida, 2012).

The CoP holds a great variety of difficulty elements to be used in the routines. One important characteristic of the RG is to allow the gymnast to link it in her own way, with a stylish presentation, clever configuration, and prefect presentation (Wang, 2013). An eventual lack of variety in the body difficulty included in the routines can cause judges and audience dissatisfaction from the point of originality and variety. RG is a visually appealing sport, thus, it is very important to keep the high interest of the public (Agopyan, 2014).

The studies published concerning the content of the RG routines (Caburrasi, 2003; Bobo, 2010; Ávila, 2011; Ávila, 2012; Trifunov, 2013; Agopyan, 2014), include the analysis of the number and the level of difficulty elements but they have no information about contribution of each type of element for the final D score. Also in consequence of the constant and quickly evolution of this sport, a permanent upgrade of these kind of studies are needed (Caburrasi, 2003; Cuk, Fink & Leskošek, 2012; Massidda, 2012; Hökelmann et al., 2012; Bucar, 2013; Pelin, 2013).

Within this context, the main goal of the present study is to identify the difficulty elements included in the routines that contribute the most to the success in competition and to analyse the diversity of the body movements included in the difficulty elements.

The present study can have an important contribution for the coaches mainly to: supporting the coaching process, defining performance profiles for individual gymnasts, ranking performances, creating data bases in order to identify the most influencing performance indicators and the tendencies in the development of RG (Liviotti, 2012).

METHODS

288 difficulty forms concerning individual routines were analysed. The routines were performed by gymnasts from 45 different countries competing at Rhythmic Gymnastics World Championship in Kiev, Ukraine in 2013. This study was done with the permission of the International Gymnastics Federation (FIG).

The official Difficulty forms, submitted prior to the competition, included the routine compositions recorded using the RG CoP symbols. All difficulty elements reported in the difficulty forms were analysed. The analyse was done considering the all sample, and the sample clustered into 3 subgroups according to gymnasts final ranking as follows: the first part of the ranking - the top 24 gymnasts, the second part of the ranking - 24 middle gymnasts and third part of the ranking – the 24 lower placed gymnasts on the ranking, to allow the comparison the technical elements within gymnasts of different levels.

The analysis was conducted by two international RG judges. The intraclass correlation coefficient (ICC) in test-retest method (intra-examiner) was 0.99. The ICC between the observers (inter-examiner) was 0.98.

The data were analyzed using the Statistical Package for Social Sciences – version 20.0 (SPSS 20.0, Chicago, USA) and Microsoft Office Excel 2007. The level of significance was set at $\alpha = 0.05$ (confidence interval of 95%). Descriptive statistics were calculated using the mean values as a measure of central tendency, standard deviation (SD) as a measure of dispersion, and minimum and maximum as measures of data range. After checking the abnormalities in the data distribution ($p<0.05$) using the Kolmogorov-Smirnov normality test, we resorted to non-parametric test (Kruskal-Wallis, Mann-Whitney and Friedman test) to determine whether there were significant differences between the three subgroups in the Rhythmic Gymnastics World Championship ranking.

A multiple regression was used to analyze the influence of each difficulty element in the gymnasts' final difficulty score.

RESULTS

The difficulty elements reported in the individual routines were grouped by technical categories: balances, jumps, rotations, masteries, dance steps, and DER, mixed difficulties (MixDif) and criteria associated to difficulty (waves and pre-acrobatics). The results for each category are presented both quantitatively (number of occurrences) and qualitatively (technical value and type) in Figure 1. From Figure 1 we can highlight the number of the mastery (4.0±2.80) and the value of the rotations with 29% of the total value of the routine (2.7±0.83 points). When we observe the three difficulty groups that are based on the body movements (jumps, balances and rotations) we can see that the rotations have the higher number (3.3±0.61) and the balances the lower number (2.4±1.00). Concerning the rotations, the gymnasts included preferably those with 0.30 points values in their routines. Between them it is possible to highlight the "pivot attitude" (0.52±0.50), the "pivot free leg in ring in back with help" (0.42±0.50) and the "rotation penché" (0.76±0.43). The most used jumps were those with 0.5 points value, mainly the "jeté with turn" (0.82±0.80) and the "jeté with a turn with back bend" (0.45±0.53); The balances with base value 0.5 points were the most performed by the gymnasts, mainly the balance "side scale with split, without help" (0.44±0.49) and balance "back scale leg high up" (0.40±0.49). The most used MixDif were the link of the balance "front scale with back split" and "ring without help" (0.15±0.52). For DER, the most used criteria to raise the value were: "change of level", "change of body rotation axis", "throw/catch outside of visual

control" and "throw/catch without the help of the hands".

Analysing the sample according to final ranking of the gymnasts, significant differences were found on the number of balances, MixDif, rotations on the flat foot or other part of the body, and "fouetté" rotations (Table 1). No other significant differences in the number of technical difficulties were found according to the final ranking of the gymnasts (Figure 2).

The number of balances was significantly higher in the gymnasts of the 3rd part of the ranking and the MixDif significantly higher in the gymnast of the 1st part of the ranking. The number of rotations on the flat foot or other part of the body is higher in the 1st part of the ranking and decreases significantly in the 2nd and 3rd parts. The number of "fouetté" rotations is significantly higher in the gymnast of the 2nd part of the ranking (Table 1).

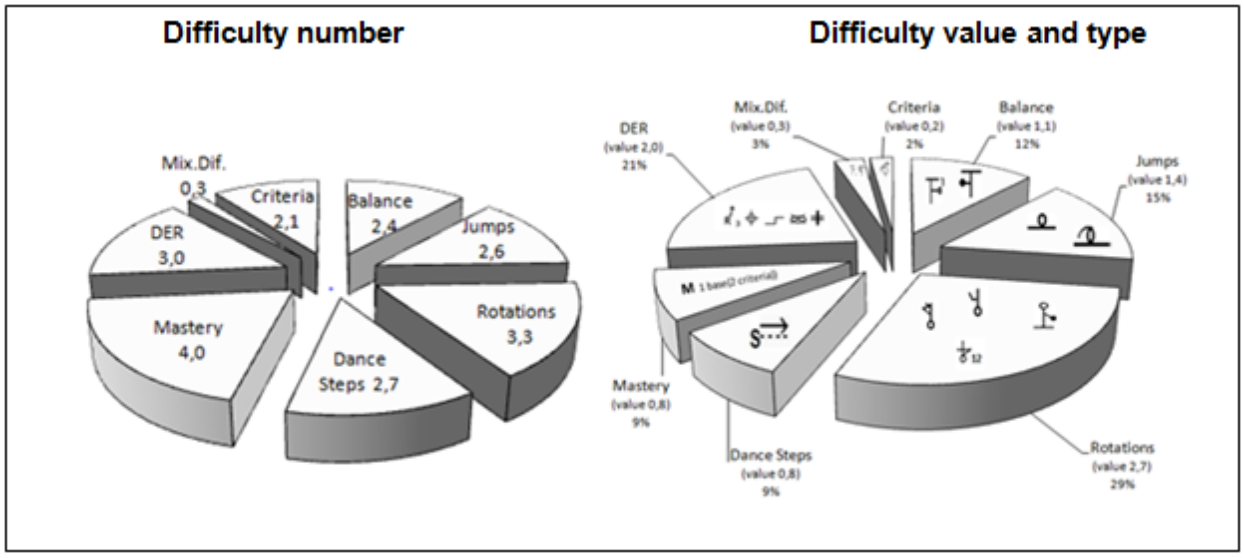

Figure1. Difficulty elements presented in the Rhythmic Gymnastics individual routines in the 2013 World Championships clustered according to number, value and type.

Table 1

Number of balances, MixDif and Rotations in the Rhythmic Gymnastics individual routines clustered according to gymnasts' final ranking in the 2013 World Championships.

	1st part of the ranking (n=96)		2nd part of the ranking (n=96)		3rd part of the ranking (n=96)		Kruskal-wallis test	**Pairwise Comparisons**
Difficulty number	Mean+sd	Min-Max	Mean+sd	Min-Max	Mean+sd	Min-Max	P=	
Balance	2.16±1.08	0-4	2.48±0.91	1-4	2.66±0.93	0-4	0.002*	rk1-rk3 0.001
Mix. Dif.	0.75±0.97	0-2	0.56±0.90	0-2	0.38±0.78	0-2	0.016*	rk3-rk1 0.012
Rot.flat foot..	1.03±0.49	0-2	1.00±0.50	0-2	0.68±0.53	0-2	0.000*	rk3-rk1 0.000 rk3-rk2 0.000
Rot. "Fouette"	0.28±0.49	0-2	0.65±0.69	0-2	0.58±0.57	0-2	0.000*	rk1-rk3 0.001 rk1-rk2 0.000

*p<0,05

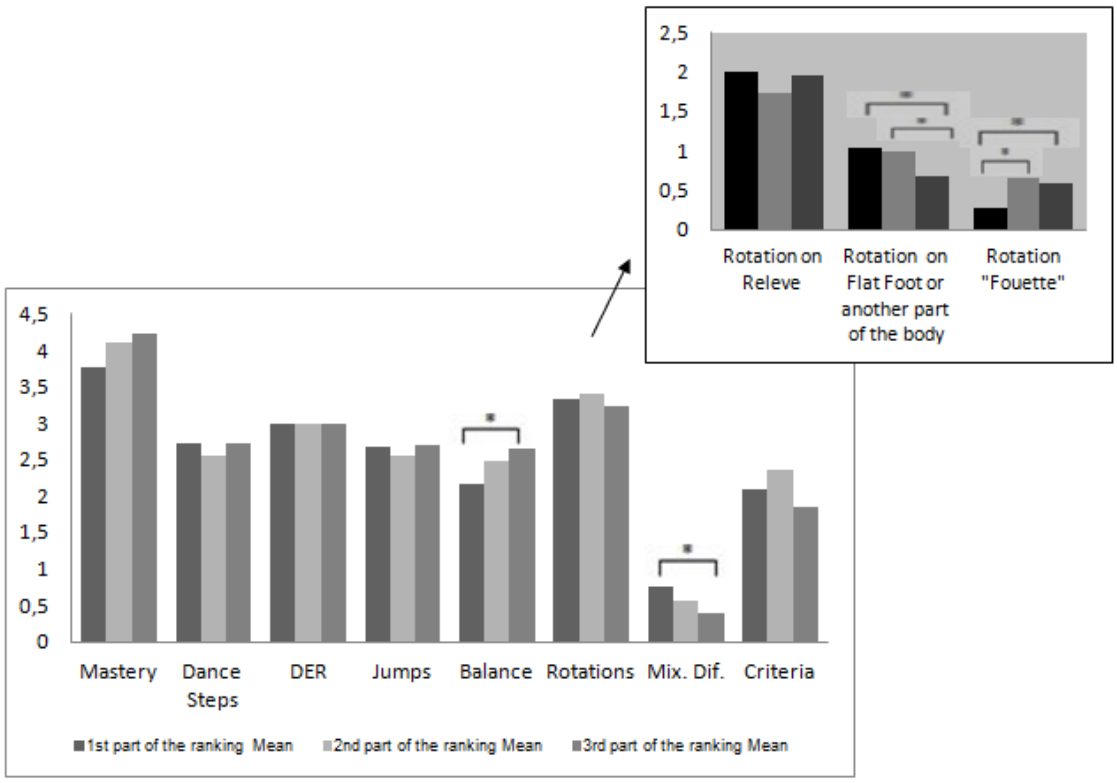

Figure 2. Average number of difficulty elements presented in the Rhythmic Gymnastics individual routines clustered according to the 2013 World Championships final ranking.(*p<0.05).

Table 2

Technical value of DER, Jumps, MixDif and Rotations presented in the Rhythmic Gymnastics individual routines clustered according to the 2013 World Championships final ranking.

	1st part of the ranking (n=96)		2nd part of the ranking (n=96)		3rd part of the ranking (n=96)		Kruskal-wallis test	Pairwise Comparisons
Difficulty value	Mean+sd	Min-Max	Mean+sd	Min-Max	Mean+sd	Min-Max	P=	
DER	2.05±0.30	1.3-2.7	2.01±0.27	1.4-2.8	1.83±0.35	1.0-2.8	0.000*	rk3-rk2 0.001 rk3-rk1 0.000
Jumps	1.54±0.44	0.7-2.8	1.4±0.45	0.7-2.7	1.25±0.33	0.5-2.3	0.000*	rk3-rk1 0.000
Mix. Dif.	0.37±0.49	0.0-1.7	0.25±0.41	0.0-1.0	0.16±0.34	0.0-1.0	0.005*	rk3-rk1 0.003
Rotations	3.00±0.88	1.2-4.7	2.89±0.66	1.2-4.3	2.22±0.71	0.7-3.9	0.000*	rk3-rk2 0.000 rk3-rk1 0.000
Rot. Releve	1.85±0.97	0.0-4.0	1.56±0.88	0.0-3.3	1.37±0.67	0.0-3.1	0.001*	rk3-rk1 0.001
Rot.flat foot..	0.89±0.44	0.0-2.3	0.80±0.37	0.0-1.7	0.49±0.40	0.0-1.4	0.000*	rk3-rk2 0.000 rk3-rk1 0.000
Rot.Fouette	0.25±0.47	0.0-2.0	0.53±0.59	0.0-2.0	0.36±0.38	0.0-1.2	0.001*	rk1-rk2 0.001

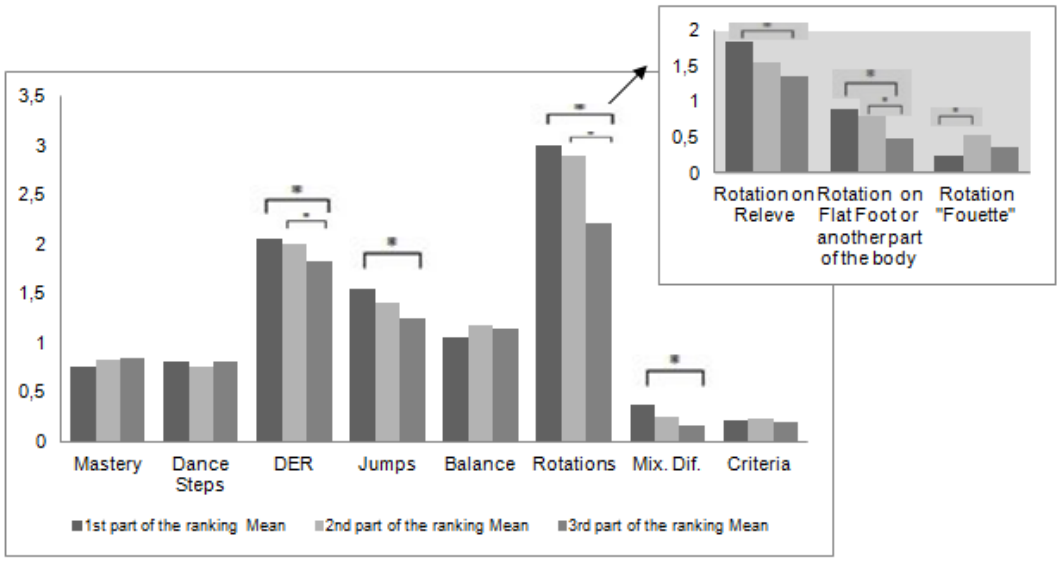

Figure 3. Technical value of the difficulty elements presented in the Rhythmic Gymnastics individual routines clustered according to the 2013 World Championships final ranking. (*p<0.05)

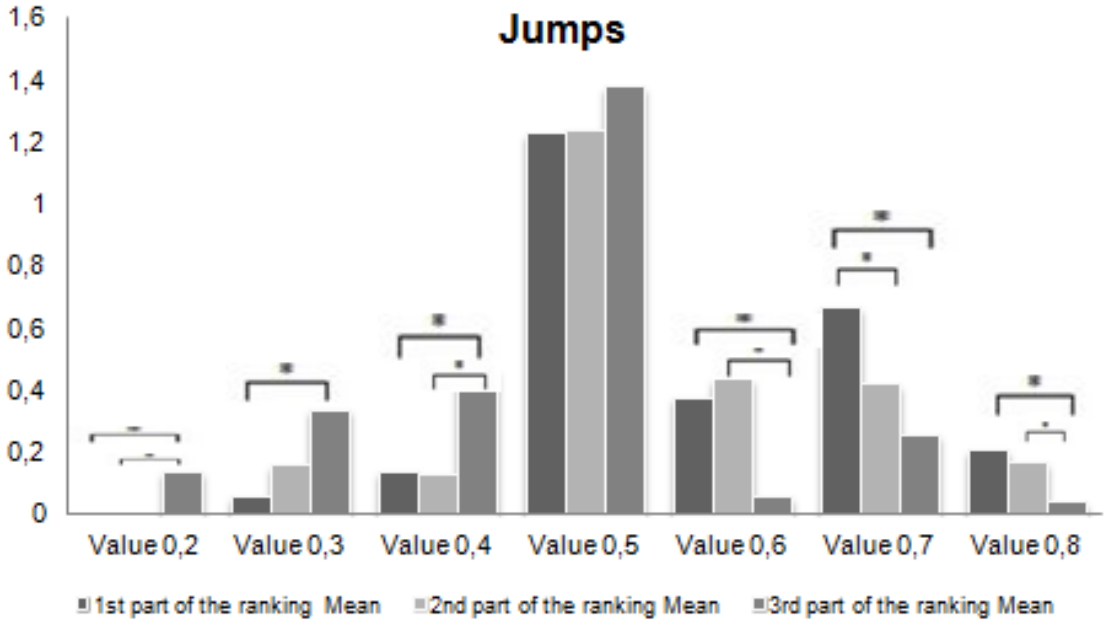

Figure 4. Number of Jump difficulties (different values) presented in the Rhythmic Gymnastics individual routines clustered according to the gymnasts' final ranking in the 2013 World Championships (Kruskal-wallis test * p<0,05).

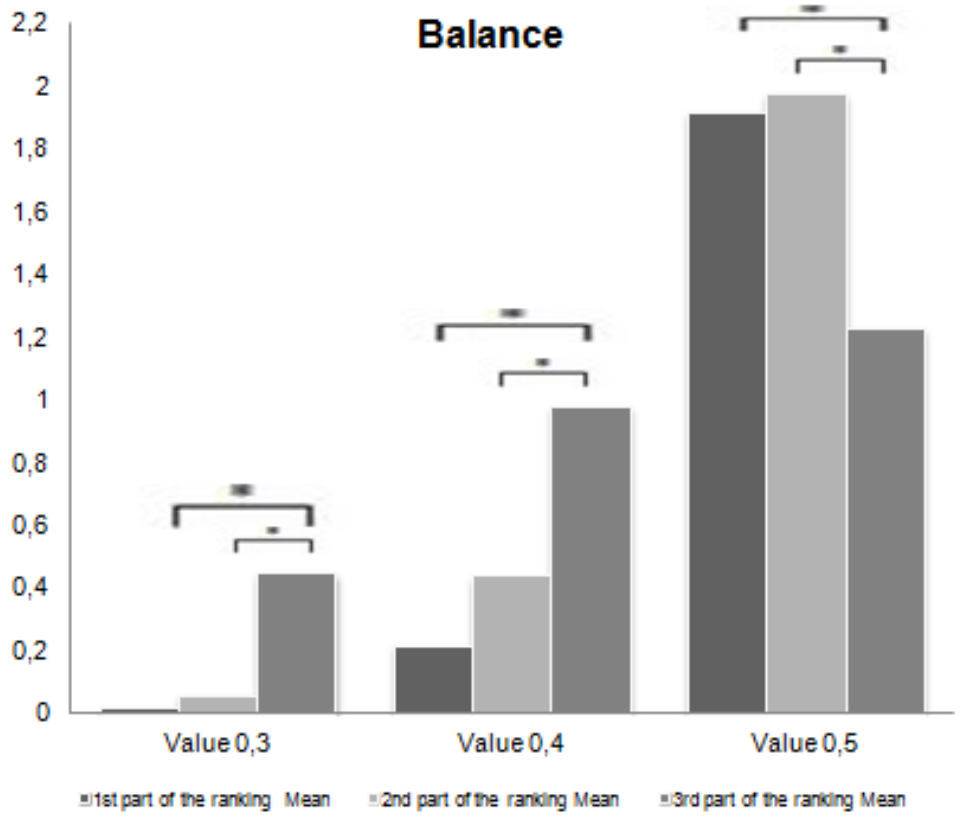

Figure 5. Number of balance difficulties (different values) presented in the Rhythmic Gymnastics individual routines clustered according to the gymnasts' final ranking in the 2013 World Championships (Kruskal-wallis test * p<0,05).

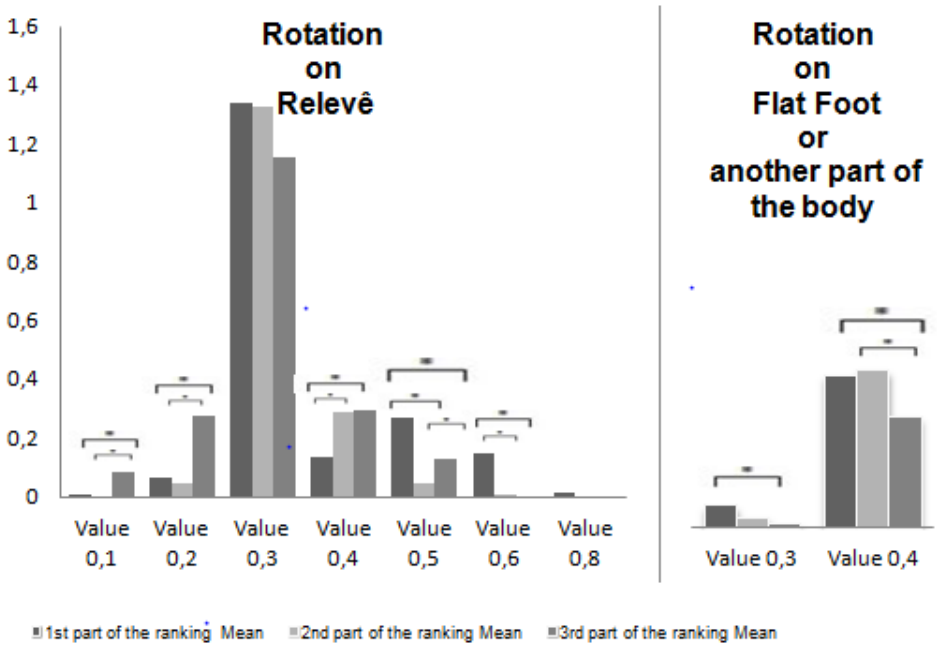

Figure 6. Number of Rotations difficulties (different values) presented in the Rhythmic Gymnastics individual routines clustered according to the gymnasts' final ranking in the 2013 World Championships. (Kruskal-wallis test * p<0,05).

The value of the DER, rotations, jumps and MixDif is higher in the gymnast placed in the 1 st part of the ranking and decreases significantly in the 2nd and 3rd parts. For mastery, dance steps, balances and criteria associated to difficulty (waves and pre-acrobatics) there were no statistically significant differences regarding the technical value, and the gymnasts' final ranking (Table 2). Concerning the value of the rotations we can highlight that the fouetté rotations had a significant higher value in the gymnasts placed on the 2nd part of the ranking when compared to the gymnast in the 1 st part. The rotations of flat foot or another part of the body registered a higher value in the 1st part of the ranking (Figure 3).

Jumps

Analysing the value of the jumps included in the routines according to the final ranking of the gymnasts, we found significant differences for all jumps except the jumps with 0.5 points value. The routines of the gymnasts placed in 1st part of the ranking had a higher number of jumps 0.7 and 0.8 points value. The jumps of value 0.2, 0.3 and 0.4 points were the preferred of gymnasts placed in the 3rd part of the ranking. The jumps with 0.6 points value are performed preferably by the gymnasts on the 2nd part of the ranking. The jumps with 0.5 points value jumps were the preferred of all gymnasts independently of their place on the final ranking. There were not significant differences for the gymnasts ranking regarding the jumps of 0.5 value jumps (Figure 4).

Balances

We found significant differences in the number of balance difficulties when we compare the routines performed by the gymnasts of different parts of the final ranking. The gymnasts ranked in the 3rd part of the ranking had a higher number of balances with 0.30 and 0.40 points value in their routines. On the other hand the gymnasts ranked on the 1st and 2nd parts preferred to include in their routines balances of 0.50 points (Figure 5).

Rotations

There were significant differences in the rotations included in the routines in all parts of the final ranking excepted for the rotation of 0.5 points value. The routines of the gymnasts ranked in the 3rd part had a higher number of rotations on "relevé" of 0.1, 0.2 and 0.4 points value. On opposite, the gymnasts placed in the 1st and 2nd parts preferred to include 0.5 and 0.6 points value rotations on "relevé" in their routines. The rotations on relevé with 0.3 points value were the most performed by all gymnasts independently of their position in the final ranking (Figure 6). Concerning the rotations on flat foot or another part of the body, it was clear that the gymnasts placed in the 1st and 2nd parts of the ranking preferred to include this type of rotation with 0.4 points value in their routines.

DISCUSSION

This study provides a quantitative and qualitative analysis of the difficulty elements used in the individual routines of the 2013 RG World Championships.

The 288 individual routines studied were clustered into three subgroups according to the gymnasts' final ranking in the World Championships. We discussed the results (number, value and type) in 3 dimensions: (1) global analysis of the composition of the routines; (2) analysis by group of difficulty elements; (3) ranking of the gymnasts.

In a global point of view the routines hold an average value of 9.30 points, very close to the maximum possible score of 10 points. Despite the World Championships being one of the most important competition in the calendar, this result may lead to a false analysis, as it could mean such a high a plateau of international excellence which in reality only occurs amongst gymnasts at the top of the ranking. Ávila, (2011) studied the difference between the departure score (presented by

the coach in the difficulty form) and the final score obtained by the gymnast and concluded that the majority of the gymnasts reach very significant differences, of 2 or more points between these two scores.

We also highlight the fact that the rotations and the DER, together represented 50% of the total value of the composition. This result showed an important change in the global content of the routines in this Olympic Cycle. Studies such as Caburrasi (2003) and Ávila (2011) showed that in the previous Olympic cycles the highest contribution in the routines value came from the Jumps. The increase in the rotations and DER values happens because in the present Olympic cycle it is possible to add some criteria to these difficulties that allow the gymnast to increase its value and degree of complexity (FIG, 2012). These results can be analysed in two different perspectives. On the one hand, it represents an upgrade of the execution quality, but on the other hand, it means that an extreme importance is given to 2 types of difficulty elements leading to an under estimation of the other groups. We also remarked the lack of variety and diversity in the elements chosen that has been repeatedly mentioned in previous studies concerning individual routines (Bobo, 2003; Agopya, 2014) and group routines (Ávila, 2011b; Ávila 2012; Ávila, 2012b). Therefore it is possible to conclude that the RG routines present a consistent pattern in the usage of the difficulty elements.

The type of difficulty elements used in the routines is similar, with some difficulty elements being repeated several times in the routines. This means that the routines' composition is not defined by being unique, with diversity and creativity, characteristics that are necessary for the enrichment of the routines composition (Balcells, 2009; Leandro, 2015) and reflect the spectacular of the choreography (Pelin, 2013).

The analysis according to the type of difficulty showed us similar results as Agopyan (2014) for routines performed on the last Olympic cycle: the rotation difficulties (mainly the "relevé" rotations) were the preferred of the gymnasts and the balance difficulties the less used. The rotation difficulties are very complex elements to perform (Lebre, 2011; Vitrichenko et al, 2011), but they are also those where the gymnast can get more points, once the CoP (FIG,

2012) allows to add the base value of the difficulty for each rotation performed. The lower number of balances in the routines is, probably, due to the fact that the gymnasts spend considerable time of the routine to perform them because they are static difficulty elements (Gateva, 2015) and they have low values: 0.50 points is the maximum possible value for a balance, according to the CoP (FIG,

2012). These are the main reasons for the preference of the gymnasts to include more difficulties in rotation and less in balance in their routines. The routines only last for maximum 90 seconds and they have to optimize the time available to get the maximum of points allowed (10 points). The gymnasts, with the intention of getting top scores should present routines with a high level of difficulty combined with good execution quality (Agopyan, 2014).

The mastery and dance steps have comparatively lower possible values than the jumps, rotations and balances. These groups have an inferior degree of execution complexity, they are less valued in the CoP (FIG, 2015). To promote the inclusion of these types of elements in RG routines, and therefore have more interesting choreographies their value should be increased (Livotti, 2012; Leandro, 2015). One of basic requirements of RG is that the gymnast should show an optimal use of the body together with the apparatus handling. In this way, to raise the difficulty departure score the gymnast must increase of both body and apparatus difficulty level included in the routine (Agopyan, 2014).

The analysis of the results according to the gymnasts' final ranking showed that the higher placed gymnasts chose preferentially elements with a higher complexity (MixDif, rotations on flat foot or other part of the

body and "fouetté" rotations) and the lower placed gymnasts chose elements with lower complexity (balances) as described also by Gateva (2015).

Regarding the difficulty elements value, the jumps were the elements with higher value for the gymnasts in the first and second parts of the ranking. With the exception of the jumps of 0.5 points value, the gymnasts higher placed (1st and 2nd part of the ranking) include preferably the jumps with higher value and the gymnast placed on 3rd part preferred the jumps of 0.3 and 0.4 points value, which confirms the expectable. According to Bobo (1998) and Bobo, (2003), as a norm the best gymnasts hold physical and artistic capacities that allow them to perform more and higher level elements with high execution complexity. The rotations, DER and MixDif had higher values in the routines of the gymnasts placed in 1st part of the ranking and decreased in the routines of the gymnasts placed in the second and third parts. The complexity of this type of difficulties is very high and demands an extraordinary coordination, a perfect control of the apparatus technic and a lot of practice hours, (Lebre, 2011; Vitrichenko et al, 2011), which justifies that they are preferably used by the gymnasts highly ranking.

CONCLUSIONS

The rhythmic gymnasts who competed at the 2013 World Championships used in their routines very similar difficulties elements with limited variety. The more used difficulties were the rotation "attitude", rotation with "free leg in ring in back with help", "rotation in penché"; balance "side scale with split, without help" and balance "back scale leg high up"; jump "jeté with turn" and "jeté with a turn with back bend". The highest valued elements are DER and rotations and these represent 50% of the total value of the routine. These groups showed an important contribution to the final D score. The balances were the less used difficulty group.

The routines had differences in the composition pattern between the gymnasts according to the their final ranking in the following items: (i) the number of rotations of flat foot or other part of the body, "fouetté" rotations and MixDif; (ii) the value of jumps, rotations, DER and MixDif. Concerning the dance steps and mastery, no differences were found between the routines of gymnasts place in the three parts of the ranking.

This study provides updated information about the individual routines content in rhythmic gymnastics, to be considered: (i) to the possible modifications of the present Code of Points, in particular for the definition of the composition requirements in order to have higher level of variety and diversity in the routines, and (ii) to the training process to achieve the high performance level in the individual gymnasts.

REFERENCES

Agopyan, A. (2014). Analysis of Body Movement Difficulties of Individual Elite Rhythmic Gymnasts at London 2012 Olympic Games Finals. *Journal of Scientific Research, 19*(12), 1554-1565.

Arkaev, L.I. & Suchilin, N.G.(2004). *How to create champions - the theory and methodology of training top-class gymnasts.* Oxford: Meyer&Meyer Sport.

Ávila-Carvalho, L., Klentrou, P., Palomero, M. d. L., & Lebre, E. (2012) Analysis of the Technical Content of Elite Rhythmic Gymnastics Group Routines. *The Open Sports Sciences Journal,* 5, 146-153.

Ávila-Carvalho, L., Klentrou, P., & Lebre, E. (2012). Handling, Throws, Catches and Collaborations in Elite Group Rhythmic Gymnastics. *Science of Gymnastics Journal, 4*(3), *37-47*.

Ávila-Carvalho, L., Leandro, C., & Lebre, E. (2011). 2009 Portimão Rhythmic Gymnastics World Cup. Scores analysis. In N. T. Cable & K. George (Eds.), *Book of abstracts of the 16th Annual Congress of the European College of Sport Science.* Liverpool, UK. 579-580.

Ávila-Carvalho, L., Palomero, M. d. L., & Lebre, E. (2011b). Estudio del valor artístico de los ejercicios de conjunto de Gimnasia Rítmica de la Copa del Mundo de Portimão 2007 y 2008. *Apunts. Educación Física y Deportes, 1.er trimestre* 103, 68-75.

Ávila-Carvalho, L., Palomero, M. d. L., & Lebre, E. (2009c). Difficulty score in Group Rhythmic Gymnastics. Portimão 2007/2008 World Cup Series. *Palestrica Mileniului III. Civilizatie si sport, Anul X, 3*(37), 261-267.

Balcells, M., Martín, C., & Anguera, M. (2009). *Instrumentos de observación ad hoc para el análisis de las acciones motrices en Danza Contemporánea, Expresión Corporal y Danza Contact-Improvisatio*. Apunts educación física y deportes.Ciencias aplicadas a la actividad física y el deporte, 14-23.

Bobo M, Sierra E.(2003). *Estudio de las repercusiones de los cambios de código de puntuación en la composición de los ejercicios de gimnasia rítmica en la técnica corporal.* Available from: http://www.cienciadeporte.com/congreso/04%20val/pdf/p3.pdf.

Bobo M, Sierra E. (1998). *Una nueva propuesta de dificultades corporales en gimnasia rítmica deportiva.* Libro de resúmenes del VI Congreso de Educación Física e Ciencias do Deporte dos Países de Lingua Portuguesa Deporte e Humanismo en clave de Futuro.

Bucar, P. M., Cuk, I., Pajek, J., Kovac, M., & Leskosek, B. (2013). Is the Quality of Judging in Women Artistic Gymnastics Equvalent at Major Competitions of Different Levels? *Journal of Human Kinetics,* 37, 173-181.

Caburrasi, E.F., Santana, M.V. (2003). *Análisis de las dificultades corporales en los Campeonatos Europeos de Gimnasia Rítmica Deportiva Granada 2002*. Available from: http://www.efdeportes.com/efd65/grd.htm.

Čuk, I., Fink, H., & Leskošek, B. (2012). Modeling The final score in Artistic Gymnastics by different weights of difficulty and execution. *Science of Gymnastics Journal*, 4, 73 – 82.

FIG. (2012). *Code of Points for Rhythmic Gymnastics Competitions*. Available at: http://www.fig-gymnastics.com/site/page/view?id=472

Ferreirinha, J., Carvalho, J., Côrte-Real, C., & Silva, A. (2011). Evolução do Valor Real de Dificuldade dos Exercícios de Paralelas Assimétricas de Ginástas de Elite nos Ultimos Ciclos Olímpicos. *In FGP* (Ed.), Da Prática à Ciência. Artigos do 2º e 3º Congresso de FGP (pp. 71-78). Lisboa.

Gateva, M., Gospodarski, N., Treneva, V., Avramov, D., Ivanov, N., & Andonov, K. (2015). Comparison Between The Static Balance Of Practitioners From Different Sports and Non-Athletes. Edited by Radmann, A., Hedenborg, S., Tsolakidis, E. *Book of abstracts of the 20th Annual Congress of the European College of Sport Science*. p. 569. Malmo, Sweden.

Hökelmann, A., Breitkreutz, T., & Liviotti, G. (2012). *Changes in performance structure during group competitions in rhythmic gymnastics*. Edited by Prof. Derek M. Peters & Dr. Peter G. O'Donoghue, *Book of abstracts* of the World Congress of Performance Analysis of Sport IX University of Worcester, UK. p99.

Leandro, C., Ávila-Carvalho, L., Sierra-Palmeiro, E., & Bobo-Arce, M. (2015). Accuracy in Judgment the Difficulty Score in Elite Rhythmic Gymnastics Individual Routines. *Science of Gymnastics Journal, 7*(3):81-93.

Leandro, C., Ávila-Carvalho, L., Sierra-Palmeiro, E., & Bobo-Arce, M. (2015). What Do Rhythmic Gymnastics Judges Think About Their Code Of Points?. Edited by Radmann, A., Hedenborg, S., Tsolakidis, E. *Book of abstracts of the 20th Annual Congress of the European College of Sport Science* (pp. 569). Malmo, Sweden.

Lebre, E. (2011). Technical principles for the new framework. Crossroads to the Future. International Federation of Gymnastics Scientific [Press release].

Liviotti, G. & Hökelmann, A. (2012). *Which Quantifiable Performance Parameter(s) Determined the Medals Winners at the World Championship 2011 In Rhythmic Gymnastics – Group Competition?*. In Rsupesy &T.(Ed.), *Book of abstracts* of the VI International Scientific Conference of Students and Young Scientists "Modern University Sport Science" . Moscow, p43.

Liu, X.X., & Kuang, L. (2001) Review of evolvement course of international evaluation rules in rhythmic gymnastics and its effects on technique development. *Journal of Beijing Sport University, 3*(24), 412-415.

Massidda, M. & Calò, M.C. (2012). Performance scores and standings during the 43rd Artistic Gymnastics World Championships, 2011, *Journal of Sports Sciences, 13* (30), 1415-1420.

Pelin, R. A.(2013) Studies Regarding The Rhythmic Gymnastics From The Olympic Games. *Sport & Society / Sport si Societate*, 13, 61.

Sands, W.A. ,Caine, D.J., & Bornes, J. (2003). Scientific aspects of women´s gymnastics .(vol.45). Basel: S. Karger A.G. Trifunov, T., & Slobodanka, D. (2013). The structure of difficulties in the routines of the best world and serbian rhythmic gymnasts. *Physical Culture, 67*(2), 120-129.

Vitrichenko, N., Klentrou, N., Gorbulina, N., Della Chiaie, D. & Fink, H. (2011). Groups. In FIG (Ed.), *Rhythmic Gymnastics. Technical Manual. Level 3.* 3-55. Lousanne: FIG Academy.

Wang,M., Lu,M., & Sun, X. (2013). Structural characteristics of the rhythmic gymnastic difficulty system examined from the perspective of the new rules. *Journal of Physical Education / Tiyu Xuekan*, *5*(20), 117.

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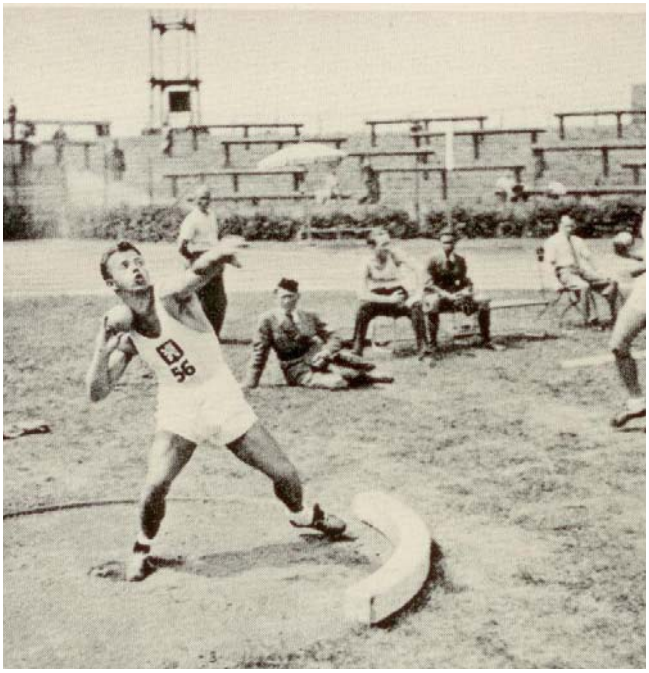
SHORT HISTORICAL NOTES V

Anton Gajdoš, Bratislava, Slovakia

Ph.D. Anton Gajdoš born on 1.6.1940 in Dubriniči (today Ukraine) lives most of his life in Bratislava (ex TCH, nowadays SVK). He comes from gymnastics family (his brother Pavel have world championship medals) and he devoted his life to gymnastics. His last achievement is establishment of Narodna encyklopedia športu Slovenska (www.sportency.sk). Among his passion is collecting photos and signatures of gymnasts. As we tend to forget old champions and important gymnasts, judges and coaches, we decided to publish part of his archive under title Short historical notes. All information on these pages is from Anton's archives and collected through years.

ALOIS HUDEC (CZE, EX TCH)

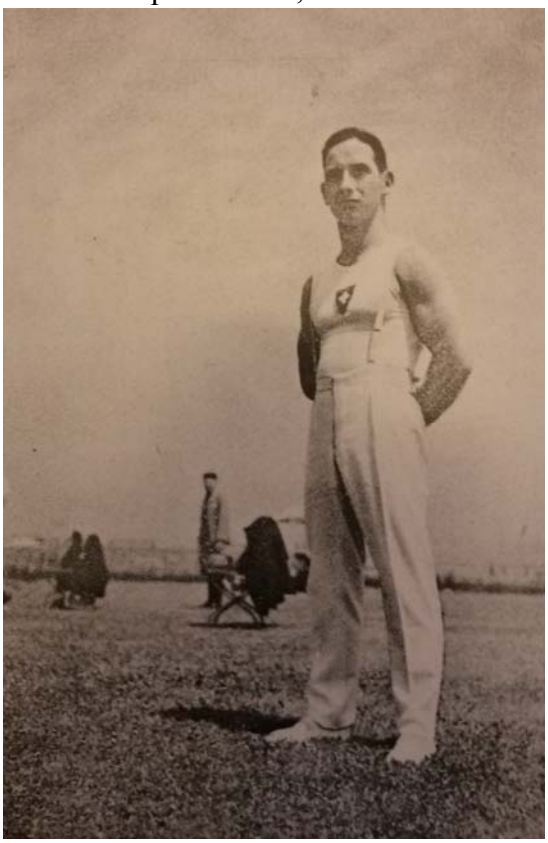
Born on 12 July 1908 in Račice u Vyškova was the best Czech gymnast before the WWII. His best competitions were Olympic Games in Berlin 1936, where he was the best man on the rings, unfortunately he missed some other medals in team competition, all around and parallel bars, where he managed to be on 4th place. Also both Worlds before and after competition in Berlin were very successful for Alois. In 1934 at Worlds in Budapest he got gold on rings and silver as team member. He was most decorated at Worlds in Praque in 1938, where he received gold for rings and team competition and silver for floor exercise, parallel bars and high bar. In the time before WWII, competitions also included sometimes swimming and track and field disciplines (shot put from WC1938 in Praque). He died 23 January 1997 in Praque.



Alois performed excellent inverted cross, on photo is no sign of safeguards neither overgrip, Photo is from OG in 1936.

EUGEN MACK (SWITZERLAND)

Born on September 1st, 1907 and died on October 29, 1978. Eugen Mack was an extraordinary gymnast. At OG in Amsterdam in 1928 he took a gold with Swiss team and on vault, on horizontal bar he was 3rd. Many teams at OG 1932 in Los Angeles (USA) did not competed, the best teams from Europe e.g. Switzerland, Czechoslovakia, Yugoslavia stayed at home and missed a moment for even higher sport results. At OG in Berlin in 1936 with the team he earned silver and took also silver in all around, pommel horse and vault, bronze on floor.



At the Worlds, Switzerland started to compete for the first time in 1934 in Budapest. Swiss team took a gold and Eugen was the best in all around, pommel horse, vault parallel bars, second on floor, and rings. His second World Championship in 1938 in Praque (photo is from Praque 1938) was not so succesfull, he remained world title on vault, while he earned silver with the team, on floor and bronze for all around.

His medals on floor were actually on grass.

CZECHOSLOVAKIA TEAM WORLD CHAMPIONS 1938

Czechoslovakia organized world championship in 1938 in Praque. Their gymnasts won the championship and their team consisted of (from left to right): coach Josef Čada, Jan Sladek, Gustav Hruby, Emanuel Loeffler, Jan Gajdoš, Josef Novotny, Jindrih Tintera, Vratislav Petraček, Alois Hudec. Victorious march through Praque.

Slovenski izvlečki / Slovene Abstracts

ASIMETRIČNOST OBREMENITVE NOG PRI SETAVAH NA GREDI

Maja Bučar Pajek, Petr Hedbávný, Miriam Kalichová, Ivan Čuk

Asimetrična obremenitev nog lahko vpliva na rezultate na gredi in na povečanje tveganja za nastanek poškodbe. Analizirali smo sestave na gredi in ugotavljali, koliko prvin je takih, ki imajo asimetrično obremenitev nog. Asimetričnost obremenitve smo določali glede na videoposnetke sestav, izvedenih na gredi na tekmovanju I na mednarodnem tekmovanju B svetovnega pokala v Ljubljani 2014. Analizirali smo odrive in doskoke, in ugotavljali kolikokrat je bilo delovanje enakomerno z nogami, kolikokrat je bila bolj obremenjena leva noga in kolikokrat desna. Razlika med nogami vsaj 0,01 sekunde pri stiku s podlago, smo določili kot asimetrične. Analizirali smo 19 sestav in smo ugotovili pomembno asimetrijo obremenitev. Desna noga je imela 42.87% vseh obremenitev (v povprečju 12,47 ± 3.32 prvin na sestavo), medtem ko leva noga in obe nogi hkrati sta imeli 29.08 in 28.05% vseh obremenitev (v povprečju 8,58 ± 2,97 in 8,21 ± 3,07 prvine na sestavo). Obremenitev desne noge je bila bistveno večja v primerjavi z levo nogo in nogami skupaj ($p = 0,002$ in 0,003). Le 4 telovadke (20,8%) so imele več obremenitev na levo nogo. Dodatni pregled pravilnik za ocenjevanje je pokazal, da v glavnem vsebuje prvine (v 60% primerov), kjer je ena noga bolj obremenjena ob odrivu in doskoku. Dokazali smo, da je na gredi prisotna asimetrična obremenitev nog. Predpostavljamo tudi, da je lahko enostranska porazdelitev bremena povezano z enostransko prevlado poškodb.
Ključne besede: ženske, orodna telovadba, poškodbe, lateralnost

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PRIMERJAVA ODRIVOV IZ DRŽE, NASPROTNEGA GIBANJA IN GLOBINSKEGA SKOKA Z NOG IN ROK PRI MLADIH TELOVADCIH ZDA

Timothy J. Suchomel, William A. Sands, Jeni R. McNeal

Cilj raziskave je bil ugotoviti in primerjati značilnosti odrivov z nogami (LE) in rokami (UE) pri mladih telovadcih članih državne reprezentance ZDA. Enaindvajset telovadce je izvedlo odriv iz drže (SJ), z nasprotnim gibanjem (CMJ), in globinskim skokom (DJ) na pritiskovni plošči. Izračunane in analizirane so bile povprečne vrednosti največje višini skoka (MXHT), največja sila (PF), razmerje razvoja sile (RFD) in največja moč (PP). Dodatno so bili ovrednotene vrednosti PF in PP glede na značilnosti vzorca. Izračunane so bile štiri analize variance za ponovljene meritve v modelu 2x3. Značilne glavni vplivi so se pokazali pri UE nasproti LE za MXHT, PF, RFD in PP (vsi $p < 0.001$). Značilni so bili vplivi glede na vrsto skoka pri: MXHT, PF, RFD in PP (vsi $p < 0.001$). Prav tako so bile značilnosti glede na vrsto skoka in vrsto okončine pri MXHT, PF, RFD in PP (vsi $p < 0.001$). Izmerjeni telovadci so bili uspešnejši pri CJ glede na SJ, ampak precej slabši so bili pri globinskih skokih. Čeprav izvajajo mnogo globinskih skokov na parterju in preskoku tako z UE in LE, telovadci pri globinskem skoku niso izkazali hitrega raztega-skrčka in je to verjetno tudi posledica da nimajo teh sposobnosti.

Ključne besede: razteg-skrček, hitrost, navpični skok, analiza sile.

RAZLIKE MED VRHUNSKIMI TELOVADKAMI IN ZAČETNICAMI PRI PREHODIH LETNO S PROTIGIBANJE NA DVOVIŠINSKI BRADLJI

Aurore Huchez, Diane Haering, Patrice Holvoet, Franck Barbier, Mickael Begon

Cilj raziskave je bil ugotoviti različne strategije gibanja pri prehodih letno z nižje na višjo lestvino s protigibanje in s takojšnjim prehodom v naopor vzklopno na dvovišinski bradlji. Enajst telovadk je trikrat poskusilo izvesti omenjeno povezavo prvin. Telovadke so bile razdeljene v dve skupini glede na njihovo uspešnost, šest jih je uspelo izvesti povezavo (vrhunske), in pet ne (začetnice). S pomočjo 3D kinematičnega sistema (snemanje je bilo izvedeno s 250Hz) so bile izračunane naslednje spremenljivke: položaj in vrtilna količina ob zapuščanju lestvine, trajanje leta, najmanjši vztrajnostni moment v letu, in položaj telesa ob prijemu. Značilne razlike so bile med obema skupinama v vseh delih povezave. Začetnice so enako robustno izvedle celotno povezavo kot vrhunske, vendar veliko manj uspešno, saj so zapustile spodnjo lestvino preden je težišče telesa prešlo višino lestvine, z manjšo navpično hitrostjo, ki je povzročila krajši in nižji let. Začetnice so imele tudi večji vztrajnostni moment v letu. Trenerji naj bodo pri začetnicah predvsem pozorni na kot v trenutku zapuščanja nižje lestvine in poskusijo preiti s težiščem telesa preko višine lestvine.

Ključne besede: dvovišinska bradlja, bimoehanika, prehod letno, kinematika,

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PREDLOG NAČINA DOLOČANJA TEHNIČNIH NAPAK PRI ORODNI TELOVADBI: ŠTUDIJ PRIMERA

Saša Veličković, Miloš Paunović, Dejan Madić, Vladan Vukašinović, Edvard Kolar

Cilj raziskave je bil ugotoviti tehnične napake pri orodni telovadbi z uporabo kinematične analize dveh telovadcev različnih stopenj uspešnosti. Vzorec merjencev sta predstavljala dva merjenca (en vrhunski in en srednjega razreda), ki sta vsak izvedla deset točev iz stoje na rokah v stojo na rokah, ob tem jih je vrhunski telovadec izvedel brez napak, telovadec srednjega razreda pa z napakami. Narejena je bila 3D kinematična analiza vseh prvin s pomočjo APAS sistema, kjer smo spremljali 17 telesnih točk in 15 segmentov. Značilnost razlik smo preverjali s t-testom za neodvisne vzorce. Dobljeni rezultati kažejo, da imajo dobre izvedbe večjo hitrost težišča telesa, bokov, vrh stopal; prav tako je težišče telesa bolj oddaljeno od osi vrtenja, in v vesi vznosno je kot v ramenih večji ter kot v bokih manjši, ter ob prehodu iz vese v oporo je hitrost iztegovanja v bokih in ramenih večja. Vse omenjene spremenljivke vplivajo, da preide telovadec v brezoporni del kasneje in v ponovni prijem pride s stegnjenimi rokami, kar pomeni izvedbo brez napake. Pridobljeni rezultati o razlikah med dobrimi in slabimi izvedbami so navodilo vaditeljem, na kaj morajo biti pozorni pri prvini, prav tako pa je to tudi splošni napotek, kako naj se določijo tehnične napake.

Keywods: toč nazaj, bradlja, kinematične značilnosti.

POGOJI IN SPRETNOSTI POTREBNI ZA POUČEVANJE TELOVADBE: PRIMER POSLUŠANJA GLASU UČITELJEV

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Soočeni smo s problemom, da orodna telovadba v španskih šolah polagoma izginja iz učnih načrtov. Cilj analize je bil ugotoviti kakšno je razmišljanje skupine učiteljev telesne vzgoje do poučevanja telovadnih vsebin. Bolj natančno, raziskovali smo, kakšne izkušnje in znanja so pridobili tekom šolanja na Univerzi, in težave s katerimi se srečujejo ob pričetku službovanja. Uporabljena je bila kvalitativna analiza in program Aquad 7 za določanje značilnosti vsebine intervjujev. Rezultati kažejo, da kot študenti niso pridobili primernih znanj, da bi lahko dobro izpeljali začrtani učni program. Čeprav je ena skupina učiteljev menila, da je uspešno izvedla učni načrt na začetku službovanja, dve skupini pa sta predstavili povsem nasprotna stališča. Ena neuspešna skupina je poskusila izvesti učni načrt, vendar se ni počutila dovolj samozavestno, kar je povzročilo strah in neodločnost, druga skupina pa ni izvedla učnega načrta, ker enostavno ni imela primernih materialnih pogojev za delo. Izobraževanje učiteljev bi moralo upoštevati realnost šolskega prostore in upoštevati učiteljeve potrebe.

Ključne besede: izobraževanje, učitelji telesne vzgoje, začetniki, telovadba.

SODELOVANJE DRŽAV PAN AMERIŠKE TELOVADNE ZVEZE NA GIMNAESTRIADI LETA 2011

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Članek se osredotoča na Gymnaestrado (WG), največji mednarodni zbor telovadcev vseh starosti, ki ga organizira mednarodna telovadna zveza. (FIG). Cilj je bil analizirati sodelovanje članic Pan Ameeriške telovadne zveze (PAGU) na 14. WG, ki je bila v Lausanne v Švici leta 2011. Podatki za analizo so predstavljali pol strukturirani pogovori z osmimi vodji delegacij od enajstih sodelujočih držav. Rezultati so pokazali, da je imela Brazilija največjo delegacijo, nato Kanada in ZDA, katere tudi tradicionalno sodelujejo na tem dogodku. Največ je bilo članic delegacij (74,5%) in predstave so bile močno obarvane z orodno telovadbo in ritmiko, kakor tudi plesom. PAGU delegacije so se povečale v primerjavi s preteklostjo, in PAGU države so bile druga celinska zveza z največ udeleženci (6,64%). Udeležba je močno odvisna od ekonomske moči, saj so bile doslej vse WG prirejene v Evropi. Ugotovimo lahko, da PAGU države še vedno vrednotijo WG kot drugorazreden dogodek in dajejo prednost tekmovalnemu delu in državnim ekipam.

Ključne besede: telovadba za vse, Severna Amerika, Centralna Amerika, Južna Amerika, telovadni zlet.

TEHNIČNE ZNAČILNOSTI SESTAV VRHUSKIH RITMIČARK

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Osnovni cilj raziskave je bil ugotoviti katere prvine so uporabile ritmičarke na svetovnem prvenstvu v Kijevu leta 2013 ter na ta način ugotoviti strukturo sestav posameznic. Podatki so bili pridobljeni iz formularjev, ki jih morajo ritmičarke oddati sodniški komisiji, analizirano je bilo 288 sestav. Ritmičarke so bile razdeljene v tri kakovostne razrede, glede na končni vrstni red na tekmovanju. Težavnost prvin je bila ugotovljena glede na Pravila za ocenjevanje (FIG, 2012). Neparametrijski testi - Kruskal-Wallis, Mann-Whitney in Friedmanov test so bili uporabljeni, za ugotavljanje razlik med kvalitetnimi skupinami ritmičark. Osnovna ugotovite je bila, da imajo vse ritmičarke podobne vsebine, ki imajo majhno raznolikost. Najbolj cenjene so prvine dinamične prvine z vrtenji in meti (DER) in predstavljajo 50% vseh vsebin Pri plesnem delu in rokovanju z orodjem med skupinami ni bilo razlik. Razlike med skupinami so bile pri uporabi števila obratov na celem stopalu, ali drugih delih telesa, obratih tipa Fouetté, mešanih težavnostih, težavnosti skokov, obratov, DER in mešanih težavnostih.

Ključne besede: težavnost prvin, posameznice, ocenjevanje, ritmika

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