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Science of Gymnastics Journal (ScGYM®)

Science of Gymnastics Journal (ScGYM®) 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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CONTENTS

EDITORIAL

Dear friends,

A year has gone by since we published the first issue of our journal, so we can congratulate ourselves on achieving our first birthday! As this issue is also our last of the year, perhaps some statistics are appropriate.

In 2010 alone we published 15 articles by authors from various countries including (in alphabetical order) Australia, Finland, Germany, Greece, Hungary, Portugal, Slovenia, and the United States of America. From the journals inception in October 2009 to the beginning of 2010, 6 articles were published also by authors from Bosnia and Herzegovina, China, and Croatia. This results in a total of 21 published articles by authors from 11 different countries. Our friend from the editorial board William Sands (USA) wrote for the successful SIGARC symposium in Sao Paolo Campinas: less scientific articles on gymnastics topics have been published in recent years (by PubMed Database) comparing to decades ago. Through the SIGARC symposium and our journal we are increasing the number of articles in the gymnastics field. Authors have written from a wide range of scientific paradigms. We started in 2009 with medicine, biomechanics, didactics, and terminology; continuing in 2010 with psychology, motor control, metrics, history, and the theory of training. Topics dealt with high performance sport, physical education, and rehabilitation. Samples also represented a wide range of gymnastics disciplines and included participants from men's artistic gymnastics, women's artistic gymnastics, and rhythmic gymnastics. We hope in the near future to publish articles from trampolining, acrobatics, and aerobics. It is worth noting that studies were not solely concerned with athletes, but judges and Code of points were also analysed.

It is hoped that the research published in this journal will inform everyday practice in our field of gymnastics. Keith Russell (Canada) the president of the FIG Scientific Commission shares this vision, and supports our work. It should also be noted that from 1 October 2009 to 1 October 2010 our website received over 11,000 visitors from all over the world (101 countries).

The congress 'Current trends in the development of gymnastics' organised by the German Association of Sport Science was recently hosted by the German Sport University of Cologne. German scientists and their guests from Switzerland, Belgium, Japan, and the United Kingdom presented some interesting topics, and we hope to share this knowledge in the near future.

In the current issue we have five articles. The first article deals with training loads in women's artistic gymnastics in the pre-pubertal period. This piece of work will make coaches think about how to plan training properly and more safely, with consideration for the health of the gymnast. The second article analyses the contents of the gymnastics curriculum in school, and how the current curriculum is delivered. The third article is about rhythmic gymnastics and apparatus difficulty for group routines. The fourth article is concerned with manual guidance in gymnastics. This topic is rarely researched, and the article provides interesting results. The final article looks at how difficulty scores on apparatus affect all around scores in men's gymnastics. For all around gymnastics coaches there is still time to change training models in an effort to be more successful at the Olympic Games in London 2012.

Wishing you inspiring reading,

Ivan Čuk
Editor-in-Chief

TRAINING LOAD IN PRE-PUBERTAL FEMALE ARTISTIC GYMNASTICS

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Original research article

Abstract

An understanding of the multiple factors affecting young gymnasts is required to assist in optimizing performance and injury prevention. We aimed to determine the effects of participation level (international and national level gymnasts), apparatus (beam and floor) and training phase (pre-competition and competition) on estimates of training load in 25 female artistic gymnasts (mean age 9.5, SD = 1.6 years, training age 1.9, SD = 0.7 years). Video analysis was used to determine frequency of observed gymnastic-specific movements involving estimates of ankle and wrist impacts, landings, balance-related skills, and rotations. To further estimate training load, 16 gymnasts performed sport-specific skills, on a portable force platform. Results from a series of ANOVAs showed training load differences between the two groups. Compared with national level gymnasts, international gymnasts demonstrated increased hours of training, and a greater frequency of observed impacts (independent of time). Differences were also observed between the two phases of periodised training in both participation levels however, international gymnasts followed a more refined training program. No between group differences were evident for ground reaction forces on the beam and floor. Periodisation and training load should be monitored objectively to assist in ensuring the longevity of athletes and ideally minimising injury risk.

Keywords: *gymnastics, pre-puberty, training load, periodisation, ground reaction force.*

INTRODUCTION

Female artistic gymnastics is a dynamic sport, habitually exposing young gymnasts to training programs higher in volume and intensity, than other sports for children of similar age. Intensive training at a young age may create complications for female gymnasts. Literature suggests a training load threshold exists in which gymnasts training more than 15 to 18 $hrs.wk^{-1}$ before and during puberty may experience decreased growth, resulting in reduced final adult stature (Theintz, Howald, Weiss, & Sizonenko, 1993). Training load in gymnastics is typically quantified by assessing weekly hours of gymnastics specific training. More research is needed to determine the type and magnitude of gymnastic-specific loading relative to non-elite or national level gymnasts.

In addition to reporting training load through weekly exposure, many gymnastics skills have been analysed to determine the specific impact loading on the skeleton. Ground reaction forces to both the upper and lower extremity have previously been recorded. The majority of these skills are advanced level skills and place forces of 13 to 14 times body weight on the skeleton (Brown et al., 1996; Panzer, 1987). Few intermediate skills have been assessed, with forces varying from two to four times body weight for the wrists (Daly, Rich, Klein, & Bass, 1999; Davidson, Mahar, Chalmers, &

Wilson, 2005; Koh, Grabiner, & Weiker, 1992) and 10 times bodyweight for the ankles (Daly et al., 1999).

Video analysis used to record the frequency of gymnastic-specific movements is another method used to quantify gymnastics loading. Gymnastic-specific movements including static, swing and impact movements have been used to quantify the frequency of gymnastics loading during different phases of training, for male international level gymnasts (Daly et al., 1999). To the best of our knowledge, similar techniques have not been conducted with female artistic gymnasts.

Phases of training, also known as periodised training typically consist of three phases; preparation, competition and transition (Bompa & Carrera, 2005). Gymnastics coaches are encouraged to follow periodised training programs for all aspects of the sport in order to prevent and minimise the risk of injury, optimise peak performance, and ensure adequate preparation and recovery (Brooks, 2003).

Impact forces and injury risk increase as a gymnast progresses through the competitive levels (Caine & Nassar, 2005). However, by following a periodised training program, ensuring gymnasts have adequate skill and strength requirements and by monitoring overall loading the risk of injury should decrease. As with any sport, injury resulting from gymnastics participation is inevitable. Within female artistic gymnastics, the floor apparatus is associated with the highest injury risk (Caine, Bass, & Daly, 2003; Kirialanis et al., 2002; Verhagen, Mechelen, Baxter-Jones, & Maffulli, 2000), followed by the balance beam (Caine, Cochrane, Caine, & Zemper, 1989; Petrone & Ricciardelli, 1987).

The present study uses a multidisciplinary approach, combining several sub-disciplines of sports science to understand more about gymnastics loading on pre-pubertal female artistic gymnasts. The primary goal of the study was to compare differences in frequency of observed gymnastic-specific movement patterns, independent of time, between two levels of gymnastics participation during the pre-competition and competition training phases. The secondary goal was to estimate ground reaction forces at the wrist and ankle associated with selected fundamental gymnastics skills and to determine if differences exist between high (international) and low (national) skilled gymnasts.

METHODS

Participants

Twenty-five pre-pubertal girls aged 7-13 years were recruited for this study. Participants comprised of an international levels training squad (*n* = 12) training an average of 26.42 $hrs.wk^{-1}$ (SD = 3.86 $hrs.wk^{-1}$) and an age-matched national levels squad (*n* = 13) training 13.85 $hrs.wk^{-1}$ (SD = 2.64 $hrs.wk^{-1}$). Participants were injury-free and had a minimum training age of one year in the sport of women's artistic gymnastics. Ethical approval was obtained from the University's Human Research Ethics Committee. Participants were volunteers from whom written parental consent and participant assent were obtained.

Procedures

Anthropometric Assessments

Anthropometric measures were recorded to assist in the description of participants. Gymnasts wore leotards during collection of anthropometric data. Body mass was recorded using digital scales (A & D Personal Precision Scale UC321) accurate to ± 0.05 kg. Standing and sitting height was measured using a stadiometer (Surgical & Medical Products, Melbourne, Australia) accurate to ± 0.001 metre. The measurement was taken as the maximum distance from the floor or bench to the vertex of the skull when the head was in the Frankfort Plane. Measures of standing height and body mass were used to calculate body mass index [weight (kg) / $height^2$ (m)].

Questionnaires

Parents and guardians of gymnasts completed a survey profiling their daughters' gymnastics specific and total physical activity. For descriptive purposes, parents also estimated the pubertal stage of development of their daughter using a pictorial representation of Tanner's five stage model of pubertal maturation (Duke, Litt, & Gross, 1980; Schmitz et al., 2004; Tanner, 1968).

Video Analysis

Four separate training sessions of gymnasts from the national and international levels groups were recorded using two JVC digital video cameras (GR-DVL820EA). Two recorded sessions occurred in the competition phase of the periodised training program and two in the pre-competition phase. To quantify training load the frequency of gymnastic-specific elements during floor and beam training was retrospectively recorded through video analysis of individual gymnasts during training. The gymnastic-specific elements of wrist and ankle impacts were denoted by any rebound contact with the floor or beam for less than one second. For example, a cartwheel was identified as two wrist and two ankle impacts. The remaining elements observed during sessions included: balance (any pose or hold maintained for greater than three seconds), landing (contact with the floor or beam for three seconds), and rotation (movement around any of the three body axes). The frequency of these elements during time-matched beam and floor sessions was recorded for both the international and national gymnasts.

Ground Reaction Forces

To further estimate training load, a uni-axial Kistler Quattro Jump portable force platform (9290AD, Kistler Instruments Corp., Amherst, NY) sampling at 500 Hz was used to quantify the impact of loading through wrists and ankles during selected gymnastic skills performed on floor and beam apparatus. A random sub-sample of gymnasts from the international (n = 8) and national (n = 8) levels groups were selected to perform skills on the force platform. Floor skills performed on the platform included: a jump full turn, split leap, round-off, back flip and handspring. Beam skills performed on the force platform included: straight jump, split jump, handstand, backward walkover and cartwheel. When performing beam skills a 0.1 m wide balance beam guide was created using magnesium carbonate chalk on matting placed over the force platform. Only skills that were deemed by an accredited and experienced gymnastics coach to be satisfactory on the actual apparatus were accepted for analysis. Skills performed on the force platform were selected based on the ability of gymnasts from both groups to execute the skills safely and successfully. During training, international gymnasts were not limited to performing fundamental skills and would therefore be performing skills with higher ground reaction forces than those selected for analysis.

The force platform setup was surrounded with safety matting to maximise gymnasts' safety and simulate a typical training environment. A pilot reliability study showed the effect of the matting on the force output was consistent during both static (R^2 = 0.915) and dynamic (R^2 = 0.965) trials producing systematic attenuation of forces across all conditions. Therefore, the matting responded in a uniform fashion for all gymnasts, without affecting force output.

Statistical Analysis

Following tests for normal distribution, a series of independent t-tests or non-parametric equivalent tests were applied to detect any baseline differences between gymnastics groups. Similar tests were used to compare results from dependent variables in the two levels of participation and across the two phases of the periodised training program. Force plate data were analysed the same way. For descriptive purposes effect size and 95% confidence intervals were calculated.

A three-way (3 x 2) ANOVA was used to compare differences in observed loads for two participation levels (international and national), two training phases (pre-competition and competition), and two apparatus (beam and floor). Specifically, loads consisted of wrist and ankle impacts, balance, landings, and rotations. Following Pearson's correlation, multiple linear regression analyses were used to assess the contribution of independent variables (participation level, training phase and apparatus) to the observed variability in the dependent variables. Statistical significance was set at an alpha level of $p \leq 0.05$. Statistical analyses used SPSS, (version 17.0, SPSS Inc, Chicago, Ill.).

RESULTS

Independent *t*-tests showed the two levels of gymnastics participation compared favourably for age, mass, standing and sitting height, body mass index, and training age (Table 1). Non-parametric data of pubertal status were assessed using Mann-Whitney *U* test. No differences occurred between the international and national groups for proxy reports of pubic hair and breast development. Total weekly hours of gymnastics training was the only variable showing significant difference between groups.

Table 1. *Descriptive characteristics for international and national level female artistic gymnasts*

	International Gymnasts *Mean (SD)*	National Gymnasts *Mean (SD)*	*p* Value
Age (yr)	9.25 (1.86)	9.77 (1.24)	0.426
Mass (kg)	27.66 (4.83)	30.46 (5.23)	0.179
Standing Height (cm)	130 (10)	135 (8)	0.158
Sitting Height (cm)	69 (4)	71 (4)	0.139
Body Mass Index ($kg.m^2$)	16.12 (1.04)	16.45 (1.08)	0.446
Training Age (yr)	1.92 (0.79)	1.85 (0.69)	0.814
Gymnastic Training ($hr.wk^{-1}$)	26.42 (3.86)	13.85 (2.64)	<0.0001*
Pubertal Status (Tanner stage 1 to 5)	1[a]	1[a]	1.000

[a] Median values reported following Mann-Whitney *U* test

* Denotes significant difference

Gymnastic-Specific Movement Patterns

The overall trend for ankle impacts and balance related skills was to increase from pre-competition to competition for both groups of gymnasts. International gymnasts were exposed to fewer impacts, landings and rotations during competition than pre-competition, whereas the national gymnasts were exposed to more. Overall, when comparing the two groups of gymnasts for the same duration, international gymnasts had higher frequencies of observed gymnastic-specific movements (Table 2).

Table 2. *Frequency of accumulated gymnastic-specific movement patterns observed within a 30 minute training session during the pre-competition and competition phases on the beam and floor apparatus*

	International Level Gymnasts				National Level Gymnasts			
	Beam		Floor		Beam		Floor	
	Pre-comp	Comp	Pre-comp	Comp	Pre-comp	Comp	Pre-comp	Comp
Wrist Impact [abc]	93.08 (29.14)	63.50 (22.10)	86.75 (14.77)	60.79 (22.48)	37.73 (15.99)	57.77 (19.92)	30.38 (10.89)	35.27 (13.63)
Ankle Impact [abc]	143.79 (34.58)	87.92 (22.19)	108.85 (30.19)	106.83 (31.55)	79.92 (18.58)	90.91 (24.64)	54.88 (17.51)	65.55 (12.98)
Landing [abc]	10.95 (6.34)	8.54 (4.95)	21.20 (5.42)	13.83 (4.90)	9.29 (5.51)	7.77 (3.60)	13.15 (9.32)	16.50 (5.29)
Balance [abc]	8.47 (6.47)	26.63 (16.34)	0	11.00 (8.33)	6.83 (7.09)	3.90 (1.41)	1.40 (0.55)	2.21 (1.05)
Rotation [a]	92.13 (25.04)	83.33 (21.25)	107.80 (18.59)	81.92 (13.21)	42.62 (17.50)	64.50 (22.67)	52.46 (16.68)	60.18 (22.13)

Data presented as mean (standard deviation)
[a] denotes main effect for group – international vs national (p<0.05)
[b] denotes main effect for apparatus – beam vs floor (p<0.05)
[c] denotes main effect for training phase – pre-competition vs competition (p<0.05)

Participation level demonstrated the strongest main effect with all dependent variables reaching significance. Main effects for apparatus and training phase were also present for all dependent variables, with the exception of rotation (Table 2). Interaction effects from the three-way ANOVA for all dependent variables are shown in Table 3. A participation level x training phase interaction effect showed the strongest two-way relationship, with all dependent variables achieving significance. Two three-way interactions were observed for ankle impacts [F(1, 180) = 18.925, *p* < 0.0001] and landings [F(1, 173) = 4.831, *p* = 0.006].

Linear regression analyses were conducted following significant Pearson's correlation coefficient effects. Regression analyses revealed the strongest predictor (R^2_{adj} = 51.1%) of observed variability in rotations was participation level [*F*(1, 94) = 100.453, *p* < 0.0001]. During data entry, international gymnasts were assigned the value "1" and national gymnasts "2". Consequently, the rotation regression equation [y = (-38.426 * participation level) + 129.002] represented a negative relationship between participation level and rotations. Specifically, international gymnasts executed a higher frequency of rotations compared with national gymnasts.

Table 3. *Female artistic gymnastics, interaction effects for a three-way ANOVA*

	Interaction Effects			
Dependent Variables	Participation Level x Apparatus	Participation Level x Phase	Apparatus x Phase	Participation Level x Phase x Apparatus
Wrist Impact	0.069	<0.0001*	0.313	0.101
Ankle Impact	0.033*	<0.0001*	0.001*	<0.0001*
Landing	0.409	0.001*	0.979	0.006*
Balance	0.001*	<0.0001*	0.490	-
Rotation	0.454	<0.0001*	0.008*	0.802

* Denotes significant difference

Explained variance in dependent variables was weak to moderate, ranging from 34% to 51%. Therefore, other factors in addition to participation level, apparatus and training phase must have influenced the dependent variables.

Ground Reaction Forces

Mean peak ground reaction forces (PGRF) are reported relative to body weight and displayed in Table 4. Independent *t*-tests revealed no differences between the estimates of ankle and wrist forces in international and national gymnasts for any of the selected skills. The floor apparatus routinely exposed gymnasts to greater forces relative to body weight than the beam. Similarly, the lower extremities were exposed to greater PGRF than the upper extremities, across both apparatus. On the beam, the split jump exposed the ankles of gymnasts to the highest PGRF (international gymnasts M = 4.51, SD = 1.09 times body weight; national gymnasts M = 5.50, SD = 1.20 times body weight). The ankle impact associated with the round-off demonstrated the highest PGRF on the floor for the international (M = 8.06, SD = 1.33 times body weight) and national (M = 8.46, SD = 2.04 times body weight) level gymnasts.

Training Load

Training load differences were evident between participation level, hours of training and the frequency of observed gymnastic-specific skills. For gymnastic-specific movement patterns, international level gymnasts generally recorded higher frequency of observed movements within a standardized 30 minute training period. Participation level also had a major influence on all gymnastic-specific skills and training phase. Ankle impacts were the most sensitive measure of gymnastic-specific movements. Frequency of ankle impacts varied according to participation level, apparatus and training phase.

Overall training load is higher for international than national level gymnasts. International gymnasts are exposed to ground reaction forces up to 14 times body weight (Panzer, 1987) and train 26 $hrs.wk^{-1}$. Female national gymnasts are typically exposed to forces up to 10 times body weight (Daly et al., 1999) and train 14 $hrs.wk^{-1}$. In addition to increased loading through exposure time and ground reaction forces, international level gymnasts performed more gymnastic-specific movement patterns than national gymnasts, within a matched time period. Therefore, when total hours of participation, frequency of movement patterns and ground reaction forces are considered, loading was substantially greater for international level gymnasts.

There was an absence of between group differences for measured ground reaction forces. These results differ from previous studies who reported higher vertical ground reaction forces among highly skilled gymnasts compared with recreational athletes/non-gymnasts (McNitt-Gray, 1991; Sabick, Goetz, Pfeiffer, Debeliso & Shea, 2006), although tasks were not gymnastics specific.

Table 4. *Peak ground reaction forces, relative to body weight, applied to the wrists and ankles for specific fundamental beam and floor gymnastics skills*

	International *Mean (SD)*	National *Mean (SD)*	Effect Size	Δ 95% CI	P Value
Beam Skills					
Straight Jump (ankles)	4.51 (1.09)	5.50 (1.20)	0.86	-0.988 -2.21 – 0.24	0.106
Split Jump (ankles)	5.89 (1.04)	5.59 (1.29)	0.26	0.296 -0.96 – 1.55	0.620
Handstand (wrists)	1.30 (0.20)	1.30 (0.14)	0	0.001 -0.18 – 0.18	0.988
Handstand (ankles)	1.66 (0.25)	1.82 (0.27)	0.61	-0.154 -0.43 – 0.13	0.260
Cartwheel (wrists)	1.04 (0.13)	1.17 (0.20)	0.77	-0.135 -0.32 – 0.05	0.135
Cartwheel (ankles)	2.04 (0.26)	2.31 (0.41)	0.79	-0.276 -0.65 – 0.09	0.132
Backward Walkover (wrists)	1.55 (0.34)	1.33 (0.25)	0.74	0.226 -0.97 – 0.55	0.155
Backward Walkover (ankles)	1.86 (0.24)	2.03 (0.18)	0.80	-0.172 -0.40 – 0.06	0.131
Floor Skills					
Back Flip (wrists)	4.10 (0.36)	3.99 (0.72)	0.19	0.109 -0.52 – 0.74	0.714
Back Flip (ankles)	5.87 (1.13)	6.09 (1.25)	0.18	-0.128 -0.60 – 1.17	0.739
Handspring (wrists)	2.41 (0.76)	2.37 (0.67)	0.06	0.045 -0.73 – 0.82	0.902
Handspring (ankles)	7.88 (1.46)	8.25 (2.53)	0.18	-0.370 -2.59 – 1.85	0.726
Round off (wrists)	2.19 (0.38)	1.99 (0.40)	0.51	0.204 -0.21 – 0.62	0.132
Round off (ankles)	8.06 (1.33)	8.46 (2.04)	0.23	-0.398 -2.24 – 1.45	0.651
Split Leap (takeoff)	3.41 (0.46)	3.30 (0.52)	0.22	0.108 -0.42 – 0.64	0.670
Split Leap (landing)	4.65 (0.93)	4.08 (0.50)	0.76	0.561 -0.24 – 1.36	0.156
Jump Full Turn (ankles)	5.03 (0.78)	4.79 (0.88)	0.29	0.238 -0.65 – 1.13	0.576

Training Load - Frequency

Of the three independent variables (participation level, apparatus, and training phase), participation level appeared to have the strongest influence on observed variability in skills involving rotations and wrist impacts. These dependent variables may be strongly associated with participation level due to the more refined skill demands required for success as participation level increases. For example, more skilled gymnasts perform a greater number of wrist impacts by combining discrete skills into a serial sequence (tumbling row) and single rotations progress to double rotations. The increased impact loads associated with international level gymnasts, occurred independent of hours of participation.

Ankle impacts and landings revealed three way interactions. Among international level gymnasts, observations of fewer ankle impacts on beam during the competition phase than the pre-competition phase could be synonymous with more "whole" versus "part" practice. Training for international level gymnasts involved a relatively high demand for connective dance elements, combined with more serial skills. The skill quality contrast may partially explain the interaction for participation and training phase in observations of lower limb skills. Furthermore, the absence of apparatus-based differences in ankle impacts for national level gymnasts may suggest a more limited skill base to practice and perfect during the two training phases.

In contrast, observed landing frequencies increased for both apparatus between the two phases of training for international level gymnasts. Observed frequencies almost doubled on beam compared with floor and perhaps partially explain previous reports of high injury rates on the beam (Caine et al., 1989) and with landings (Kirialanis et al., 2002), at least with the international level gymnasts. Increased landings were also observed between the pre-competition and competition phases of training for national level gymnasts. However, trends differed as the increases in the competition phase were greater on floor than beam. Additional landings occurred during competition for both groups which could be attributed to the injury preventative strategy of landing in foam pits in the pre-competition phase of training when skills are still being refined. During this study, landings into the foam pit were disregarded due to a lack of impact and control during contact. Participation level and apparatus interactive effects of greater landings on beam for international than national level gymnasts may be attributed to an advanced capacity for flight-based skills on the beam and perhaps a greater need to practice more advanced skills and dismounts repetitively, even during the competition phase.

Training Load – Ground Reaction Forces

No differences in ground reaction force relative to body weight were observed between high (international) and low (national) skilled gymnasts. It is possible forces relative to body weight observed in the present study, may have differed between groups if skills could have been assessed during a sequence of skills or movements, such as a tumbling row. Instead, skills were assessed in isolation. Furthermore, between group differences may have emerged if dismounts from the beam (approximately 0.9 – 1.2 m high) were assessed (McNitt-Gray, 1991).

The ground reaction forces reported in the present study compared favourably with previous reports on male gymnasts (Daly et al., 1999). Vertical ground reaction forces at the wrist (Daly et al., 1999) ranged from 1.5 to 3.6 times body weight for male gymnasts compared with 2.0 to 4.1 times body weight on the floor apparatus in the present study. Similarly, the ankle was exposed to higher ground reaction forces than the wrist, four to ten times body weight for the young male gymnast (Daly et al., 1999) and three to eight times body weight in the female gymnasts from the current study. The forces recorded on the floor for the present study should be similar to the results of the previous study (Daly et al., 1999) as three of the same skills were analysed. Additionally, participants were approximately the same age, height and mass. Impacts within the present study on young female gymnasts were substantial and frequent and may have consequences for enhancing musculoskeletal growth (Daly et al., 1999) and, or, contribute to reported injuries (Seegmiller & McCaw, 2003).

Training Load – Periodised Training

Periodised training was defined from the results of the present study by the recognised variation in training volume (observed frequency of gymnastic-specific movements) between phases. The two groups of gymnasts demonstrated discernable differences in periodised training for the pre-competition and competition training phases. However, periodised training was more evident in international level gymnasts than national level gymnasts. Specifically, international level gymnasts decreased their observed gymnastic-specific movement patterns from the pre-competition to competition phase, whereas national level gymnasts increased their movement patterns. This may be due to the general increased duration of training for international level gymnasts who subsequently distribute skill practice across a greater volume of time.

Future Research

The present study provides sufficient results to justify further studies involving the entire periodised year. Although, to capture specific training phases such as transition or tapering before competition, an international group may be required. Comparisons between participation groups could also be further enhanced by the expansion of the present research to prospective injury monitoring and analysis of sequential activity involving more apparatus.

A limitation of the current study was the ability to include only the two most injurious apparatus across two phases of the periodised year. As training load on the vault and uneven bars was not reported, total training load has been under reported. Furthermore, response variables such as heart rate and RPE were not assessed simultaneously with training load.

A more extensive range of gymnastics skills, ability to capture skills in sequence or as a dismount from an apparatus may be required to demonstrate between group differences for ground reaction forces. Skill quality from an accredited judge was not assessed in conjunction with quantitative impact forces. Future studies could benefit from the addition of quality assessment and joint kinematic data concurrent with ground reaction force measurements in which skills are performed in sequence or tumbling series.

CONCLUSION

Independent of time, differences exist in estimates of training load for international and national level gymnasts performing on floor and beam apparatus. These between group differences existed in different phases of the periodised year and across apparatus. International level gymnasts were exposed to a higher frequency of impacts than national level gymnasts across both apparatus throughout the periodised program. This effect was even more pronounced with the greater hours of exposure and higher impact forces to "loading" opportunities.

Ground reaction forces associated with national level gymnastics skills were lower than those previously reported for international level gymnastics skills. Between group differences were not evident in performing fundamental gymnastics skills for higher and less skilled gymnasts.

Coaches must be aware that as the frequency and magnitude of impacts increase, there is a greater need to implement and follow a periodised training program. Such a program should ensure the longevity of athletes and minimise the risk of injury.

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IMPLEMENTATION OF THE GYMNASTICS CURRICULUM IN THE THIRD CYCLE OF BASIC SCHOOL IN SLOVENIA

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Original research article

Abstract

In physical education curriculum for the basic school, gymnastics is one of the most important contents. In the first and the second three-year cycle of basic school, physical education can be taught by the class teacher or a PE teacher, while in the third cycle only specialised PE teachers are qualified to teach. The aim of our study was to find out how PE teachers comply with the prescribed gymnastics curriculum content. Our sample included 147 PE teachers, stratified by gender, region and urban/rural area. The sample is representative for Slovenia as 36.7% of all PE teachers were included in the survey. Variables were represented by a questionnaire. Data was analysed by SPSS 14.0 and frequencies were calculated. Results show PE teachers spend 9.8 hours on gymnastics per academic year. Mostly they teach easy contents (roll forward, roll backward, cartwheel, handstand, etc.) where supporting assistance is not necessary and the likelihood of falls and injuries is small. At the same time, PE teachers avoid gymnastic elements which include a flight phase, turns or have a small support area as they think such elements are not appropriate for primary school.

Keywords: *gymnastics, basic school, third three-year cycle.*

INTRODUCTION

Gymnastics offers a great range of locomotive, stability and body control movements which are highly important for the development of children. Gymnastics requires a great diversity of movements: transitions from dynamic to static elements and vice versa, frequent changes of the body position in space. Successful performance of each element requires accurate muscular activity of specific intensity, through the space and at the right moment. Gymnastic elements are classified as typical combined non-cyclic movements and as such they develop the ability of movement in space and body control in the unsupported phase. From the child development perspective, gymnastics is, along with athletics, one of the key sports as it includes elements that can be performed in different directions (forward, sideways and backward), on three levels (head level, hip level and horizontal level) and around three axes (frontal, sagittal and vertical), in the support phase and through no support phase (Novak, Kovač, & Čuk, 2008).

Gymnastic contents as part of the PE curriculum in Slovenia have a history of more than one hundred years. They first appeared in the basic school curriculum in 1874 when physical education was first introduced and included the compulsory SPIESS system (Kompara & Čuk, 2006). In the following decades, the curriculum changed and was updated and the one that applies in Slovenia today (M Kovač & Novak, 2001) mandates PE as a compulsory subject in all years of basic school and prescribes its scope and structure, general and operative objectives and knowledge standards for selected sport disciplines. The current curriculum for specific sport contents provides detailed practical and theoretical themes that shall be implemented in all nine years of the basic school.

The basic school in Slovenia today takes nine years to complete. Physical education is allocated 834 lessons in total (105 lessons per year from year 1 to year 6, 70 lessons per year in years 7 and 8 and 64 lessons in the final year 9) (Anon., 1998). The current curriculum details some practical and theoretical gymnastic themes that shall be implemented in all nine years of the basic school. The gymnastics programme prescribed by the curriculum aims to provide logical progression and development continuity. The basic school programme is in terms of contents, organisation and teaching methods staged over three three-year cycles and knowledge standards for physical education defined by the curriculum correspond to this structure.

The physical education curriculum is open-ended in design, providing the teacher with a relatively high level of autonomy and responsibility to plan one's own lessons. It is the teacher who decides how much of the total amount of time will be spent on a particular activity or content. Such open-ended design ensures better interaction between the teacher, pupils and other factors that impact on the physical education. In gymnastics, such open-ended nature is necessary as some schools lack facilities for this type of lessons (apparatus, installations, aids) while pupils in higher years sometimes lack knowledge of gymnastics (Bučar Pajek, 2003; Majerič, 2004; Štemberger, 2003). In such cases, the open-ended nature of curriculum enables the teacher to adjust the programme to the actual working conditions and to plan for a sensible and optimal continuous progression building upon the skills pupils have already mastered.
However, the open-ended curriculum has another side which is becoming quite apparent from research results: while teachers hold very positive views on the benefits of gymnastic exercises for the psychosomatic development of children (Medved, 1985; Rogelja, 1985; Turšič, 2007), research studies conducted on students at the Faculty of Sport (Bučar Pajek, 2003; Tome, 1983) show that teachers tend to implement only a small proportion of gymnastic contents recommended by the curriculum.

Authors of research studies to date mainly focused on the teaching and mastering of individual gymnastics elements (end product); however, the most important part in learning gymnastic elements is the development of different skills and movements comprising gymnastics knowledge. The learning process must include all seven didactical steps (selection of the element appropriate to the learner's level, selection of the appropriate teaching method, selection of the type of movement content, selection of the type of exercise, detection and correction of errors in the performance and assistance and selection of the supporting method) in which different types of movement content, such as preparatory exercises, pre-exercises and element development exercises, hold a special position.

The aim of our study is to establish to what extent the gymnastic content recommended by the physical education curriculum is implemented in the third cycle (Table 1) of the basic school in Slovenia, including preparatory exercises, pre-exercises and element development exercises, which are not part of the curriculum but are nevertheless required as the basis to learn gymnastic exercises.

The decision to make the third cycle the focus of our research was based on the fact that PE teachers teaching in the third cycle are specialised PE teachers who have studied the abovementioned subjects at the Faculty of Sport, as part of the course 'Sports Gymnastics Methods and Techniques'.

Table 1. *Gymnastic contents in the third cycle (Kovač and Novak, 2001)*

YEAR 7	YEAR 8	YEAR 9
PRACTICAL CONTENT	PRACTICAL CONTENT	PRACTICAL CONTENT
Calisthenics with music	Calisthenics	Calisthenics
Acrobatic: - Rolls combined with other elements - Dive roll on soft mat - Cartwheel, - Handstand with assistant's support	Acrobatic: - rolls, - dive roll, - cartwheel, - handstand. Higher level: - handstand and roll forward, - roll backward to handstand. Connecting elements into exercise.	Acrobatic: - rolls, - dive roll on soft mats, - cartwheel, - handstand, - connecting elements into exercise. Girls: - Connecting acrobatic and rhythmic elements.
Middle high Beam – short exercise with walking, one jump, one turn and dismount.	Beam: - Connecting walking, jumps, turns, scales and dismount. Higher level: - Optional exercise on high beam.	- Beam: short exercise with walking, jump, turn, hold element and dismount.
Vault: - Split and squat jump on soft mats with assistant support.	Vault: - Split and squat with assistant support.	Vault: - Split and squat jump with assistant support.
Mini trampoline: - Straight jump, split jump, tucked jump, piked jump, piked split jump.	Mini trampoline: - Straight jump, split jump, tucked jump, piked jump, piked split jump. - Jumps and basketball dunk.	Mini trampoline: - Straight jump, split jump, tucked jump, piked jump, piked split jump.
Rope and bar climbing. Bar, Parallel bars, Uneven bars: - Swing in hang and support, - felge, - one leg side swing in support, - half turn in support, - dismount from support.	Climbing. - Bar, Parallel bars, Uneven bars: elements chosen by pupils' abilities	Climbing. Bar, Parallel bars, Uneven bars: optional elements
SPECIFIC THEORETICAL CONTENT	SPECIFIC THEORETICAL CONTENT	SPECIFIC THEORETICAL CONTENT
Good posture exercises. Strength and movement exercises. Assistance and support – basic grips. Assessment methods in gymnastics.	Composition and conduct of gymnastic exercise clusters. Composition and conduct of calisthenics. Assistance and support – basic grips. Assessment in gymnastics.	Composition and conduct of calisthenics. Assistance and support – application of grips.

METHODS

The test sample includes 147 PE teachers who taught physical education in the third cycle in basic schools in Slovenia in the academic year 2004/2005. This represents 36.7% of all PE teachers who teach in the third cycle in basic schools in Slovenia. The sample was further stratified by the type of settlement (town, country), region (in accordance with the official regional divisions in Slovenia) and by gender; it is hence a representative sample for Slovenia.

The variable sample is represented by the questionnaire titled 'Implementation of the curriculum for gymnastics in the third cycle of the basic school' and comprises three clusters: the first cluster includes questions on the number of implemented physical education lessons with gymnastic content; the second cluster includes questions related to the implementation of gymnastic contents and movements and the third cluster focuses on questions relating to the suitability of gymnastic exercises. The respondents were informed of the survey purpose and procedure and gave their written consent to participation in the research project. The respondents answered to closed-ended questions YES or NO and to open-ended questions by writing their reply on the appropriate line.

The data was processed using statistics application SPSS 14.0 for Windows. In accordance with the research study goal, we calculated the frequencies and performed t test to analyse the differences between the excecuted and prescribed curriculum content (implementation of the content versus 100% required curriculum implementation).

RESULTS

Results show that the number of lessons PE teachers use for gymnastic content is low: in year 7, only 15.1% (10.6 lessons) of all PE lessons are dedicated to gymnastics, in year 8 13.8% (9.7 lessons) and in year 9 it is 14.3% of all lessons (9.2 lessons) that are spent on gymnastics (Figure 1, Figure 2, Figure 3).

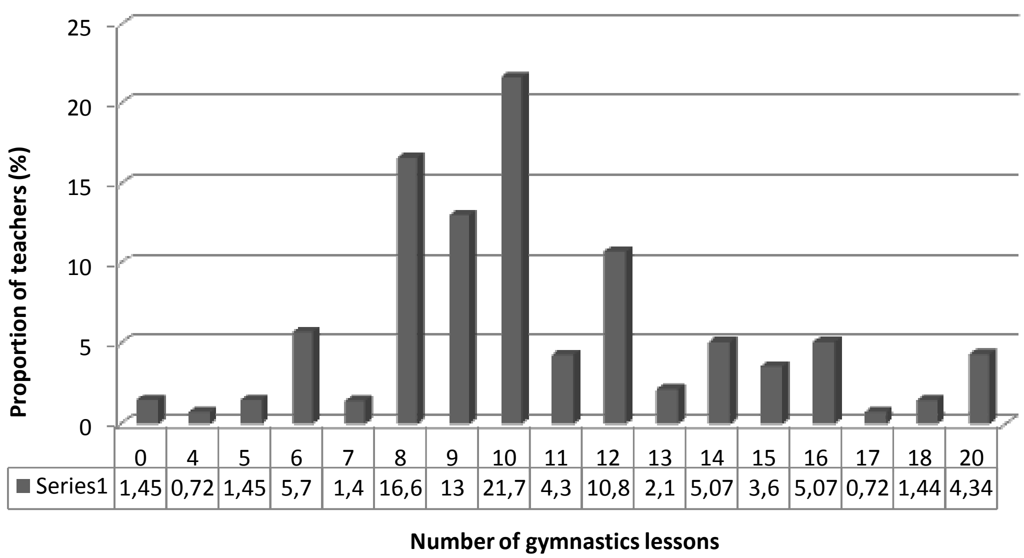

Figure 1. *Gymnastics lessons in year 7*

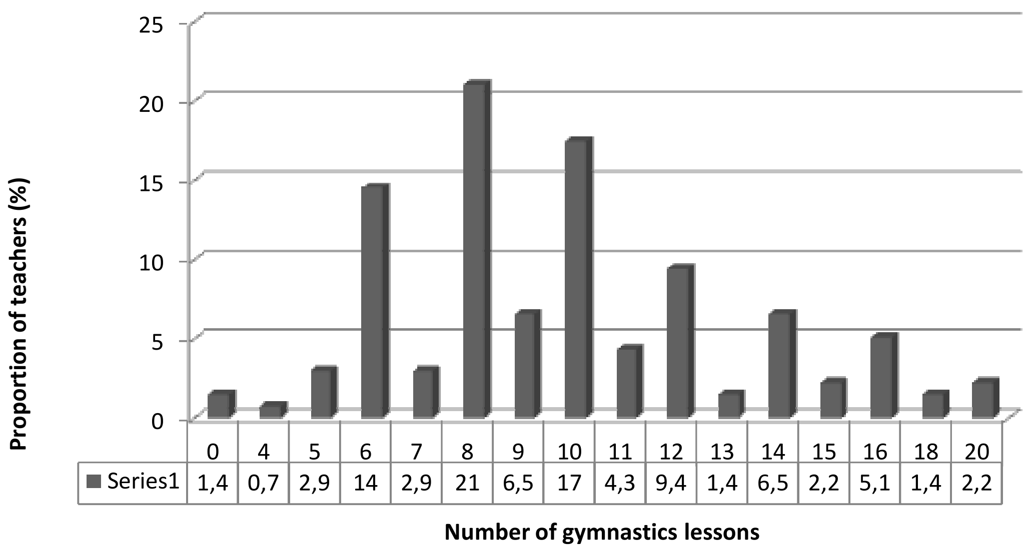

Figure 2. *Gymnastics lessons in year 8*

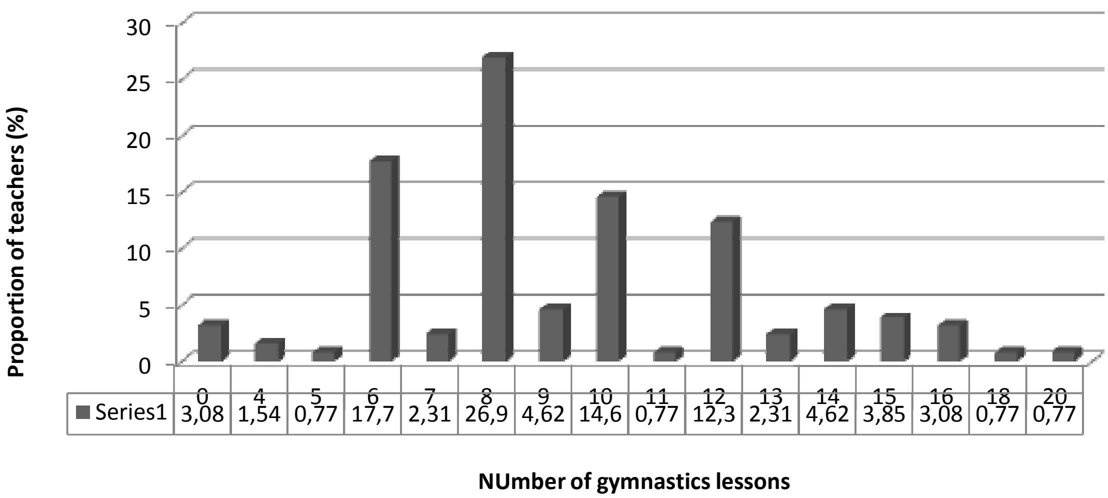

Figure 3. *Gymnastics lessons in year 9*

We were also interested in the implementation of gymnastic content and its suitability to the pupil age level in years 7, 8 and 9. Teachers answered questions with 'yes' (implemented / suitable) or 'no' (not implemented / not suitable). In Table 2, letter 'i' is used for the implementation and letter 's' for the content suitability.

Results of our survey show that the percentage of implementation of the gymnastic content decreases from year 7 to year 9 in acrobatics, on the beam and for the vault jump. In all three years of the last cycle in basic schools, PE teachers are least likely to teach elements on the bar, the uneven/parallel bars and on the beam. The least implemented elements include: half turn in support on bars and on the bar (64.4%), cut on the bars and on the bar(47.5%), dismount backward from support on the bars and on the bar (47.3%), jump on the beam (44.6%), swing in support on the bars and on the bar (43.5%), swing in hang on the bars and on the bar (41,3%), scale on the beam (30,3%), dismount from the beam (29.6%), dive roll forward in acrobatics (24.6%) and straight jump and piked split jump on the mini trampoline (19.6%).

Table 2. *Implementation and suitability of gymnastic elements in years 7, 8 and 9*

Element (from the curriculum)	Implementation/Suitability								
	Year 7			Year 8			Year 9		
	N	Yes%	No%	N	Yes%	No%	N	Yes%	No%
ACROBATICS									
Roll forward_i	142	98.6	1.4	140	97.1	2.9	124	91.9	8.1
Roll forward _s	134	98.5	1.5	130	96.9	3.1	118	95.8	4.2
Roll backward _i	141	97.2	2.8	139	93.5	6.5	122	98.3	10.7
Roll backward _s	131	96.2	3.8	130	92.3	7.7	116	87.9	12.1
Dive roll_i	139	77.7	22.3	140	78.6	21.4	123	69.9	30.1
Dive roll _s	133	85.0	15.0	134	83.6	16.4	120	81.7	18.3
Cartwheel_i	141	95.0	5.0	142	95.8	4.2	125	92.0	8.0
Cartwheel _s	138	95.7	4.3	140	95.7	4.3	125	93.6	6.4
Handstand_i	140	97.1	2.9	142	97.9	2.1	125	98.4	1.6
Handstand _s	137	98.5	1.5	140	98.6	1.4	125	99.2	0.8
BEAM									
Walk_i	125	78.4	21.6	125	74.4	25.6	110	71.8	28.2
Walk_s	121	87.6	12.4	121	85.1	14.9	107	85.0	15.0
Jump_i	123	58.5	41.5	123	55.3	44.7	109	52.3	47.7
Jump_s	116	75.0	25.0	117	73.5	26.5	104	68.3	31.7
Turn_i	119	76.5	23.5	119	75.6	24.4	105	71.4	28.6
Turn_s	115	84.3	15.7	116	83.6	16.4	103	81.6	18.4
Scale_i	119	70.6	29.4	119	69.7	30.3	105	68.6	31.4
Scale_s	113	81.4	18.6	114	83.3	16.7	101	82.2	17.8
Dismount_i	118	72.0	28.0	119	69.7	30.3	105	69.5	30.5
Dismount_s	114	83.3	16.7	116	85.3	14.7	103	83.5	16.5

VAULT									
Split jump_i	146	96.5	3.5	140	96.4	3.6	125	94.4	5.6
Split jump_s	139	97.8	2.2	139	97.1	2.9	125	96.8	3.2
Squat jump_i	141	95.0	5.0	141	95.0	5.0	125	93.6	6.4
Squat jump_s	139	97.1	2.9	140	95.7	4.3	126	94.4	5.6
MINI TRAMPOLINE									
Straight jump_i	140	82.9	17.1	142	81.0	19.0	126	84.1	15.9
Straight jump _s	138	97.8	2.2	139	97.1	2.9	125	96.0	4.0
Piked split jump_i	138	79.0	21.0	139	79.1	20.9	123	82.9	17.1
Piked split jump _s	137	94.9	5.1	138	94.9	5.1	124	95.2	4.8
BAR/PARALLEL. UNEVEN BARS									
Swing in hang_i	138	59.4	40.6	139	56.8	43.2	122	59.8	40.2
Swing in hang _s	133	89.5	10.5	138	89.5	10.5	118	89.8	10.2
Swing in support_i	135	54.8	45.2	135	57.8	42.2	120	56.7	43.3
Swing in support _s	128	80.5	19.5	128	86.7	13.3	114	86.0	14.0
Felge_i	139	72.7	27.3	140	70.0	30.0	125	71.2	28.2
Felge_s	136	90.4	9.6	137	90.5	9.5	123	91.9	8.1
Leg side swing in support_i	136	52.2	47.8	138	51.4	48.6	121	53.7	46.3
Leg side swing in support _s	129	80.6	19.4	130	83.8	16.2	115	85.2	14.8
Half turn in support_i	136	34.6	65.4	137	35.0	65.0	119	37.0	63.0
Half turn in support _s	128	67.2	32.8	128	71.7	28.9	113	72.6	27.4
Dismount from support_i	137	49.6	50.4	137	53.3	46.7	120	55.0	45.0
Dismount from support_s	130	77.7	22.3	130	80.0	20.0	115	84.3	15.7
XA (implementation)		74.92			74.17			73.63	
SD		18.71			18.39			17.78	
SE		4.29			4.22			4.08	
XA + 1.96 SE		83.33			82.44			81.62	
XA (suitability)		87.95			88.24			87.55	

SD	9.13	7.89	8.14
SE	2.09	1.81	1.86
XA + 1.96 SE	92.05	91.79	91.21
XA – 1.96 SE	83.84	84.69	83.88
p(t-test) implementation-suitability	< 0.000	< 0.000	< 0.000

Legend*: i – implementation; s – suitability, XA- average, SD – standard deviation, SE – standard error, p - probability*

Teachers in general believe that the suitability of exercises is lower than it is in curriculum and suitability is higher than their implementation. Under less suitable elements for the third three-year cycle they list dive roll forward in acrobatics, jump on the beam and half turn in support on bars and on the bar.

We also examined to what extent gymnastic content and movements (preparatory exercises, pre-elements and element development exercises) that are not prescribed by the curriculum were implemented (Table 3). Teachers answered 'yes' (implemented) and 'no' (not implemented).

Pre-exercises are implemented in a high percentage in all three years of the last cycle (in years 7 and 8 70% and in year 9 67%). However, results also show a significant decrease in some preparatory exercises (vertical bar climbing, rope climbing, ladder climbing and bunny jumps).

Table 3. *Implementation of gymnastic content and movements (preparatory exercises, pre-elements and element development exercises) that is not prescribed by the curriculum*

Gymnastics content, not included in the curriculum	IMPLEMENTATION								
	Year 7			Year 8			Year 9		
	N	Yes%	No%	N	Yes%	No%	N	Yes%	No%
PREPARATORY EXERCISES									
Bar climbing	141	91.5	8.5	141	84.4	15.6	122	77.9	22.1
Monkey bars climbing	131	39.7	60.3	130	33.1	66.9	113	30.1	69.9
Rope climbing	138	57.2	42.8	137	54	46	118	52.5	47.5
Ladder climbing	140	87.1	12.9	139	80.6	19.4	119	31.1	68.9
Wall climbing	136	31.6	68.4	136	30.1	69.9	119	31.1	68.9
Bunny jumps	139	91.4	8.6	138	86.2	13.8	120	85.0	15.0
PRE-ELEMENTS									
Shoulder stand	141	96.5	3.5	141	90.8	9.2	121	86.8	13.2
Jumping to arms support	138	83.3	16.7	138	83.3	16.7	119	83.2	16.8
Jump into knee support on box	137	77.4	22.6	136	70.6	29.4	117	67.5	32.5
Jump into squat	13	84.9	15.1	13	80.4	19.6	11	76.5	23.5

support on box	9			8			9		
Runway. roll forward on high soft mat	139	76.3	23.7	139	73.4	26.6	119	68.9	31.1
Hang bar/bars	137	75.2	24.8	137	73.7	26.3	117	72.6	27.4
ELEMENTS DEVELOPMENT									
Roll backward to handstand	140	29.3	70.7	141	37.6	62.4	121	45.5	54.5
Handstand. roll forward	139	71.2	28.8	140	78.6	21.4	120	82.5	17.5
One leg turns	131	56.5	43.5	131	58.8	41.2	113	56.6	43.4
Leaps	132	62.9	37.1	132	64.4	35.6	114	62.3	37.7
Connecting elements on floor	137	83.9	16.1	137	85.4	14.6	118	83.9	16.1
Connecting acrobatic and rhythmic element on floor	133	48.9	51.1	134	48.5	51.5	114	50.9	49.1
Short exercise on floor	134	74.6	25.4	136	72.1	27.9	116	76.7	23.3
Connecting elements on beam	127	55.9	44.1	128	56.3	43.8	110	53.6	46.4
Short exercise on beam	125	51.2	48.4	125	49.6	50.4	107	51.4	48.6
Dunking from mini trampoline	139	25.9	74.1	139	33.8	66.2	118	36.4	63.6
Changing front and back hang on bar/bars	133	24.8	75.2	133	26.3	73.7	112	28.6	71.4
Connecting elements on bar/bars	137	48.2	51.8	138	50.0	50.0	116	53.4	46.6
Short exercise on bar/bars	138	39.1	60.9	139	43.2	56.8	119	48.7	51.3

DISCUSSION

Gymnastic contents have been part of the PE curriculum ever since physical education was first introduced in the education system. As open-ended curricula provide teachers with a higher level of autonomy, it often happens that contents that require more management and where injuries are more likely are not allocated enough lessons in the annual work plan (Kovač, 2006). In recent discussions among physical education teachers, 12 lessons have often been mentioned as the minimum number (Peček & Dežman, 2003). Our survey has shown that the actual number is even lower (Figure 1, Figure 2, Figure 3) as gymnastics accounts for 10.6 lessons in year 7 (15.1%), 9.7 lessons (13.8%) in year 8 and 9.2 lessons (9.2%) in year 9.

In the study titled 'Views of physical education teachers from Ljubljana basic schools on the role of the gymnastics programme in the upper basic school', M. Medved (1985) made an assessment that PE teachers on average spent 20% of all PE lessons on gymnastic exercises. According to the curriculum of the time, physical education was allocated 105 lessons per year which means that teachers on average spent around 20 lessons on this sport discipline. D. Rogelja (1985) who also researched on the situation in Ljubljana basic schools, came to the conclusion that 56% of PE teachers dedicated 16-30% of all lessons to gymnastics, 29.7% of teachers spent 0-15% of lessons on gymnastics and 14.3% spent more than 31% of lessons on gymnastic exercises.

When external assessment was introduced nation-wide at the end of the nine-year basic school program, authors Kovač, Dežman & Lorenci (2002) were interested in examining the extent to which teachers followed the curriculum in the last three-year cycle and which types of contents were paid more attention than others. Even though all teachers claimed they followed and fully implemented the recommended curriculum, their responses did not correspond with their statements. Using range analysis (the first selection was given weight function 3, the second 2 and the third 1), the authors discovered that teachers paid most attention to track and field sports (46 points) and ball games (45 points), and considerably less to gymnastics (20 points).

This raises the question of whether it is possible to successfully teach, reinforce and monitor knowledge gained in the ten lessons allocated to gymnastics and then assess it at the end of each cluster. Teachers may want to consider the proposal that they can implement gymnastic contents (some preparatory exercises – climbing, push-ups, scales, basic gymnastic vertical jumps; and pre-elements) in the introductory part of the lesson or its conclusion, regardless of the lesson's main objective. By continuously including gymnastic elements in the curriculum, teachers will be able to improve or at least maintain the level of movement abilities in their pupils throughout the year. For children, the period between the ages of ten and fifteen is a very sensitive period in their development characterised by fast growth, especially of extremities. The accelerated development of the body unbalances the established movement patterns leading to temporary stagnation or even decline in the movement development process (Strel, Kovač, Jurak, & Bednarik, 2001). This is a perfectly normal and understandable phenomenon; nevertheless, children sometimes find it hard to accept it (Horvat, 1994) and this diminished movement efficiency often turns them away from sports. This stage in their development is probably the breaking point when teachers find it especially hard to maintain a positive attitude to sports and movement in their pupils.

In terms of implementation of gymnastic content (Table 2), teachers belive curriculum is to difficult and they do not introduce the whole curriculum content to the pupils, teachers seem to implement those elements which are technically easier to perform, for example exercises in which the body never enters a phase of no support (roll forward, roll backward, handstand, handspring to the side, walking on the beam, etc.). Elements which include a flight phase, a turn or a reduction in the support surface are more difficult to teach and teachers also find them less suitable. The least implemented are exercises on the bar and the parallel/uneven bars where only one exercise, felge, of the six listed is implemented in high percentage. Interestingly enough, felge is the hardest to perform among the six listed exercises.

Based on different examinations of implementation of gymnastic content in basic schools, different authors have noticed different reasons for their non-implementation. Šturm & Strel (2002) see poor results in the development of muscular strength in arms and shoulders as a consequence of negligent attitude toward gymnastic elements in training programmes and superficial attitude toward systematic and holistic development of basic movement abilities. Strel, Kovač & Jurak (2004) have found that in recent decades there has been a very significant decline in the arm and shoulder strength, specifically 20% per decade. Exercises on bars are especially effective in building up strength in arms and shoulders. Kovač (2006, pp. 11-

18) has noticed that teachers apparently do not teach certain contents or teach them on a very limited scale as pupils do not meet the standards recommended by the curriculum (Kovač & Novak, 2001). Some authors (Majerič, 2004; Šturm & Strel, 2002) note that teaching is not systematic and results of some research studies show that teachers in the first and the second three-year cycle spend too few lessons on gymnastics which leads to very modest knowledge of gymnastics in children (Majerič, 2004; Štemberger, 2003). Teachers in the third cycle also spend too few lessons on gymnastics (Turšič, 2007). Children find it easiest to learn gymnastic elements in the first years of school, whereas later they need many repetitions to automate more complex movements (Tušak, 1994). This can only be achieved if the learning process is appropriately organised with sufficient number of lessons, optimal teaching techniques and appropriate methodical procedures (Kovač, 2006).

Results (Table 2) also show that there are fewer performances of elements on the beam. Elements on the beam in the current curriculum are only aimed at girls which is a serious deficiency as the beam works as a key apparatus in the learning of body control and correct posture regardless of the child's sex (Bučar Pajek, 2009). In sports today, proprioceptive training is performed in order to improve muscular coordination, posture and balance, to improve body awareness in the space and to subsequently become less prone to injuries. All current training programs for adults are based on proprioceptive training and body stabilization as this type of training counterbalances the consequences of the modern sedentary lifestyle and prevents lower back pain (Bučar Pajek & Pajek, 2009). In its narrow sense, proprioception is defined as the ability of the body to consciously and subconsciously recognise the relative position of neighbouring parts of the body in the space (Enoka, 1994). This type of training consists of various balancing exercises. On the beam, the supporting surface is reduced and the body finds itself in unstable positions. By devising exercises that enable advancement from easy to more demanding and from known to unknown, training can remain interesting while broadening the pupil's movement skills. Balancing exercises can be very effective, low energy and great fun and can be used in the preparatory, main or the final part of a physical education lesson. It is therefore highly recommended that teachers teach balancing exercises both to girls and to boys. They can be used in the introductory or the end part of the lesson regardless of the objective of the main part of the lesson (track and field, basketball, gymnastics, volleyball, handball, football, dance, etc.).

In our survey, special attention was paid to the implementation of gymnastic contents and movements (Table 3) which are not included in the PE curriculum in the third cycle - they are, however, included in the curriculum for the first years of basic school and play an important role in the methods by which some gymnastic elements are taught. *Preparatory exercises* can significantly impact the child's movement abilities which are important for teaching gymnastic contents. *Pre-exercises*, on the other hand, can teach pupils exercises related to the structure or part of the structure of the chosen element and are selected by the teacher as a means of teaching new contents.

Gymnastics offers a wealth of locomotive, stability and control movements. Pupils in all three cycles learn basic elements that are important, especially for one's orientation in the space (jumps and leaps, hanging and supporting oneself, rotating, crawling, rolling; elements can be performed in different directions and on different levels). These elements can later be upgraded by more complex movements on apparatus and by using different aids. Gymnastic contents in school programmes do not only entail learning elements of acrobatics, exercises on apparatus, elements of rhythmic gymnastics and jumps on small trampoline, but also learning about gymnastic exercises and their importance for the development and maintenance of human movement abilities and good posture (Kovač, 2006).

The presence of zero curriculum is noticeable in a dramatic decline in the implementation of preparatory exercises in years 7 to 9 (vertical bar climbing, rope climbing, ladder climbing and bunny jumps) and indicates that as children grow and become older, teachers progressively leave out certain elements from the gymnastic content. They probably think that children have already mastered such elements and therefore find them too easy (ladder climbing, bunny jumps) or too difficult (rope and vertical bar climbing) at this age. The objective of preparatory exercises is to maintain or improve children's movement ability levels (Čuk, Bolković, Bučar Pajek, Turšič, & Bricelj, 2006). Climbing demands from the child the highest degree of good physical condition. Climbing requires strength of the flexing muscles in the arms and a certain level of movement coordination as the child needs to wrap the rope around his or her feet or to find support on the vertical bar and coordinate the movement of legs and arms while climbing; climbing requires courage and perseverance to reach the top and then safely climb down the vertical bar or the rope. The problem occurs when children, due to insufficient strength in the arms and shoulders, are unable to climb. They are usually able to hang onto the rope or the vertical bar for a moment and then, due to insufficient strength or fear of falling, give up in this position rather than make an attempt to climb higher. In such cases, the teacher must distinguish between exercises for arm flexing and extending. For muscles that flex arms, the following preparatory exercises should be selected: vertical bar climbing, ladder climbing, wall climbing or rope climbing. Muscles that extend arms can be strengthened by preparatory exercises which require support: bunny jumps, cartwheel, standing front and back support walking moving forward and backward (perhaps as a catch-up game), etc. In this age group, it is particularly important that teachers insist on the performance of simple organic forms of movements, preparatory exercises and exercises to strengthen specific groups of muscles as this is the only way to successfully maintain or even improve the level of children's movement abilities.

Gymnastics in basic school positively impacts on specific dimensions of psychosomatic status of children and adolescents only if the training is well planned, professionally managed, pedagogically conducted and goal oriented. The teacher must be able to guide children's interests and to align them with educational premises and objectives of physical education in particular in order to provide quality education. In order to facilitate successful learning, the teacher must continuously update his or her knowledge. Understanding the importance of gymnastics for the development of a school child is not enough; in order to realise educational objectives it is necessary to implement the gymnastics programme in such a way that gymnastic contents are implemented in all stages. The teacher is the one who can adapt, in accordance with his or her knowledge and understanding of a particular sport discipline, the training programme to the given conditions, situation and the child's abilities. This is how children learn to understand a specific sport discipline as a whole, adopt it and implement it in their own free time.

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APPARATUS DIFFICULTY IN GROUPS ROUTINES OF ELITE RHYTHMIC GYMNASTICS AT THE PORTIMÃO 2009 WORLD CUP SERIES

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Original research article

Abstract

The aim of this study was to establish whether a pattern exists in the type of apparatus specific elements chosen by elite rhythmic gymnastics groups. Twenty six group exercise routines (5 hoops, and 3 ribbons and 2 ropes) performed by thirteen groups at the Portimão 2009 World Cup Series gymnastics competition were analysed. Results: (a) mastery and risk with throw: (i) all groups preferred using throws during a body flight; (ii) in the 3 ribbons and 2 ropes routines the use of catches during an element with rotation was most common, whilst in the 5 hoops routines catches without the help of the hands were used most frequently; (iii) compulsory rotations were the most commonly used elements in the 5 hoops routines, whereas the additional rotation was preferred in the 3 ribbons and 2 ropes routines. (b) mastery without throw: (i) rotations and handlings were the most frequently used elements in the 5 hoops routines whilst snakes & spirals were preferred in the 3 ribbons and 2 ropes routines; (ii) there were no records of risk without throw. (c) with regard to collaborations (COLL) the most frequently used were the COLL RR1 (these include a large throw with risk of loss of visual contact with the apparatus during its flight, as well as passing over, below or through one or several apparatus or other gymnasts during the flight of the apparatus) in the 5 hoops routines and the COLL with throw in the 3 ribbons and 2 ropes routines. This study demonstrates that it is possible to broadly identify and describe patterns of element use for each apparatus type for 5 hoops, and 3 ribbons and 2 ropes routines.

Keywords: *rhythmic gymnastics, group routines, apparatus difficulty score, evaluation, performance.*

INTRODUCTION

The first time rhythmic gymnastics (RG) groups participated in the Olympic Games was at the 1996 games in Atlanta. Since then, the standard of group performance has increasing improved. These improvements have always been ruled by the modifications in the FIG code of points. The performances in RG competitions are evaluated by a final score composed from 3 sub-scores: difficulty (which includes both body difficulty (D1) and apparatus difficulty (D2)), artistic, and execution.

The RG performance requirements of the FIG (International Gymnastics Federation) are closely linked to the code of points (CP). As the CP changes every Olympic cycle, so do the routine requirements, which become more demanding and increasingly difficult.

The increasing difficulty of RG competition exercises is what characterizes the development of RG (Lisitzkaya, 1995). In group exercises this author states that success is achieved when there is a high level of movement synchrony, proper distribution of movement in space, and a balanced conceptual and emotional expression of the different group formations. The current trends in the composition of exercises are, according to Avilés (2001): a) an increase in the variety of both body and apparatus movements (this is determined by the search for new elements and combinations, as well as by the exploration of the movement in its totality); b) a search for originality; c) an increase in the quantity of complex elements (with increasing levels of difficulty associated with each Olympic cycle); d) a decrease in connecting moves with no technical difficulty or complexity; e) a high level of technical skill in handling the various apparatus together with a high percentage of efficacy in the execution of specific technical elements; f) the development of a strong identity, based on the individual or group characteristics; g) the careful selection of music taking into account the specific interpretation given by the gymnasts; h) an increase in the number of risk and outstanding elements in the composition of the exercises; and finally i) the increase in artistic value of the composition.

The main problem regarding the final score is concerned with the apparatus difficulty score (Lebre, 2007). The latest modifications to the CP state that apparatus difficulty is a crucial element in performance assessment, and so this element now has a greater impact on the final score.

The authors believe that the understanding of the demands posed by the RG CP and the observation of the performances of high level group competitions will give a new insight into RG and the strategies used in the composition of exercise routines in high level competitions. With this in mind, we analysed the composition forms submitted by the competing groups at the 2009 World Cup in Portimão (Portimão/09-WC), Portugal. The compulsory provision of competition forms containing a description of the difficulty of the exercises (introduced in FIG, 2001) has encouraged more rigorous scoring (Ávila, 2001).

The aim of this study is to identify patterns in the choice of apparatus specific elements in high level RG groups and therefore make an assessment of the apparatus difficulty (D2).

METHODS

Analysis of the apparatus specific elements included in the routines was carried out using competition forms that each group has to provide prior to the competition. We opted for the use of these forms instead of video recording, CD or .avi captures because by doing this we ensured that the analysis would not be affected by mistakes made during the group's performance in the competition. Firstly, we investigated the differences between the type of D2 difficulty categories used in the composition of the exercises (5 hoops, and 3 ribbons and 2 ropes). The classification used to organise the different D2 difficulty categories was the official classification used in the FIG Code of Points (FIG, 2009). Thus, the authors have divided the apparatus elements into three main categories: 1. *mastery and risk with throw*, 2. *mastery and risk without throw*, and 3. *collaborations amongst the gymnasts*. In addition to this we carried out further analysis into the use of various possible elements within each of these three categories in the composition of group exercises. Again, the authors used the classification as defined by the FIG/09 CP.

In order to determine the pattern of apparatus difficulty (D2) in RG group exercises, all exercise composition sheets for the RG groups were considered. Data on apparatus specific elements for the 26 group exercise routines for the 13 competition groups performing 5 hoops, and 3 ribbons and 2 ropes exercises were extracted and recorded in a Microsoft Excel spreadsheet. SPSS version 17.0 (Statistical Package for the Social Sciences Version 17.0, Chicago, USA) and Microsoft Excel were used to analyse the data. Significance level was set at $\alpha = 0.05$ (corresponding to a confidence level of 95%).

We used the mean as a measure of central tendency, and the standard deviation as a measure of the spread of the data. In order to make comparisons between the two types of competition exercises (5 hoops versus 3 ribbons and 2 ropes) a nonparametric test (Wilcoxon test) was applied to the data.

RESULTS

The different types of apparatus difficulty (D2) elements were classified according to FIG/09 CP.

The results are presented by D2 element (*mastery and risk with throw, mastery and risk without throw*, and *collaborations amongst the gymnasts*), and by exercise (using 5 identical apparatus – 5 hoops, or using a combination of two different apparatus – 3 ribbons and 2 ropes).

Apparatus Difficulties (D2)

The D2 elements in FIG/09 CP are composed of: (1) *mastery and risk with throw*, (2) *mastery and risk without throw* and (3) *collaborations among the gymnasts.*

Figure one shows the average use and standard deviation of D2 difficulties in both the 5 hoops and the 3 ribbons and 2 ropes routines. The statistical significance of the differences between the choice of D2 elements in the 5 hoops and the 3 ribbons and 2 ropes routines were assessed using Wilcoxon test and the results are displayed in table 1.

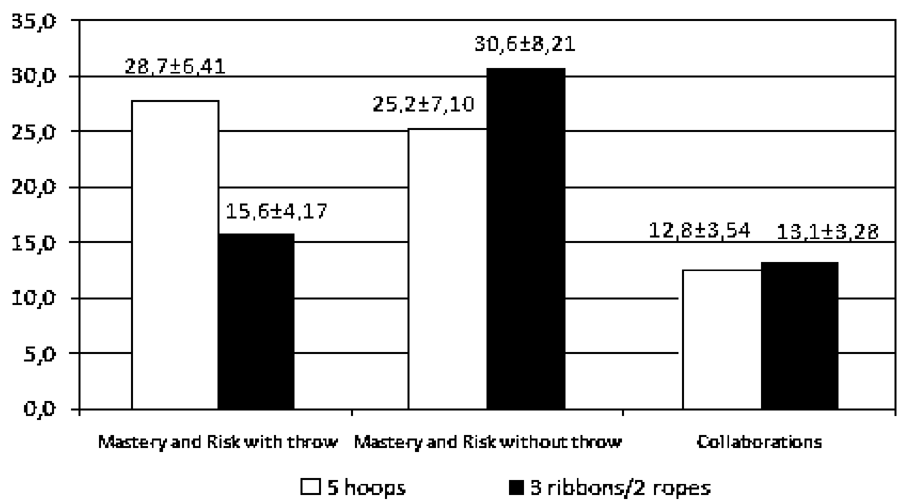

Figure 1. *Average use and Standard deviation of D2 difficulties in the 5 hoops, and 3 ribbons and 2 ropes routines at Portimão/09-WC*

Table 1. *Wilcoxon test results*

D2 (Apparatus difficulties)	Wilcoxon test (p)
Mastery and Risk with throw	0.001*
Mastery and Risk without throw	0.050
Collaborations	0.450

In the 3 ribbons and 2 ropes routines the preferred choice of D2 difficulty was the *mastery and risk without throw* (30.6 ± 8.21) (see figure 1). Nevertheless, there were no significant differences between the choice of this type of difficulty in the 3 ribbons and 2 ropes and the 5 hoops routines ($p = 0.05$) (see table 1). In the case of the 5 hoops routines the *mastery and risk with throw* were the most used D2 difficulty types (28.7 ± 6.41) (see figure 1). There were significant differences between the use of this kind of difficulty in the 3 ribbons and 2 ropes (used less frequently) and the 5 hoops routines ($p = 0.001$) (see table 1). The authors believe the differences in the use of *mastery and risk with throw* in the 3 ribbons and 2 ropes routines when compared to the 5 hoops routines are due to major differences in the demand/skill associated with the manipulation of deformable versus rigid apparatus. In one respect, deformable apparatus (as is the case of ribbons and ropes) are harder to manipulate than the hoops (rigid apparatus). Furthermore, the catches of such throws are also more difficult to execute with deformable apparatus because the apparatus must not lose its shape during the phase of flight and must not accidentally touch the ground when being caught. If any of the above situations occur, the gymnast's score will be penalized by the judges. In addition, the D2 judges may completely disregard the performance and therefore not take it into account for the final D2 score.

D2 difficulties were used least frequently in the *collaborations*, 12.8 ± 3.54 in 5 hoops routines and 13.1 ± 3.28 in 3 ribbons and 2 ropes routines. However, we must note that the use of D2 difficulties in *mastery and risk with throw* and *mastery and risk without throw* can be worth between 0.1 and 0.3 points, and its use in *collaborations* between 0.1 and 0.8 points. Thus, although the use of D2 difficulties is less frequent in *collaborations* it may still contribute to an increased final D2 score (apparatus difficulty).

Mastery and Risk with throw

The *mastery and risk with throw* includes different throw types, catches, and risk with throw.

Mastery with throw

The *mastery with throw* category includes different throw and catch types. Figure 2 displays the average use and standard deviation of the different throw types in both the 5 hoops, and the 3 ribbons and 2 ropes routines. Table 2 shows the results of the Wilcoxon test to establish whether there is a significant difference between the use of the various throw types in the 5 hoops and 3 ribbons and 2 ropes routines.

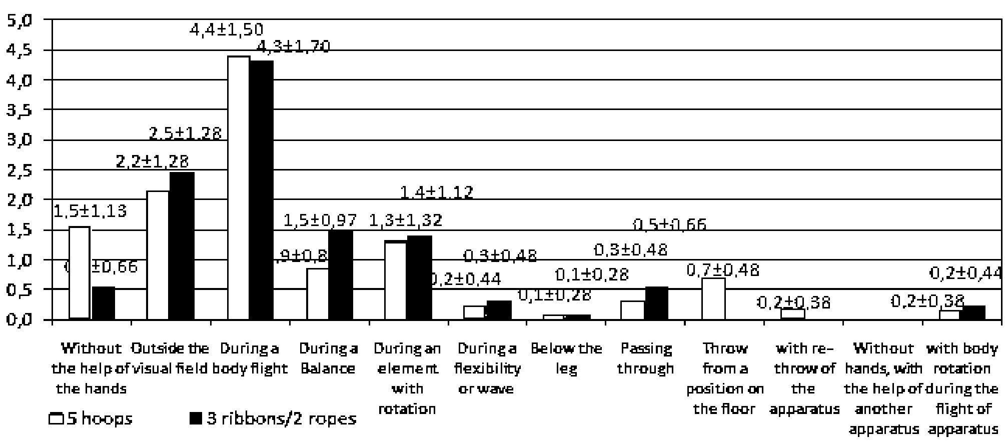

Figure 2. *Average use and Standard deviation of different throw types in the 5 hoops, and 3 ribbons and 2 ropes competition routines at the Portimão/09-WC*

Table 2. *Results of the Wilcoxon tests between the number of throws in 5 hoops, and 3 ribbons and 2 ropes competition routines present in the Portimão/09-WC (Significance level *p<0.05)*

Throw	Wilcoxon test (p)
Without the help of the hands	0.008*
Outside the visual field	0.465
During a body flight	0.805
During a Balance	0.057
During an element with rotation	0.791
During a flexibility or wave	0.564
Below the leg	1.000
Passing through	0.046*
Throw from a position on the floor	0.414
With re-throw of the apparatus	0.157
Without hands, with the help of another apparatus	1.000
With body rotation during the flight of apparatus	0.564

Figure 2 shows that in both types of routines *throws during a body flight* were most frequently used (4.4 ± 1.50 in 5 hoops routines and 4.3 ± 1.70 in 3 ribbons and 2 ropes routines). Furthermore, table two shows that there are no significant differences between the average use of this kind of throw in both types of routines (p = 0.805). This may be due to the fact that of all the different types of body difficulties (jumps, balances, pivots and flexibility/waves) jumps are most frequently used in the compositions of the groups routines in PWC 2009 (Avila-Carvalho et al., 2009c). We believe that the *throw during a body flight* is relatively easy to perform and may allow the performance of additional types of throws such as *outside the visual field*, *without the help of the hands*, and in this case the throw would be worth 0.3 instead of 0.1 points.

The second most common way to execute the throws in both routines were *outside visual field throws* (2.2 ± 1.28 in 5 hoops routines and 2.5 ± 1.28 in 3 ribbons and 2 ropes routines). Once again there were no significant differences between the average use of this kind of throw in the two types of exercise routine (p = 0.465) (see table 2). The throw types where statistically significant differences occurred between 5 hoops, and 3 ribbons and 2 ropes routines are as follows: (1) *throw without the help of the hands* (p = 0.008),which is a type of throw easily executable with the hoops as these do not loose shape during flight (unlike what happens with deformable apparatus such as ribbons and ropes) and hence is used more in the 5 hoops routines; (2) *passing through throw* which is more frequently used in the 3 ribbons and 2 ropes routines (p = 0.046) due to the dimension of the type of apparatus.

Figure 3 displays the average use and standard deviation of different catching types in the 5 hoops, and 3 ribbons and 2 ropes routines. Table 3 summarizes the statistical significance of the differences between average use of the various catches in the 5 hoops, and 3 ribbons and 2 ropes routines (again, assessed using a Wilcoxon test).

Looking at figure 3 we can conclude that during the 3 ribbons and 2 ropes routines the use of *catches during an element with rotation* was used most frequently (1.2 ± 1.30). Its use was significantly greater in the 3 ribbons and 2 ropes routines than the average use in the 5 hoops routines (p = 0.028) (see table 3). In the case of the 3 ribbons and 2 ropes routines we observed that the criteria *during an element with rotation* is usually associated with a body flight or performed *during a flexibility*, so it is a possible way to increase the D2 score because it adds 0.1 points to the initial score.

In the 5 hoops routines the use of *catches without the help of the hands* was used most frequently (2.3 ± 1.55). This kind of catch was not used in the 3 ribbons and 2 ropes routines and hence there is an obvious significant difference between the use of this type of catch in the two types of routines (see table 3, p = 0.003). This probably happens because the hoop *catches without the help of the hands* may be done in different ways that are not difficult to perform, such as *through catches between the legs*, *from a floor position,* or even *standing or catching it on the leg with hoop rotation*. Any of these situations would be worth 0.2 points without a great risk of loss of the apparatus. It is therefore not surprising that the 3 ribbons and 2 ropes routines did not make use of these types of catches as the catches of a deformable apparatus with the help of the hands would be difficult and risky. The apparatus catches must be executed without technical mistakes and this is monitored by Execution and D2 judges (FIG/09 CP).

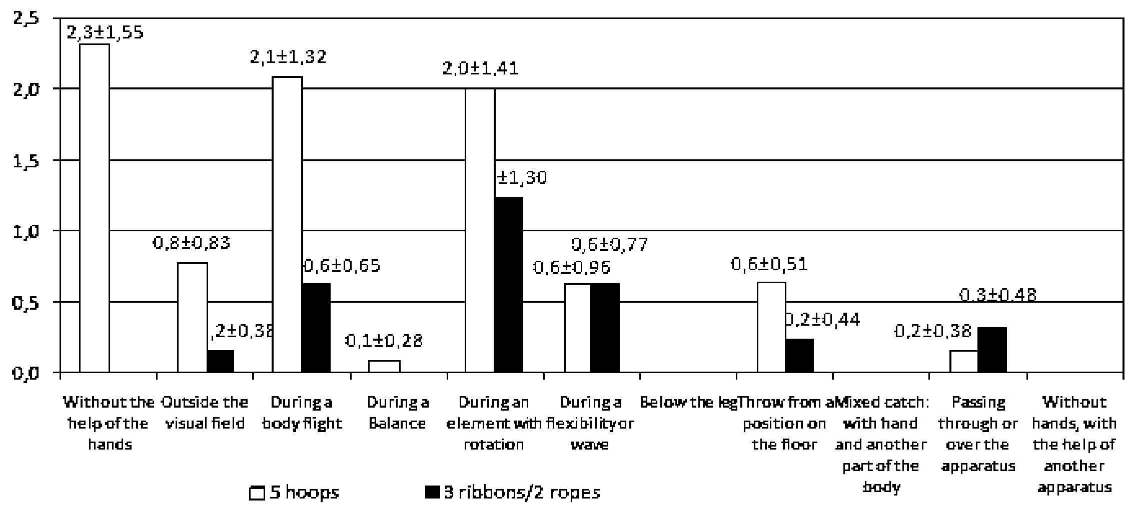

Figure 3. *Average use and standard deviation of the different catch types in 5 hoops, and 3 ribbons and 2 ropes routines performed at the Portimão/09-WC competition*

Table 3. *Results of Wilcoxon tests assessing the different types of catch used in 5 hoops, and 3 ribbons and 2 ropes competition routines at the Portimão/09-WC (Significance level *p<0.05)*

Catches	Wilcoxon test (p)
Without the help of the hands	0.003*
Outside the visual field	0.033*
During a body flight	0.006*
During a Balance	0.317
During an element with rotation	0.028*
During a flexibility or wave	0.931
Below the leg	1.000
Throw from a position on the floor	0.025*
Mixed catch: with hand and another part of the body	1.000
Passing through or over the apparatus	0.414
Without hands, with the help of another apparatus	0.157

Risk with throw

The risks with throw must comprise of at least the two following basic actions: (i) during the flight of the apparatus, a minimum of 1 element, with rotation of the body on the vertical or horizontal axis, with or without passing on the floor; (ii) during the catch of the throw, loss of visual contact with the apparatus during or immediately at the end of an element with body rotation on the horizontal axis (FIG/09 CP).

Figure four shows the average use and standard deviation of the number of body rotations in risks with throw in both type of group routines (5 hoops, and 3 ribbons and 2 ropes routines). Table four summarises the statistical significance of the differences between the average number of body rotations in risks with throw in 5 hoops, and 3 ribbons and 2 ropes routines (using a Wilcoxon test).

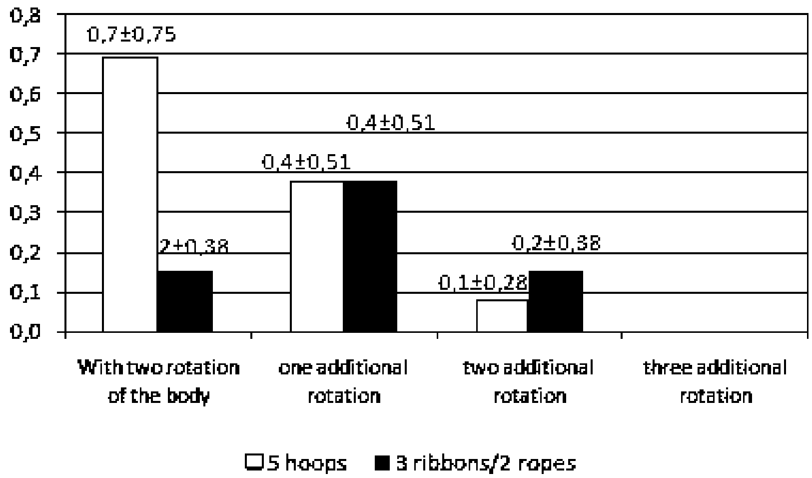

Figure 4. *Average use and standard deviation of number of body rotations in risks with throw in both type of group routines (5 hoops, and 3 ribbons and 2 ropes routines) performed at the Portimão/09-WC competition*

Table 4. *Results of the Wilcoxon tests to the mean use of number of body rotations in 5 hoops, and 3 ribbons and 2 ropes competition routines at the Portimão/09-WC (Significance level *p<0.05)*

Body rotation type	Wilcoxon test (p)
With two rotation of the body	0.038*
One additional rotation	1.000
Two additional rotations	0.564
Three additional rotations	1.000

From the observation of figure four we can see that in the 5 hoops routines the *compulsory rotations* (2 in total) in risk with throw (0.7 ± 0.75) were predominantly used. The use of such rotations was significantly higher (p = 0.038) than that in 3 ribbons and 2 ropes routines (see table 4). In the 3 ribbons and 2 ropes routines the more frequently used rotation type was the *one additional rotation* in risks with throw (0.4 ± 0.51). In this case the majority of the risks have been carried out with three body movements with rotations. The fact that the rope and ribbon are both lighter apparatus means that the respective flight times are a little longer and that allows the gymnasts more time to perform extra body elements. Despite this there were no statistically significant differences in the use of these rotations between the two types of exercise routine.

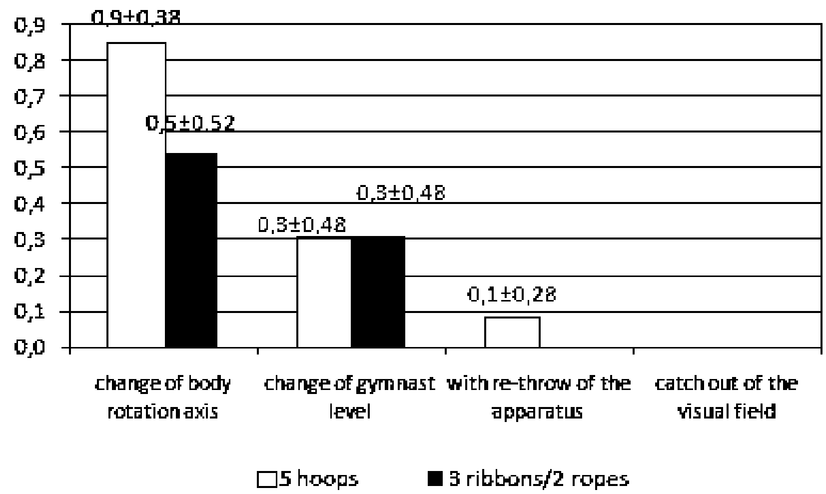

Figure 5. *Average use and standard deviation of additional criteria in risks with throw in both types of group routine (5 hoops, and 3 ribbons and 2 ropes routines) performed at the Portimão/09-WC competition*

Table 5. *Results of Wilcoxon tests between the average use of additional criteria in the 5 hoops, and 3 ribbons and 2 ropes competition routines at the Portimão/09-WC (Significance level *p<0.05)*

Additional criteria type	Wilcoxon test (p)
Change of body rotation axis	0.046*
Change of gymnast level	1.000
With re-throw of the apparatus	0.317
Catch out of the visual field	1.000

From figure five we can see that in the 3 ribbons and 2 ropes, and the 5 hoops routines the *change of body rotation axis* is the most frequently used criteria in both routines, with 0.9 ± 0.38 in 5 hoops routines and 0.5 ± 0.52 in 3 ribbons and 2 ropes routines, but with statistically significant differences between the two types of exercise routines (p = 0.046) (see table 5). When the gymnasts perform the first rotation on the vertical axis this corresponds to a bonus of 0.1 points in the final risk score, in our opinion a relatively simple way to increase the risk score.

Mastery and Risk without throw

The Mastery and Risk without throw includes: *mastery without throw* and *risk without throw*.

Mastery without throw

Figure six shows the average use and standard deviation of each individual mastery without throw categories in 5 hoops routines performed at the Portimão/09-WC. Table six shows the results of the application of Wilcoxon tests to the average use of the various *Mastery without throw* categories in 5 hoops routines.

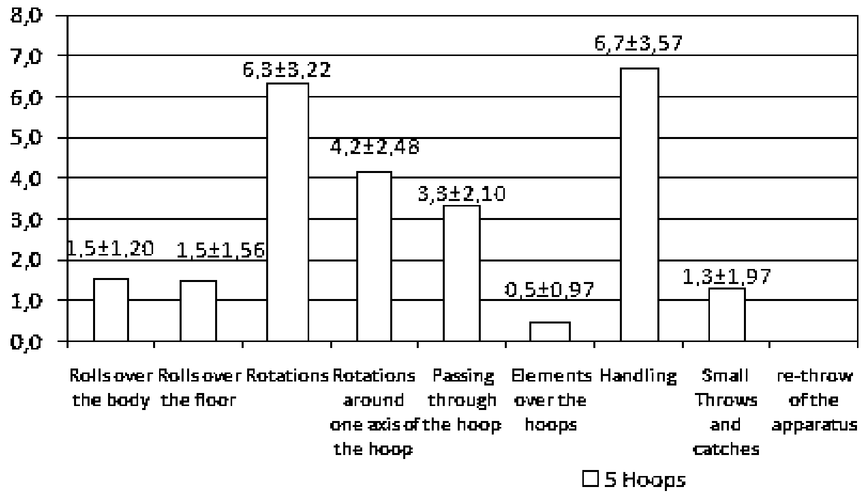

Figure 6. *Average use and standard deviation of each individual Mastery without throw category in the 5 hoops routines performed at the Portimão/09-WC.*

Table 6. *Results of the application of Wilcoxon tests to the average use of the various Mastery without throw categories in the 5 hoops routines performed at the Portimão/09-WC (Significance level *p<0.05)*

Mastery without throw - Hoops/Wilcoxon test (p)	ROF	ROT	RA	PT	O	H	STC	RT
Rolls over the body (ROB)	0.810	0.001*	0.008*	0.008*	0.046*	0.002*	0.680	0.003*
Rolls over the floor (ROF)		0.001*	0.008*	0.240	0.106	0.002*	0.918	0.011*
Rotations (ROT)			0.113	0.280	0.001*	0.554	0.003*	0.001*
Rotations around one axis of the hoop (RA)				0.501	0.002*	0.092	0.027*	0.001*
Passing through the hoop (PT)					0.004*	0.005*	0.020*	0.002*
Elements over the hoops (O)						0.001*	0.206	0.109
Handling (H)							0.001*	0.001*
Small Throws and catches (STC)								0.042*
Re-throw of the apparatus (RT)								

From figure six we can see that the *rotations* (6.3 ± 3.22) and the *handling elements* (6.7 ± 3.57) were the most frequently used types in the 5 hoops routines. The use of these two types of *mastery without throw* in the 5 hoops routines is significantly greater than that of all the remaining categories (see table six). The handlings were also the most performed apparatus elements in the hoops routines at the Portimão/08-WC (Ávila-Carvalho et al., 2009a).

The FIG/09 CP encourages the diversification of the apparatus mastery and states that the gymnasts have to achieve this during the performance of body difficulties. This is perhaps why in the Portimão/08-WC there was less variety in apparatus working (essentially composed of handlings in the 5 hoops routines performed). The *rotations* are a means of diversifying the work with the apparatus, though still technically relatively easy to use during the performance of body elements (Cardoso, 2009) and thus were quite commonly used in the compositions observed.

It is also a fact that no group in the World Cup at Portimão 2009 used a *re-throw of the apparatus* as a way of introducing variation in the use of the apparatus.

Figure seven shows the average use and standard deviation of each individual *Mastery without throw* category in the 3 ribbons and 2 ropes routines performed at the Portimão/09-WC. Table seven shows the results of the application of Wilcoxon tests to the average use of the various *Mastery without throw* categories in the 3 ribbons and 2 ropes routines.

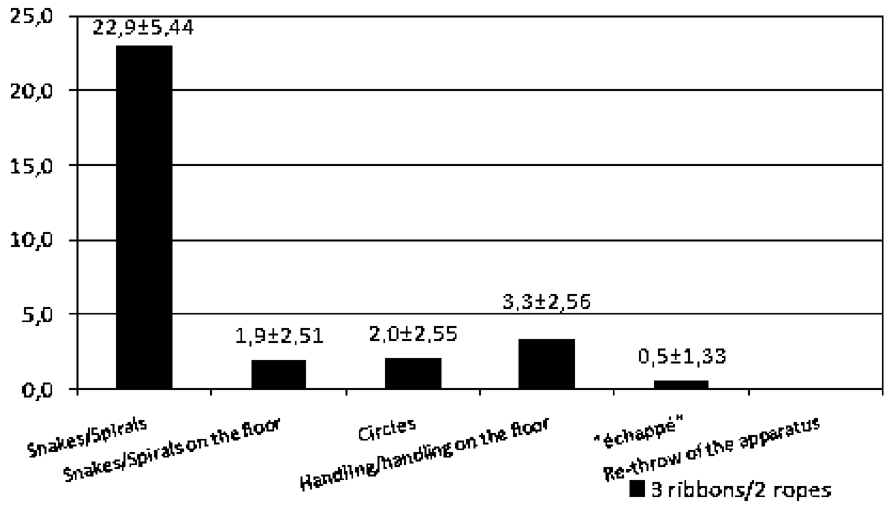

Figure 7. *Average use and standard deviation of each individual Mastery without throw category in 3 ribbons and 2 ropes routines performed at the Portimão/09-WC*

Table 7. *Results of the application of Wilcoxon tests to the average use of the various Mastery without throw categories in 3 ribbons and 2 ropes routines performed at the Portimão/09-WC (Significance level *p<0.05)*

Mastery without throw - ribbons/Wilcoxon test (p)	SF	CI	H	E	RT
Snakes/Spirals (S)	0.001*	0.001*	0.001*	0.001*	0.001*
Snakes/Spirals on the floor (SF)		0.858	0.154	0.090	0.027*
Circles (CI)			0.140	0.049*	0.011*
Handling/handling on the floor (H)				0.005*	0.005*
"Échappé" (E)					0.180
Re-throw of the apparatus (RT)					

From the analysis of figure seven we can observe that the *snakes/spirals* were the most frequently used apparatus element in the 3 ribbons and 2 ropes routines (22.9 ± 5.44). The use of this type of *mastery without throw* in the 3 ribbons and 2 ropes routines is significantly greater to that of all the remaining categories (see table seven).

The FIG/09 CP states that in order to contribute to the difficulty score, body difficulties must be executed simultaneously with apparatus mastery elements. The *snakes/spirals* are the easiest way to achieve this in 3 ribbons and 2 ropes routines (particularly due to the nature of one of the apparatus involved; the ribbons). We believe, therefore, that this is the reason why these elements are preferred, and hence the lack of diversity observed in the choice of the different types of element in this category despite the FIG/09 CP encouraging diversification.

Risk without throw

According to FIG/09 CP the *risk without throw* always includes a rolling of the apparatus on the body during a body rotation around the horizontal axis, with loss of visual contact with the apparatus.

The value of the risk may increase as follows: with passing on the floor during a body rotation; with re-throw/push-back of the apparatus, and with criteria associated with mastery without throw. There were no records of any risk without throw in both routines (5 hoops, and 3 ribbons and 2 ropes routines).

In the 3 ribbons and 2 ropes routines this is more obviously the case because, as we mentioned, the risk without throw always includes a rolling of the apparatus on the body, and this is not possible to execute with either ribbons or ropes. In the case of the 5 hoops routines we believe that this is a more difficult element (due to the high probability of dropping the apparatus) when compared to the risk with throw; and both generate the same amount of points.

Collaborations

The use of collaboration elements is summarised in figure eight. The categories considered are in accordance with the FIG/09 CP.

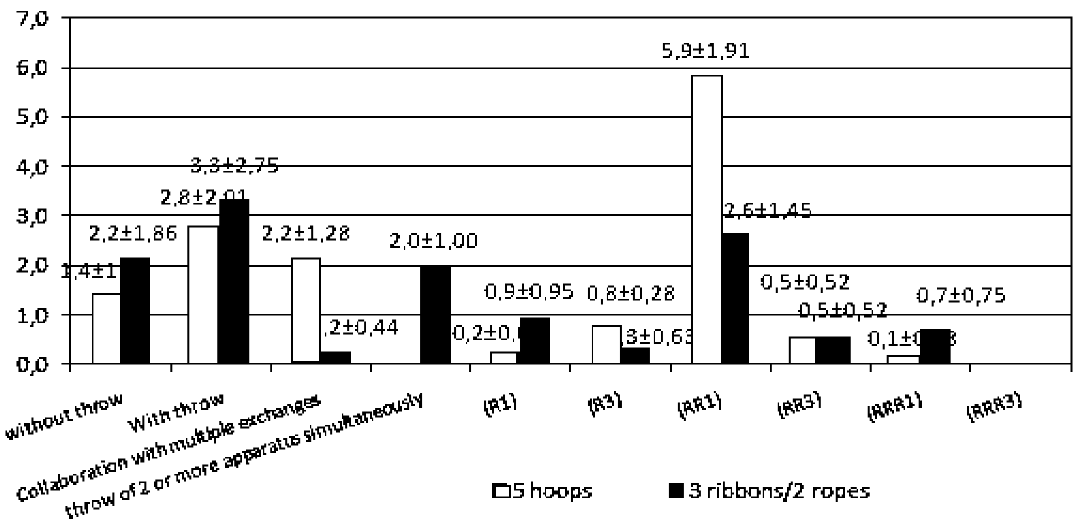

Figure 8. *Average use and standard deviation of the collaboration types in 5 hoops, and 3 ribbons and 2 ropes routines performed at the Portimão/09-WC*

Table 8. *Results of the Wilcoxon tests between the average use of the various collaboration types in 5 hoops, and 3 ribbons and 2 ropes routines performed at the Portimão/09-WC. (Significance level *p<0.05)*

Collaborations	Wilcoxon test (p)
Without throw	0.282
With throw	0.444
Collaboration with multiple exchanges	0.083
Throw of 2 or more apparatus simultaneously	0.889
(R1)	0.047*
(R3)	0.257
(RR1)	0.001*
(RR3)	1.000
(RRR1)	0.033*
(RRR3)	1.000

From figure 8 we can see that the preferred collaborations were the *collaborations RR1* in the 5 hoops routines (5.9 ± 1.91). *Collaborations RR1* include a long throw (double the height of the gymnast), a risk associated with the loss of visual contact with the apparatus during its flight, and passing above, below or through one or several apparatus or other gymnasts during the flight of the apparatus). These collaborations were used significantly more during the 5 hoops routines than in the 3 ribbons and 2 ropes routines ($p = 0.001$) (see table 8). The *collaborations with throw* was the most frequently used in the 3 ribbons and 2 ropes routines (3.3 ± 2.75). There were no statistically significant differences in the use of this type of collaboration between the two types of exercise routine ($p = 0.444$) (see table 8). The *collaborations with throw* add 0.2 points and the *RR1* add 0.5 points to the final score. This shows that coaches have a tendency to choose collaborations that are higher in risk, therefore generating higher scores in the 5 hoops routines.

We did not record any *collaboration RRR3* in either the 5 hoops or in the 3 ribbons and 2 ropes exercise routines. *Collaborations RRR3* include a throw with risk of loss of visual contact with the apparatus during its flight and passing through the apparatus, in flight, whilst the apparatus is neither being held by another gymnast nor by the gymnast passing through.

According to Ávila-Carvalho et al. (2009b) there was also no record of this kind of collaboration at the Portimão/08-WC. However at the Portimão/07-WC there were two groups that performed this kind of collaboration (Brazil and Venezuela).

CONCLUSIONS

In light of the results obtained in this study we can conclude that:

For *mastery and risk with throw* the groups preferred the higher score associated with using *throws during a body flight* for both types of apparatus. (a) In 3 ribbons and 2 ropes routines catches *during an element with rotation* were most frequently used (the application of the Wilcoxon tests demonstrated that there is a statistically significant difference in the average use of this type of difficulty between the two types of exercise routine).In the 5 hoops routines the use of *catches without the help of the hands* was most common, again with statistically significant differences in the average difficulty use between both types of exercise routines. Regarding *risks with throw* in 5 hoops routines the *compulsory rotations* (2 in total) were used most often, though this was not the case in the 3 ribbons and 2 ropes routines where the preferred element was *one additional rotation* in risks with throw (3 in total). Furthermore in risk with throw in 3 ribbons and 2 ropes and 5 hoops routines the *change of body rotation axis* was the most commonly used element in both routines, despite the fact that there are statistically significant differences in the use of this element between the two types of exercise routine.

For *mastery and risk without throw* the *rotations* and the *handling elements* were the most frequently used apparatus elements in the 5 hoops routine. The use of these types of elements in the 5 hoops routines was significantly greater than the remaining types within this category. In the 3 ribbons and 2 ropes routines the *snakes/spirals* were the most frequently used elements. Again, the use of this type of element in the 3 ribbons and 2 ropes routines was significantly greater than the remaining types within this category. There was no record of any risk without throw in the 5 hoops, and the 3 ribbons and 2 ropes routines.

Finally, the most frequently used *collaborations* were: (a) the *collaborations RR1* in the 5 hoops routines (its use being significantly greater when compared to the use in the 3 ribbons and 2 ropes routines) and (b) the *collaborations with throw* in the 3 ribbons and 2 ropes routines.

In general terms we can say that there is a broad trend for each kind of apparatus, but this trend is not the same for the two types of exercise within the same group.

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MANUAL GUIDANCE IN GYMNASTICS: A CASE STUDY

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Original research article

Abstract

Although the use of manual guidance in gymnastics is widely spread, little is known about the effects of this technique on movement kinematics. The goal of this case study was to evaluate the effects of two manual guidance procedures on movement kinematics of a back handspring and a back tuck somersault following a round-off on the floor. Based on assumptions of high-level coaches it was predicted that the sandwich-grip would have different effects on movement kinematics in both skills than the iliac crest/thigh-grip. We analyzed performance of n = 6 female gymnasts in the two skills with and without guidance. Manual guidance had significant effects on different kinematic parameters in both skills. From our results we concluded, that the sandwich-grip should be applied in the first instance if the coach's interest is to optimize the angular momentum about the somersault axis and the second flight phase in the back handspring. The optimal guidance procedure in the round-off back tuck somersault routine would be a mixture of both, the sandwich-grip and the iliac crest/thigh-grip.

Keywords*: *sandwich-grip, iliac crest/thigh-grip, movement kinematics, back handspring, back tuck somersault.

INTRODUCTION

A technique frequently used in teaching complex skills in gymnastics is guidance, which means physically, verbally, or visually directing a learner through a task performance (Schmidt & Lee, 2005; Wulf & Shea, 2002). Although gymnasts encounter all guidance types regularly throughout their career, manual guidance (also referred to as "spotting") is thought to be essential during the learning process in gymnastics (Arkaev & Suchilin, 2004; Dowdell, 2010). The learner is assisted by the hands of the coach who pushes or pulls the learner through the sequence or through specific parts of the task (Knudson & Morrison, 2002). Because guidance can be adjusted according to the learner's stage of skill and the experience of the coach, it is an adaptive procedure providing physical support, assistance, or assurance as a result of the physical force the coach applies to the learner (Arkaev & Suchilin, 2004).

When *supporting* the learner, the coach applies forces on the learner that most often influence the mechanics of the movement. When *assisting* the learner, the forces applied are reduced and the hands of the coach are in slight contact with the learner. When the learner progresses in skill execution, guidance is mainly used to *assure* the skill at hand, like for instance stabilizing specific phases of a skill or taking appropriate action in case of an unplanned fall (Sands, 1996). The transitions between the three forms of manual guidance are smooth, depending on the level of mastering the skill and the experience of the coach.

Guidance in daily gymnastics training is normally used in a way that the coach tries to *optimize* the current movement of the gymnast in an attempt to reduce errors or to dispel the learner's fear (Arkaev & Suchilin, 2004; Schmidt & Lee, 2005). Using guidance to optimize the current movement will, by definition, have strong effects on movement kinematics because the coach will either support or assist the gymnast. Because less is known about these effects in complex skills in gymnastics, the aim of this study was to evaluate the effects of two manual guidance procedures on movement kinematics in two floor routines, a round-off with a back handspring, and a round-off with a back tuck somersault.

The effects of manual guidance on performance in the acquisition and transfer of motor skills can be explained by the *specificity of learning hypothesis* (Schmidt & Lee, 2005). According to this hypothesis, the best learning experiences are those that approximate the movement components, including for instance sensory feedback of the target skill. It is suggested, that motor learning involves a sensorimotor representation, which integrates central processes and motor components with sensory information available during practice (Proteau, 1992; Mackrous & Proteau, 2007). This representation results in specificity during transfer when guidance is removed, such that performance is optimized when the conditions during transfer match the conditions during practice.

Work on the effects of either physical or manual guidance in more complex skills in gymnastics has been done by McAuley (1985), Heinen, Pizzera and Cottyn (in press), and Rosamond and Yeadon (2009). In McAuley's experiment, 39 participants learned a dive forward roll mount onto a balance beam from a springboard in one of three conditions (aided modeling, unaided modeling and control). Participants were given verbal feedback and manual guidance in the aided modeling group but no manual guidance in the other two groups. McAuley (1985) could show that guided participants enhanced their movement quality when guidance was removed. However, the author did not assess kinematic parameters of the movement.

Heinen et al. (in press) had 26 gymnasts learn the cartwheel on the balance beam and another 26 gymnasts learn the forward somersault as a dismount from the balance beam under either a guidance condition or a no-guidance condition. The authors could show that manual guidance had a significant effect on performance in the somersault but not in the cartwheel. This effect manifests itself in later steps of a methodical progression and in a transfer test. However, the authors assessed performance by means of an expert rating but did not analyze kinematic parameters of the two skills.

Rosamond and Yeadon (2009) constructed a training aid to assist the learning process of a backward handspring in gymnastics. The authors had one novice gymnast learn the back handspring and another novice gymnast relearn the skill with the training aid. The authors state, that gymnast A progressed faster in acquiring the back handspring than the rest of the training group and gymnast B showed an observable improvement in technique that occurred also at a faster rate that the rest of the training group. The training aid made gymnasts increase their take-off velocity leading to an optimized trajectory of the center of mass during the flight phase of the back handspring, indicating a short-term effect on movement kinematics. Despite that Rosamond and Yeadon (2009) observed the short-term effects of the training aid, the authors did not provide further kinematic parameters of the back handspring.

Taken the aforementioned results together, one may conclude that manual guidance can be beneficial when used with complex motor skills in gymnastics. The current research suggests that the guidance procedure used may have constrained the optimal number of degrees of freedom necessary for learners, providing them with task-specific sensory information early in practice, leading to better performance in transfer and retention (Proteau, 1992). However, given that guidance is a highly adaptive procedure that can potentially change different kinematic parameters depending on "how" the participant is guided, different guidance procedures could therefore lead to different changes in movement kinematics. These changes could in turn lead to differences in the learning or relearning of the skill. We argue that one need to know the short-term effects of different guidance procedures on movement kinematics before applying them in gymnastics.

We therefore analyzed the effect of two different guidance procedures on movement kinematics in the two routines round-off back somersault, and round-off back handspring on the floor. We have chosen the two routines for two reasons. First, both routines are essential in the learning process in competitive and recreational gymnastics. In recreational gymnastics, both routines are often –at least in Germany– an important part of the compulsory floor routines. In competitive gymnastics, an optimal technique in both routines is a necessary requirement for the development of more complex skills such as a double back somersault. Second, both routines can be guided with the same two guidance procedures, allowing for a comparison of the effect of the two procedures on movement kinematics of the two different routines.

We selected the "sandwich-grip" and the "iliac crest/thigh-grip" as guidance procedures (see method section). In order to generate hypothesis on the effects of manual guidance on movement kinematics, we asked two independent national level coaches (FIG level III license in women's artistic gymnastics) on how both procedures might influence different kinematic parameters. From the interviews of the coaches we hypothesized that both guidance procedures should neither change the time-structure, the somersault angle, nor the moment of inertia about the somersault axis. The iliac crest/thigh-grip should have a stronger effect on angular momentum and the sandwich-grip should have a stronger effect on the velocity of the center of mass. Regarding the round-off back somersault, we assumed, that the two guidance procedures should neither influence the somersault angle, the moment of inertia about the somersault axis nor the angular momentum. Both guidance procedures should have a significant effect on the time-structure and the velocity of the center of mass.

METHODS

Participants

Participants were $n = 6$ female gymnasts from a local gymnastics club, aged 16 to 22 years, with a mean age of 18.2 years ($SD = 2.0$ years). They had a minimum of six years of gymnastics experience with regular practice and participation in regional championships. All participants were informed about the purpose and the procedure of the experiment and provided written informed consent prior to participation. The experiment was carried out according to the ethical guidelines of the German Sport University Cologne. There were no injuries during the experiment.

Tasks and Materials

Experimental Tasks and Guidance Procedures. The first experimental task was a round-off with a following back handspring and a subsequent straight jump on the floor (Figure 1a). The second experimental task was a round-off with a following back tuck somersault on the floor (Figure 1b). Both tasks were performed from a short run-up, as the participating gymnasts would perform them in their daily training.

Manual guidance was provided by a highly trained female gymnastics coach who had over 15 years of experience in providing guidance to gymnasts of different age and skill levels. We instructed the coach to provide manual guidance on an optimal level for each gymnast, depending on her current mastery level of the task at hand. We chose two different guidance procedures, (1) the "sandwich-grip", and (2) the "iliac crest/thigh-grip" (Gerling, 2009).

This was done because both are the most common and well-established procedures when guiding the back handspring or the somersault in both, recreational and competitive gymnastics.

When using the sandwich-grip on the round-off back handspring, the first hand of the coach touches the gymnast's belly during the round-off whilst the second hand touches the iliac crest during the first support. The second hand stays on the iliac crest throughout the whole routine and the first hand leaves the belly in the middle of the first flight phase. It touches the belly again when the gymnast takes-off the floor prior to the second flight phase. The first hand then stays on the belly until the end of the routine. When using the iliac crest/thigh grip on the round-off back handspring routine, the first hand of the coach touches the gymnast's iliac crest during the transition from first support to the first flight phase and stays on the iliac crest until the end of the routine. The second hand touches the back of the thigh immediately after the gymnast takes-off to the first flight phase. The hand leaves the thigh prior to touch-down to second support (see Figure 2).

When using the sandwich-grip on the round-off back somersault, the first hand of the coach touches the belly of the gymnast already during the round-off, whilst the second hand touches the iliac crest during the support phase. The first hand stays on the belly until the gymnast has landed the somersault. The second hand leaves the gymnast's iliac crest immediately before he or she achieves the tucked position and touches the iliac crest again immediately before touch-down of the somersault. When using the iliac crest/thigh-grip on the round-off back somersault, the first hand of the coach touches the iliac crest during the transition from the support phase to the flight phase. The second hand touches the back of the thigh as soon as the gymnast has left the floor. The first hand stays on the iliac crest until the gymnast has landed the somersault. The second hand leaves the thigh immediately before the gymnast achieves the tucked position (see Figure 2).

Because we could not refer to any existing research to generate hypothesis on the effects of manual guidance on movement kinematics, we asked two independent national level coaches (FIG level III license in women's artistic gymnastics) on how both procedures might influence different kinematic parameters. With the help of an independent biomechanist and a top-level gymnastics coach, we chose five categories of kinematic parameters from the movement analysis data that represent the most relevant criteria from a biomechanical point of view. These categories were (1) the time-structure, (2) the velocity of the center of mass, (3) the somersault angle, (4) the moment of inertia about the somersault axis, and (5) the angular momentum about the somersault axis in both routines. These parameters can be used to model gymnastic performance (Knoll, 1999). They can furthermore be used to analyze gymnastic performance in terms of estimating the achievement of the movement goals.

The *time structure* is defined by the relative durations of the support and flight phases as well as distinct events, like take-off or touch-down during these phases. The *velocity of the center of mass* describes the directional change of the center of mass in horizontal and vertical direction. The *somersault angle* is a reliable criterion for the global orientation of the gymnast's body with regard to the horizontal. It was calculated as the angle between the line that joins the middle of the shoulders with the middle of the knees and the horizontal (Brüggemann, Cheetham, Alp & Arampatzis, 1994; Yeadon, 1990). The *moment of inertia* about the somersault axis was used as an indicator of the gymnast's posture. We calculated the moment of inertia about the transverse axis for each video frame following the suggestions by Hay, Wilson, and Dapena (1977) from the horizontal and vertical coordinates of 8 points of a 7-segment model of the human body. The *angular momentum* determines the amount of rotation and was also calculated following the suggestions of Hay et al. (1977). The values of the moments of inertia and the angular momentum were normalized to a body mass of 55 kg and a height of 1.60 m in order to permit comparison among all participants in all conditions (cf., Knoll, 1999; Kwon, 1996). All parameters were calculated with regard to distinct events in the time structure of the two routines (cf., Figure 1).

Regarding the round-off back handspring, both coaches agreed, that both guidance procedures should neither change the time-structure, the somersault angle, nor the moment of inertia about the somersault axis. They hypothesized, that the iliac crest/thigh-grip should have a stronger effect on angular momentum and the sandwich-grip should have a stronger effect on the velocity of the center of mass. Regarding the round-off back somersault, both coaches assumed, that the two guidance procedures should neither influence the somersault angle, the moment of inertia about the somersault axis nor the angular momentum. Both guidance procedures should have a significant effect on the time-structure and the velocity of the center of mass.

Movement Analysis System. An optic movement analysis system was used to determine the movement kinematics on the basis of video sequences of all performances. One digital video camera with a sampling rate of 300Hz was placed 15 meters away from the tumbling track and orthogonal to the movement direction of the gymnasts. The horizontal and vertical coordinates of 8 points (body landmarks) defining a 7-segment model of the human body (cf., Davlin, Sands & Shultz, 2004) were recorded for each frame using the movement analysis software WINanalyze 3D (Mikromak, 2008). We applied a digital filter (cut-off frequency = 6 Hz) for data smoothing and calculated a mean temporal error of ±0.0033 s and a mean spatial error of ±0.006 m. Body-segment parameters were calculated on the basis of the individual anthropometric properties of each participant (Yeadon & Morlock, 1989). To evaluate the reliability of the 7-segment model, we calculated the vertical acceleration of one gymnasts' center of mass in the after flight of a somersault sequence that was recorded with the same camera setup as mentioned above. Because the vertical acceleration should represent the gravitational acceleration, it is seen as a reliable indicator to evaluate kinematic data (Enoka, 2002). We calculated a value of $g = -(9.807 \pm 0.006)$ m/s² for vertical acceleration, which was not significantly different from the conventional standard value of $g = -9.81$ m/s², $t(5) = 0.72$, $p = .50$.

Procedure

The study was conducted in three phases. In the first phase, gymnasts arrived at the gymnasium and completed the informed consent form. In the second phase, gymnasts were asked to individually warm-up and prepare for floor exercises, as they would do in a normal training session. At the end of the warming-up, the gymnasts were asked to perform the two routines three times without guidance. In the third phase, gymnasts were asked to perform the round-off back handspring routine six times without guidance, and 12 times with manual guidance. Of these 12 trials, six trials were guided with the sandwich-grip and the remaining 6 trials were guided with the iliac crest/thigh-grip. The two guidance conditions were presented in a different order for each participant to control for sequence effects. Manual guidance was provided on an optimal level for each gymnast, depending on her current mastery level of the task at hand. All 18 performances of each gymnast were videotaped. Gymnasts could rest at will.

Data Analysis

A significance criterion of $\alpha = 5\%$ was established for all results reported. We conducted separate univariate analyses of variance (ANOVAs) with Manual Guidance as categorical predictor, including the key kinematic parameters as dependent variables. Post-hoc analyses were carried out using the Tukey's HSD post-hoc test. Cohen's f was calculated as an effect size for all *F* values higher than 1. To control for the inflation of Type I and II errors, we applied Holm's correction (Lundbrook, 1998). Reliability for each kinematic variable (Cronbach's alpha) was between .89 and .98. No significant differences were found between trials. Therefore all trials in each condition were averaged for further data analysis.

RESULTS

Effects of Manual Guidance on the Round-off Back Handspring Routine.

Together with two independent national level coaches, we assumed, that both guidance procedures should neither change the time-structure, the somersault angle, nor the moment of inertia about the somersault axis. Furthermore, we hypothesized, that the iliac crest/thigh-grip should have a stronger effect on angular momentum and the sandwich-grip should have a stronger effect on the velocity of the center of mass.

We found a significant effect of manual guidance on horizontal take-off velocity after second support (p = .0001, f = 1.64), vertical take-off after second support (p = .002, f = 1.44), somersault angle at touch-down to third support, (p = .0002, f = 1.49), and somersault angle at take-off after third support, (p = .04, f = 0.72). We found additional effects of manual guidance on moment of inertia at touch-down to third support, (p = .0008, f = 1.25), and angular momentum during the first flight phase (p = .001, f = 1.27). There was a small tendency for rejecting the null hypothesis for the effect of Manual Guidance on somersault angle at touch-down to second support (p = .06, f = 0.67, see Figure 3). The effect of manual guidance on somersault angle at take-off after third support became non significant after applying Holm's correction. However, the effects of Manual Guidance on somersault angle at touch-down to second support and on somersault angle at take-off after third support were large according to Cohen's (1988) classification, such that the effects seems to be of practical relevance although they were not significant.

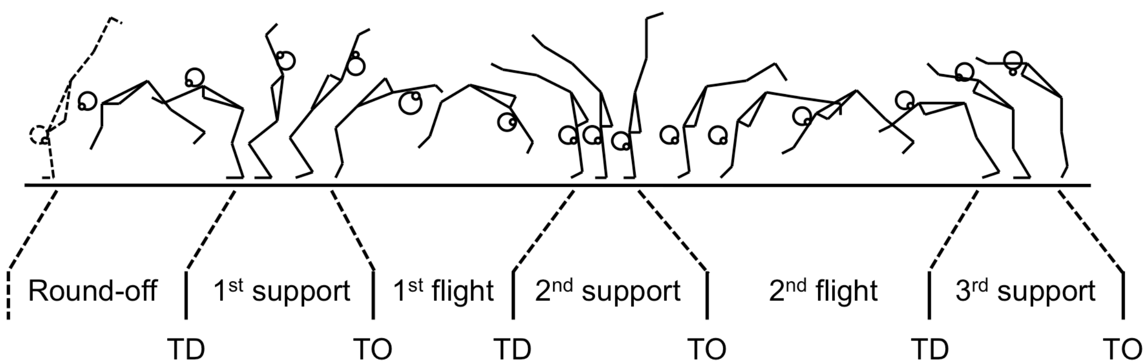
Gymnasts exhibited a larger horizontal take-off velocity, a larger vertical take-off velocity, a larger somersault angle at touch-down to third support, and a larger moment of inertia at touch-down to third support when guided with either the sandwich-grip or the iliac crest/thigh-grip compared to the no-guidance condition. Gymnasts showed a larger angular momentum about the somersault axis during the first flight phase when guided with the sandwich-grip but not when guided with the iliac crest/thigh-grip.

Effects of Manual Guidance on the Round-off – Back Tuck Somersault Routine.

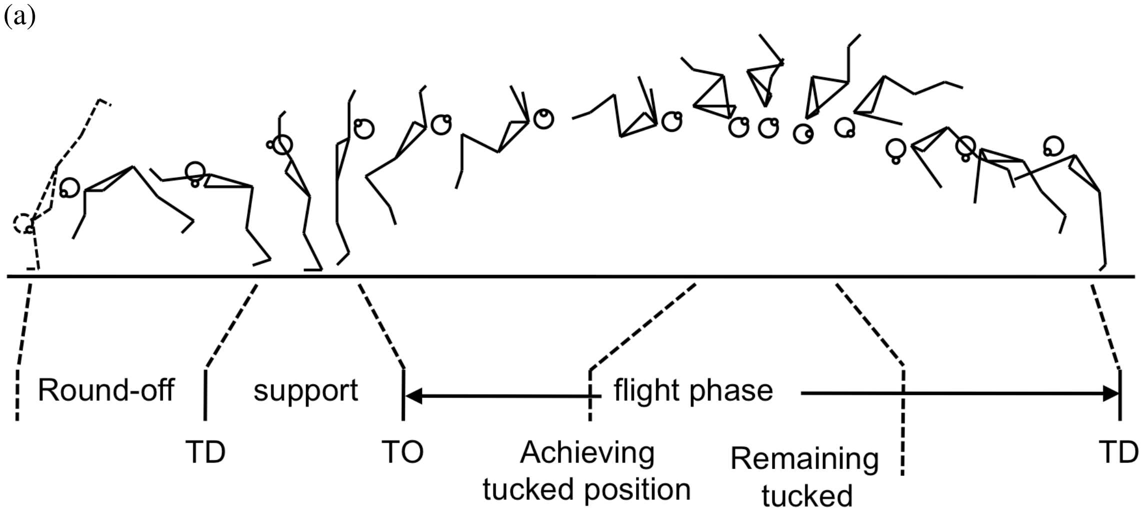
Together with two independent national level coaches, we assumed, that both guidance procedures should neither influence the somersault angle, the moment of inertia about the somersault axis nor the angular momentum. We furthermore hypothesized, that both guidance procedures should have a significant effect on the time-structure and the velocity of the center of mass

We found a significant effect of manual guidance on flight time (p = .0007, f = 0.79), horizontal take-off velocity (p = .004, f = 1.04 , vertical take-off velocity (p = .0002, f = 0.82), somersault angle at touch-down after round-off, (p = .001, f = 0.41), somersault angle at touch-down after the somersault (p = .004, f = 0.73), the moment of inertia during touch-down after the somersault (p = .001, f = 0.76). There was a tendency for rejecting the null hypothesis for the effect of Manual Guidance on angular momentum during the somersault (p = .09, f = 0.52, see Figure 4). However, the effect of manual guidance on angular momentum during the somersault was large according to Cohen's (1988) classification, such that the effect seems to be of practical relevance although it was not significant. We acknowledge that the vertical take-off velocity determines the height of flight and present this parameter here for completion purposes but did not integrate it in our statistical analyses. Compared to the no-guidance condition (Δh = 0.55 ± 0.02), gymnasts exhibited a higher flight phase in both guidance conditions (sandwich-grip: Δh = 0.67 ± 0.02 m, iliac crest/thigh-grip: Δh = 0.68 ± 0.02 m).

Gymnasts exhibited longer flight times, as well as larger vertical take-off velocities, smaller horizontal take-off velocities, and a larger moment of inertia at touch-down after the somersault when guided with either the sandwich grip or the iliac crest/thigh-grip. Gymnasts showed higher values for the somersault angle at touchdown after round-off when guided with the sandwich grip and a larger somersault angle at touch-down after the somersault when guided with the iliac crest/thigh-grip as compared to the no-guidance condition.



(a)



(b)

Figure 1. *Stick-figure sequence and definition of corresponding movement events and phases of the two routines round-off back handspring (a) and round-off somersault (b). TD = touch-down, TO = take-off. Key kinematic parameters were calculated with regard to distinct events in the time structure of the two routines.*

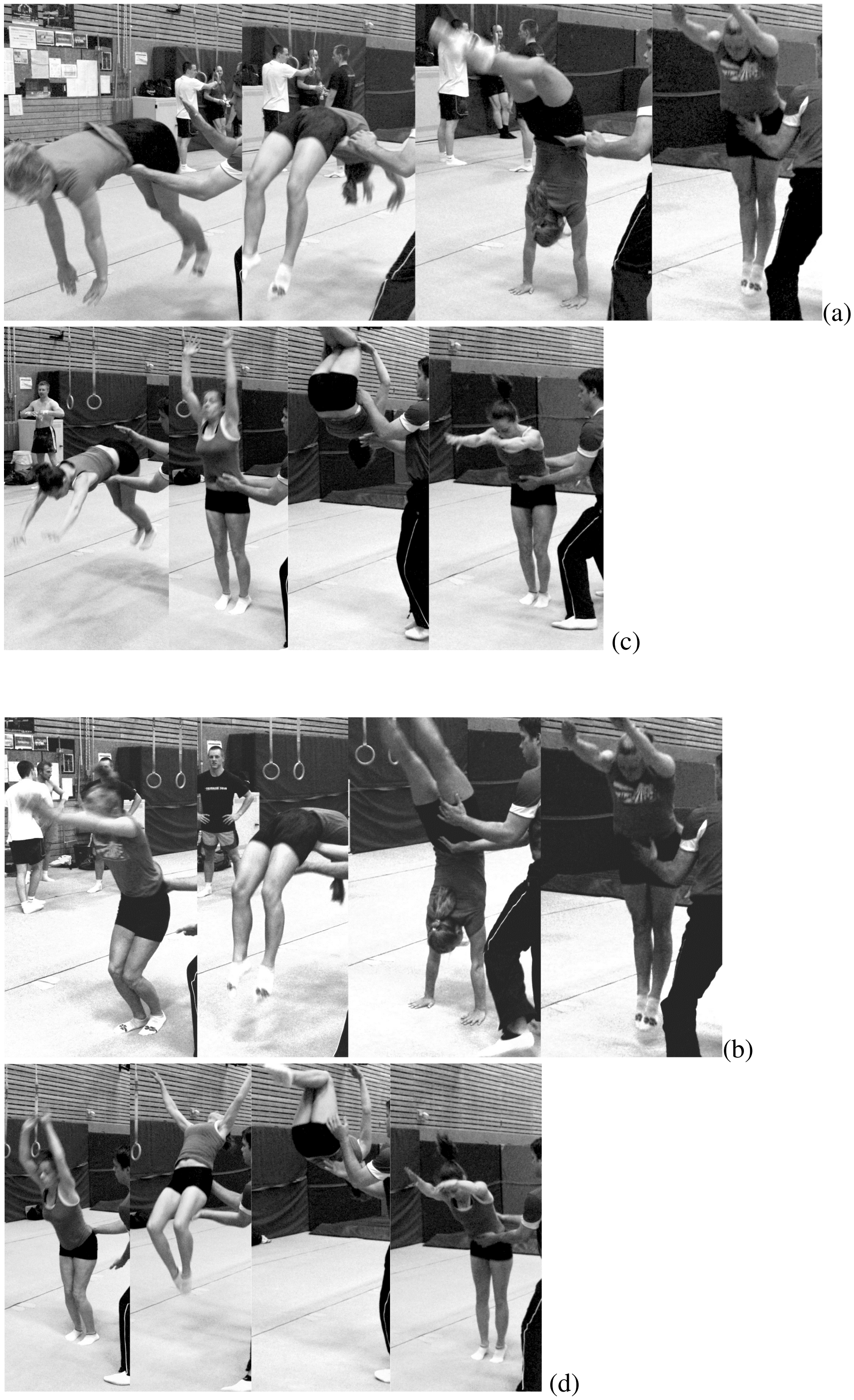


Figure 2*. Picture sequence to illustrate the two techniques to guide the back-handspring with (a) the sandwich-grip and (b) the iliac crest/thigh-grip, and the somersault with (c) the sandwich-grip and (d) the iliac crest/thigh-grip. Note: To ensure anonymity of the participants in our study, the coach and the gymnasts on the picture sequence are different from the ones who participated in our study.*

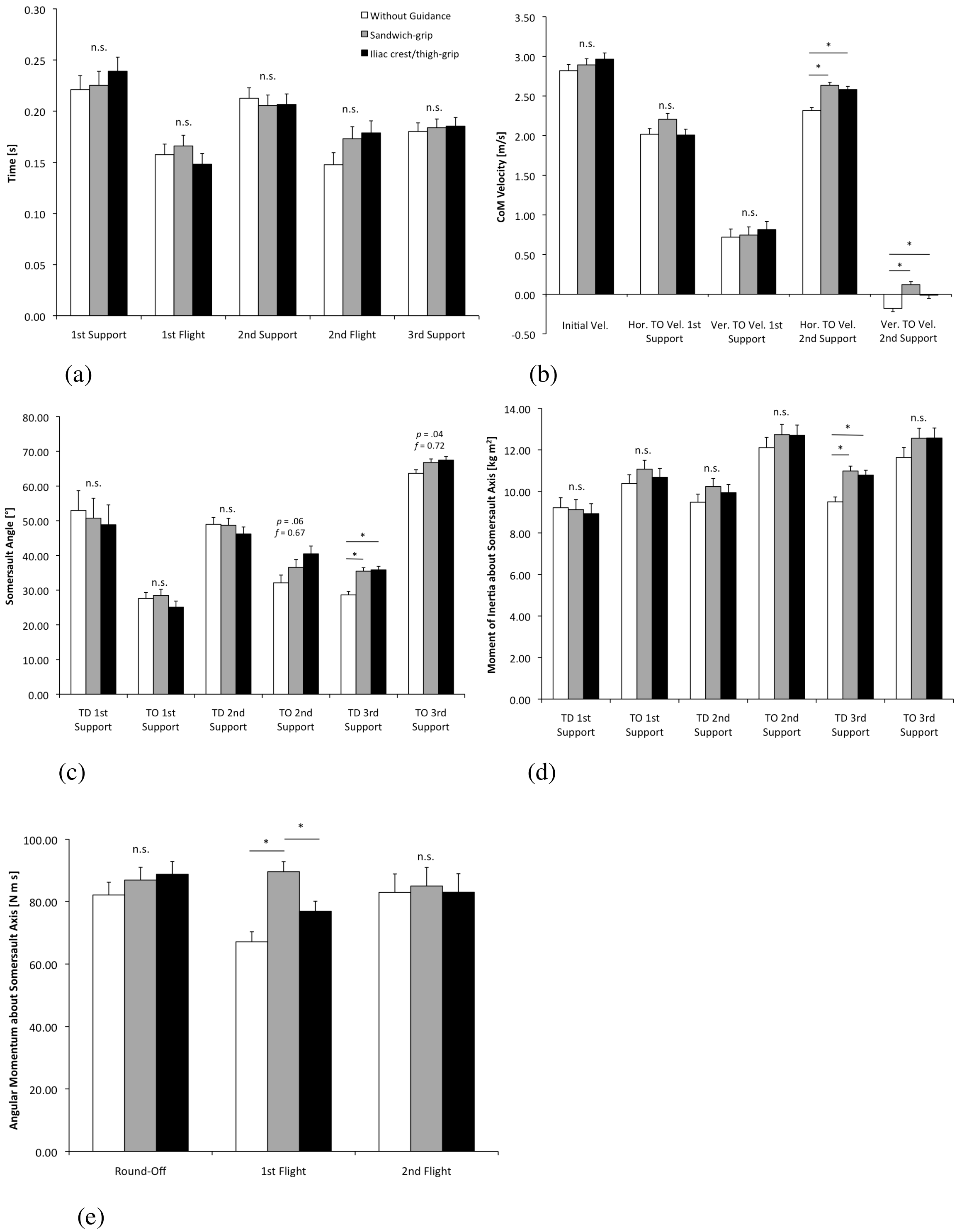


Figure 3. *Key kinematic parameters when performing the combination round-off back handspring in the no-guidance condition and the two guidance conditions: (a) variables related to the time-structure, (b) variables related to the center of mass's velocity, (c) somersault angle, (d) moment of inertia about transverse axis, and (e) angular momentum about the transverse axis. * denotes differences (p < .05) according to Tukey's HSD post-hoc test.*

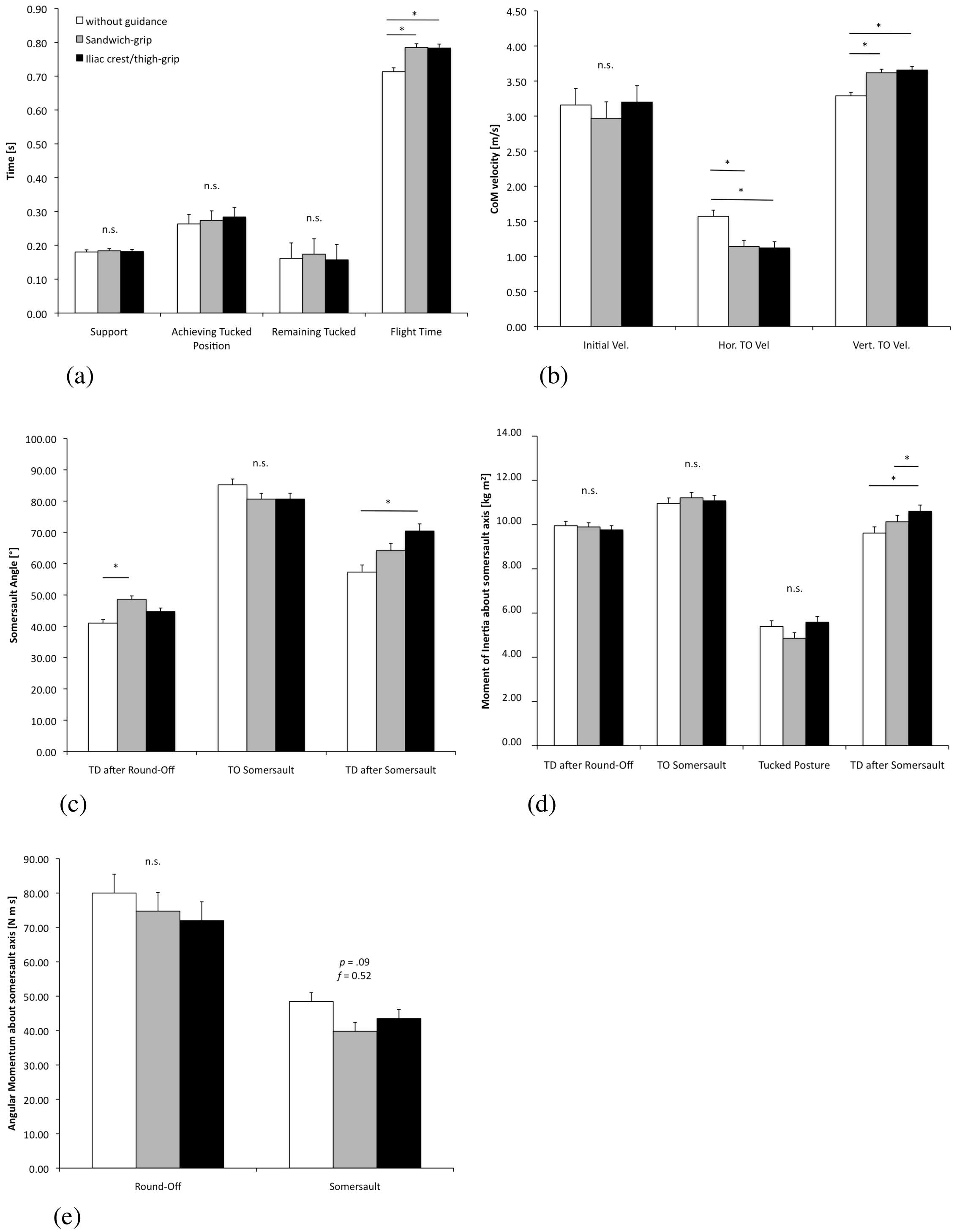


Figure 4. *Key kinematic parameters when performing the combination round-off somersault in the no-guidance condition and the two guidance conditions: (a) variables related to the time-structure, (b) parameters related to the center of mass's velocity, (c) somersault angle, (d) moment of inertia about transverse axis, and (e) angular momentum about the transverse axis. * denotes differences (p < .05) according to Tukey's HSD post-hoc test.*

DISCUSSION

The purpose of this case study was to identify the effects of two different manual guidance procedures on movement kinematics in two routines in gymnastics, namely the back handspring and the somersault after a preceding round-off. Based on assumptions of high-level coaches we hypothesized, that both guidance procedures should neither change the time-structure, the somersault angle, nor the moment of inertia about the somersault axis in the round-off back handspring. Furthermore, we assumed, that the iliac crest/thigh-grip should have a stronger effect on angular momentum and the sandwich-grip should have a stronger effect on the velocity of the center of mass. Regarding the round-off back somersault routine, we assumed, that both guidance procedures should neither influence the somersault angle, the moment of inertia nor the angular momentum about the somersault axis. We furthermore hypothesized, that both guidance procedures should have a significant effect on the time-structure and the velocity of the center of mass. We analyzed movement kinematics of female gymnasts in the two skills with and without guidance.

When performing the round-off back handspring, gymnasts exhibited a larger horizontal take-off velocity, a larger vertical take-off velocity, a larger somersault angle at touch-down to third support, and a larger moment of inertia at touch-down to third support when guided with either the sandwich-grip or the iliac crest/thigh-grip compared to the no-guidance condition. Gymnasts showed a larger angular momentum about the somersault axis when guided with the sandwich-grip but not when guided with the iliac crest/thigh-grip.

Since it is a main aim of the round-off back handspring to maintain or enhance the translational and the rotational component of the movement (cf., Knoll, 1999) it can be speculated, that the sandwich-grip helped the gymnast to achieve this goal partly by not “loosing” angular momentum from the round-off to the first flight phase, but rather maintaining it. The translational component of the routine was further optimized when using the sandwich-grip, because the vertical take-off velocity after the second support phase was positive, indicating an upward movement of the center of mass which may have been resulted from an optimization of the joint torques and the impulse during the support phase (Yeadon & King, 2002). This in turn may lead to an optimized third flight phase to prepare the following movement.

From the experience of one of the authors as a former national level coach, we argue that if the gymnasts would have been asked to perform a subsequent somersault, this somersault would have been performed technically better when the back handspring would have been guided with the sandwich-grip compared to the iliac crest/thigh-grip. However, the gymnasts in our study were asked to perform only a straight jump after the back handspring. Because there was no instruction to optimize the final jump, we cannot support the aforementioned argumentation from our data. We conclude that both guidance procedures fulfill similar demands in the round-off back handspring routine. However, if the coach’s interest is to optimize the angular momentum about the somersault axis and the second flight phase, then the sandwich-grip should be applied in the first instance.

When performing the round-off back somersault, gymnasts in our study exhibited longer flight times, as well as larger vertical take-off velocities, smaller horizontal take-off velocities, and a larger moment of inertia at touchdown after the somersault when guided with either the sandwich grip or the iliac crest/thigh-grip. Gymnasts showed higher values for the somersault angle at touchdown after round-off when guided with the sandwich grip and a larger somersault angle at touch-down after the somersault when guided with the iliac crest/thigh-grip as compared to the no-guidance condition.

The reduced horizontal take-off velocity together with the increased vertical take-off velocity after the support phase indicates an optimized impulse and therefore an optimized deflection of the center of mass's trajectory during the support phase in both guidance conditions. When applying the sandwich-grip, the gymnast was in a more upright position at touchdown after the round-off which could lead in an optimized load distribution in the passive structures of the musculoskeletal system (Brüggemann, 2000) and an optimization of the joint torques during the support phase (Yeadon & King, 2002). A longer flight time (which was found in both guidance conditions) could help gymnasts to optimize their landing preparation (Davlin et al., 2004). However, a longer flight time may also result in higher reaction forces during touchdown (Brüggemann, 2000; McNitt-Gray, 2000), and it can be assumed, that the load distribution was optimized during landing when using the iliac crest/thigh-grip because the gymnast landed in a more upright position. The coach's hand on the gymnast's belly prior to the landing phase could trigger tactile information on the abdominal muscles, leading to a task intrinsic feedback that may not be optimal for competitive gymnasts, because these gymnasts in general show only marginal activation of the abdominal muscles during the landing phase of a back tuck somersault (Brüggemann, 2000).

In the round-off back tuck somersault routine the optimal guidance procedure would be to initially use the sandwich-grip to help the gymnast optimizing the support phase. Before the gymnast reaches the tucked position the coach should switch to the iliac crest/thigh-grip to help the gymnast optimize his or her landing phase. The coach should prepare the landing area with a cushioning surface to act upon the to be expected higher reaction forces due to the longer flight time. If the sandwich-grip is used to guide the landing phase anyhow (which may be necessary when the gymnast makes specific movement errors), the coach should try to reduce the forces on the gymnast's belly to a minimum to provide an optimized task intrinsic feedback.

We want to highlight three specific aspects in our study that need to be taken into account in further experiments. First, manual guidance was provided on an optimal level for each gymnast, depending on her current mastery level of the task at hand, but the precise amount of force the coach applied during each trial was not controlled in our experiments. It would be of interest to assess the applied forces by using gloves with integrated pressure measurement sensors. This measurement could more specifically answer the question when exactly the forces were applied and how large they were.

Second, we analyzed movement kinematics of the two routines but did not assess muscular activation or ground reaction forces. Since there are wireless sensors available to measure muscular activation in complex movements and there are tumble tracks equipped with force plates it would be of interest to analyze the interplay between changes in muscular activation, changes in movement kinematics and changes in ground reaction forces in different guidance conditions. This could provide a more detailed analysis on the possible causes of the effects of different guidance procedures on complex skills in gymnastics.

Third, we only had one high level coach providing manual guidance but did not ask different coaches to provide manual guidance. Furthermore, we had 6 near expert gymnasts in our study but did not analyze novice gymnasts. Therefore the conclusions of our study may be limited to the effect of manual guidance on movement kinematics in the optimization of the two different routines. In order to generate more general conclusions about the effects of different manual guidance techniques, subsequent studies should incorporate a group of coaches in their design. It could furthermore be fruitful to recruit gymnasts on different levels of mastering the target skill in order to evaluate differential effects of manual guidance on movement kinematics.

CONCLUSIONS

We conclude, that the optimal guidance procedure in the back somersault would be to use the sandwich-grip to help the gymnast to optimize the support phase. During the landing phase, the iliac crest/thigh grip should be used in the first instance. We further conclude that both guidance procedures fulfill similar demands in the round-off back handspring routine, if the general aim is to optimize an already mastered routine. However, if the coach's interest is to particularly optimize the angular momentum about the somersault axis and the second flight phase, then the sandwich-grip should be applied in the first instance. We state that manual guidance seems to be a powerful technique for influencing the movement kinematics of complex motor skills in gymnastics if it is applied in a differential and professional manner, and its effects on movement kinematics seem to be strongly task dependent.

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HOW APPARATUS DIFFICULTY SCORES AFFECT ALL AROUND RESULTS IN MEN'S ARTISTIC GYMNASTICS

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Original research article

Abstract

On a sample of 49all-around male gymnasts at the 2009 European Championships the implications of the difficulty scores were tested in relation to the success in all-around competition. After the regression, cluster and ANOVA analysis, three groups of quality all-around gymnasts were determined, while only one group had a chance to win an all-around medal; difficulty scores between all six apparatus were not equal; the highest prediction of the all-around score was the parallel bars difficulty score.

Keywords**:** *artistic gymnastics, man, strategy, all around.*

INTRODUCTION

After the Olympic Games (OG) in 2004 the International Gymnastics Federation (FIG) made changes to the Code of Points. One of these changes was the implementation of a new philosophy of an open scoring system, prepared by Fink and Fetzer (1993), which had previously been introduced at the FIG symposium in Lugano in 1993. Prior to 2006 all disciplines in men's artistic gymnastics (FIG, 2000) were limited to a maximum final score of 10 points. In the past, different maximum scores were allowed, before World War II (WWII) the maximum score was sometimes between 11 and 16 points. After WWII the maximum score was limited to 10 points (Štukelj, 1989). Despite changes to what 10 points actually represented, it was decided that this represented exercise content and exercise presentation. The proportion of exercise content and exercise presentation had also changed; in the end it became equal to approximately 50:50 (Bučar 1998).

Exercise content was mostly characterized by difficulty and special requirements. In the Code of Points 2006 (FIG, 2006) the whole philosophy of evaluating gymnastics exercises changed. No longer was one maximum score (10 points) for evaluating exercises used. New rules (FIG, 2009) defined D and E score, where D score evaluates exercise content (difficulty, special requirements, and bonus points) and the E score evaluates exercise presentation. 'D scores' start at zero points and increase according to the difficulty the gymnast demonstrates, how the exercise is constructed (the exercise must include elements from all five element groups, and no more than 4 from one group), and how difficult elements are connected (bonus points).

The system works well for apparatus specialists; the more you show the greater the score, however in all around (AA) gymnasts a problem can exist. The problem is with the apparent equality between apparatus i.e. the vault has special rules compared to floor exercise, pommel horse, rings, parallel bars, and horizontal bar. Gymnasts in AA competition only perform one vault, and compared to the other apparatus the vault is similar to only one element from the other exercises. Therefore, on the vault the D score is known in advance (FIG, 2009). According to the results of men's AA qualifications at OG 2008 Čuk and Atiković (2009) found that the vault is considered to be the most valuable apparatus, and the pommel horse was undervalued among AA gymnasts. Using the Code of Points, it is very hard to obtain a high D score on the pommel horse, whereas it is easier to obtain a high D score on the vault. Pairwise *t*-tests showed that D scores between the vault and other apparatus, and between the pommel horse and other apparatus were significantly different.

Table 1. *Average D score (multiplied by 1000) and standard error of sample (N=44) at OG 2008 for MAG all-around gymnasts Čuk and Atiković (2009)*

	Mean	Std. Error
FXA Score	6015.91	50.572
PHA Score	5677.27	69.189
RIA Score	5943.18	95.257
VTA Score	6445.45	65.306
PBA Score	6090.91	84.834
HBA Score	5897.73	80.530

However, the new Code of Points presented in 2009 (FIG, 2009) has a number of changes that impact the D score. In the past (Hadjijev, 1989), it was expected that the least amount of training time was spent on the vault, and the most amount of time was spent on the pommel horse. Training times on other apparatus were similar (the gymnasts preferences, abilities, and individual characteristics are also important in determining training time spent on each apparatus).

Using the 2009 Code of Points, one of the most experienced Slovenian international judges Enis Hodžić calculated maximum difficulty scores for each apparatus. Results were Floor exercise=7.9; Pommel Horse=7.6; Rings=7.6: Vault=7.4; Parallel Bars=8.1; High Bar=8.5. It is clear that the maximum difficulty scores are different for each apparatus.

The 2009 European Championships (EC) in Milan was the first major competition in the world to use the 2009 Code of points. It is therefore interesting to see how the AA gymnasts coped with the new rules, as their performances might be a guideline for the Olympic cycle up to the OG 2012 in London. The number of AA gymnasts has diminished over the last two decades (at OG in 1992 all the gymnasts were competing in AA in order to get into finals, while at OG 2008 and at WC 2007 only half of them competed in the AA competition). It is interesting to see how all-around gymnasts are coping with the new Code of Points and what kind of strategies they are using to improve their results.

METHODS

Our sample was composed of 49 AA gymnasts who competed at the EC in Milan 2009 qualification event. From official results we made 6 variables of D scores: Floor Exercise (FX) , Pommel Horse (PH) , Rings (RI), Vault (VT), Parallel Bars (PB) and Horizontal Bar (HB) . To evaluate the AA we used the AA final score (AAFS). To assist the statistical presentation, D and E scores were multiplied by 1000; so a score of 6 points had a value of 6000. SPSS 15.0 was used to calculate Kolmogorov-Smirnov to test the normality of the variables distributions, Pearson correlations, pair-wise *t*-tests between D scores of all apparatus, and a linear regression analysis between AAFS and D scores (method enter). We also prepared the classification of gymnasts with the method of Euclidian square distances using D scores. Clusters were then compared with one way ANOVA and Tamahne 2 post hoc test. All statistics used an alpha level of $p < 0.05$.

RESULTS AND DISCUSSION

Table 2. *Descriptive statistics*

	N	Minimum	Maximum	Mean	Std. Error	Std. Deviation	K-S test
FXDscore	49	3900	6400	5381.63	77.956	545.693	Normal
PHDscore	49	3000	6800	4997.96	115.709	809.961	Normal
RIDscore	49	2500	6500	5273.47	103.624	725.366	Normal
VTDscore	49	4600	7000	6012.24	76.578	536.048	Not Normal
PBDscore	49	3400	6500	5202.04	99.808	698.656	Normal
HBDscore	49	3100	6800	5269.39	114.070	798.489	Normal
AAFS	49	64325	89150	81395.41	693.419	4853.936	Normal

Table 3. *Pairwise t-test (N=48)*

Pair	t	Sig. (2-tailed)
FXDscore - PHDscore	3.532	.001
FXDscore - RIDscore	1.170	.248
FXDscore - VTDscore	-10.537	.000
FXDscore - PBDscore	2.151	.037
FXDscore - HBDscore	1.149	.256
PHDscore - RIDscore	-2.713	.009
PHDscore - VTDscore	-8.881	.000
PHDscore - PBDscore	-2.148	.037
PHDscore - HBDscore	-2.390	.021
RIDscore - VTDscore	-7.475	.000
RIDscore - PBDscore	.825	.413
RIDscore - HBDscore	.042	.967
VTDscore - PBDscore	9.105	.000
VTDscore - HBDscore	7.087	.000
PBDscore - HBDscore	-.781	.439

Table 4. *Pearson correlation matrix*

	HBDscore	PBDscore	VTDscore	RIDscore	PHDscore	FXDscore
AAFS	.720*	.830*	.606*	.743*	.697*	.710*
HBDscore	1.000	.682*	.452*	.605*	.511*	.537*
PBDscore		1.000	.517*	.639*	.620*	.583*
VTDscore			1.000	.431*	.350*	.700*
RIDscore				1.000	.576*	.511*
PHDscore					1.000	.425*
FXDscore						1.000

*all correlations are significant p<0.01

Table 5. *Regression analysis (method Enter), predicted AAFS variable*

R	R Square	df1	df2	Sig.
.920(a)	.847	6	42	.000

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta	B	Std. Error
(Constant)	38244.832	3455.332		11.068	.000
HBDscore	.753	.536	.124	1.405	.167
PBDscore	2.324	.687	.335	3.384	.002
VTDscore	.677	.780	.075	.868	.390
RIDscore	1.357	.578	.203	2.349	.024
PHDscore	1.163	.484	.194	2.401	.021
FXDscore	1.868	.826	.210	2.262	.029

Cluster analysis with the method of Euclidian distances gave the best results with 3 clusters, where 21, 6 and 22 gymnasts were grouped. Those with three clusters were used in further analyses via a one way ANOVA.

Table 6. *ANOVA results with Tamahne 2 post hoc test*

		Sum of Squares	df	Mean Square	F	Sig.
FXDscore	Between Groups	7179162.028	2	3589581.014	23.210	.000
	Within Groups	7114307.359	46	154658.856		
	Total	14293469.388	48			
PHDscore	Between Groups	15670726.654	2	7835363.327	22.784	.000
	Within Groups	15819069.264	46	343892.810		
	Total	31489795.918	48			
RIDscore	Between Groups	12291159.555	2	6145579.777	21.806	.000
	Within Groups	12964350.649	46	281833.710		
	Total	25255510.204	48			
VTDscore	Between Groups	6085986.395	2	3042993.197	18.163	.000
	Within Groups	7706666.667	46	167536.232		
	Total	13792653.061	48			
PBDscore	Between Groups	17029687.693	2	8514843.847	61.199	.000
	Within Groups	6400108.225	46	139132.788		
	Total	23429795.918	48			
HBDscore	Between Groups	18955315.399	2	9477657.699	37.426	.000
	Within Groups	11648766.234	46	253234.049		
	Total	30604081.633	48			

						95% Confidence Interval for Mean	
	Group	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound
FXD score	1	21	5057.14	344.342	75.142	4900.40	5213.89
	2	6	4966.67	674.290	275.278	4259.04	5674.29
	3	22	5804.55	342.925	73.112	5652.50	5956.59

	Total	49	5381.63	545.693	77.956	5224.89	5538.37
PHD score	1	21	4904.76	618.447	134.956	4623.25	5186.28
	2	6	3650.00	476.445	194.508	3150.00	4150.00
	3	22	5454.55	578.773	123.395	5197.93	5711.16
	Total	49	4997.96	809.961	115.709	4765.31	5230.61
RID score	1	21	5119.05	520.211	113.519	4882.25	5355.84
	2	6	4166.67	882.421	360.247	3240.62	5092.71
	3	22	5722.73	417.398	88.989	5537.66	5907.79
	Total	49	5273.47	725.366	103.624	5065.12	5481.82
VTD score	1	21	5666.67	425.833	92.924	5472.83	5860.50
	2	6	5800.00	438.178	178.885	5340.16	6259.84
	3	22	6400.00	385.450	82.178	6229.10	6570.90
	Total	49	6012.24	536.048	76.578	5858.27	6166.22
PBD score	1	21	4952.38	400.773	87.456	4769.95	5134.81
	2	6	4000.00	428.952	175.119	3549.84	4450.16
	3	22	5768.18	328.614	70.061	5622.48	5913.88
	Total	49	5202.04	698.656	99.808	5001.36	5402.72
HBD score	1	21	5061.90	529.600	115.568	4820.83	5302.98
	2	6	3916.67	636.920	260.021	3248.26	4585.07
	3	22	5836.36	437.031	93.175	5642.60	6030.13
	Total	49	5269.39	798.489	114.070	5040.03	5498.74

The descriptive statistics and Kolmogorov-Smirnov test (Table 2) showed that only the vault data D scores were not normally distributed. The score distribution was leptokurtic and skewed to the left, meaning that higher values are more common. Despite trying to normalize variables with logarithmic functions (ln and $\log_{10}$), the abnormality persisted, so we decided to continue analyses with raw data. Comparing the average of all-around D scores on the apparatus from OG2008 and D scores from EC2009 it can be noted that there is a huge lowering of D scores when the2009 Code of Points were used. On average, D scores were lower by 0.6 points; the greatest lowering was on parallel bars, and least on the vault. The 2009 Code of Points did not affect AA gymnasts on the vault, but mostly on the parallel bars.

Table 7. *Differences between AA scores from OG2008 and D scores from EC2009*

	OG2008	EC2009	Diference
FX	6015.91	5381.63	634.28
PH	5677.27	4997.96	679.31
RI	5943.18	5273.47	669.71
VT	6445.45	6012.24	433.21
PB	6090.91	5202.04	888.87
HB	5897.73	5269.39	628.34

At the beginning of the Olympic cycle with the adoption of the 2009 Code of Points lower start values (as the value of some elements were lowered, less bonus points on apparatus) were expected, however the drop in scores was more severe than expected (from 0.43 to 0.88 point). If we compare what AA gymnasts could achieve according to maximum scores using the2009 Code of Points, it is noted that they were already achieving 81.2% of maximum possible score on the vault, while on all other apparatus they are below 70% of the maximum score. If we take into consideration the best gymnast by D score on each apparatus, the percentage of maximum D scores were higher, but vault was still the apparatus where the best AA gymnast was already reaching 94.6%, while the best gymnast on other apparatus was below 90%.

Table 8. *Theoretical maximum D scores by Code 2009 and achieved ones at EC2009*

Max Dscore Code 2009	Average AA gymnasts % of max Dscore	The best AA gymnast Dscore Code 2009 from AA gymnast	The best AA gymnast % max Code 2009
7900	68.1	6400	81.0
7600	65.8	6800	89.5
7600	69.4	6500	85.5
7400	81.2	7000	94.6
8100	64.2	6500	80.2
8500	62.0	6800	80.0

The pair-wise *t*-test (Table 3) showed 10 significant different pairs out of 15 pairs; all pairs with pommel horse and vault were significant different, and floor exercise with parallel bars. The average D scores on the vault were the highest and were lowest on the pommel horse. Similar results were obtained at OG2008 (Čuk, Atiković, 2009).

Pearson's correlations (Table 4) between apparatus D scores were all statistically significant, medium high. Correlations between all AAFS and each apparatus D scores were slightly higher, the highest was with parallel bars D score (0.83 – 68.9% of common variance). Surprisingly the lowest correlation was with the vault D scores (0.61 – 36.3% of common variance). The descriptive statistics and *t*-tests showed that the vault had important differences to other apparatus, but correlations revealed that for AA gymnasts the vault score had the lowest impact on AA score. Coefficient of multiple correlations (Table 5) between dependent variables of the AA final score and independent variables of apparatus D scores were statistically significant and very high (0.92). D scores explained over 84% of the final AA score, in general more difficult exercises attained better results in the AA. Significant predictors of AA success are parallel bars, rings, pommel horse and floor exercise D scores. It was interesting to observe that the vault and high bar D scores were not significant predictors of AAFS. On the vault there was not enough discrimination among gymnast's D scores..

Cluster analyses identified 3 groups of gymnasts. ANOVA (Table 6) showed they differed significantly on D scores. The third group (22 gymnasts) was very good on all events and had significantly higher D scores on all apparatus compared to the other groups. The first (21 gymnasts) and the second group (6 gymnasts) were equal on floor exercise and vault (the second group exceeded the first); while on the other apparatus the first group had higher D scores. Only the third group had the quality (level of D scores) of winning medals, so the questions to be asked are: why do gymnasts from the first and the second group compete in AA at all? Are they just trying to enter AA finals or are they just young gymnasts with a better potential future?

CONCLUSIONS

Based on the results presented it can be concluded that:

- with the 2009 Code of Points, for all-around results the six apparatus are not equal to obtain D scores;
- with the2009 Code of Points, for all-around gymnasts, the vault and the pommel horse D scores significantly differ from other apparatus;
- with the 2009 Code of Points, the vault D scores do not discriminate between all-around gymnasts;
- all-around gymnasts have the lowest D scores on pommel horse;

- with D scores only we can predict 84% of all-around final score;
- after the Code of Points changed in 2009, the all-around gymnast who attained the highest D score on parallel bars has the best chance of good all-around results;
- D scores for the vault and high bar did not significantly predict all-around final scores; vault D scores did not discriminate sufficiently (to many gymnasts with same D score), while on the high bar the lack of discrimination could be due to an increased number of falls. It seems it is more important to perform a slightly less difficult exercise well than a difficult exercise with a fall;
- three groups of all-around gymnasts were classified (with 21, 6, and 22 gymnasts), and only the third group had potential of winning an all-around medal, as their D scores on all apparatus are much higher.

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Slovenski izvlečki / Slovene Abstracts

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TRENAŽNE OBREMENITVE TELOVADK V PREDPUBERTETNEM OBDOBJU

Razumevanje mnogih dejavnikov, ki vplivajo na razvoj telovadke je pogoj za ustrezno načrtovanje vadbe in preprečevanje poškodb. Cilj raziskave je bil ugotoviti vplive tekmovalnega nivoja telovadk (državni in mednarodni), orodja (gred in parter) in vadbenega obdobja (predtekmovalno in tekmovalno) na oceno vadbene obremenitve pri 25 telovadkah (povprečna deklic starost 9,5 let +- 1,6, vadbebni staž 1,9 let +-0,7). Na osnovi video analize je bila ugotovljena gostost opazovanih gimnastičnih prvin, ki so imele vpliv na obremenitev gležnjev in zapestij, doskoki, ravnotežne prvine in prvine z letom. Dodatno so bile 16 telovadkam izmerjene obremenitve na prenosni tenziometrijski plošči. Rezultati analize ANOVA so pokazali razlike med tekmovalnima nivojema telovadk. Telovadke mednarodnega nivoja so imele večje število ur treninga in večjo gostost opazovanih dejavnikov (neodvisno od obdobja). Razlike so bile tudi med predtekmovalnim in tekmovalnim obdobjem, ob tem da so imele telovadke mednarodnega nivoja bolj posebno vadbo. V silah na podlago na gredi in parterju ni bilo razlik med skupinama. Načrtovanje in izvedba vadbenih obremenitev bi morala biti nepristransko nadzorovana s ciljem imeti zdrave in dolgoletno uspešne telovadke.

Ključne besede: ženska športna gimnastika, predpuberteta, vadbena obremenitev, načrtovanje, sile na podlago.

Maja Bučar Pajek, Ivan Čuk, Marjeta Kovač in Barbara Jakše

REALIZACIJA GIMNASTIČNIH VSEBIN V TRETJEM TRILETJU OSNOVNE ŠOLE V SLOVENIJI

Znanje gimnastike, ki ga opažamo pri študentih fakultete za šport je iz leta v leto slabše, kar kažejo tudi nekateri izsledki raziskav (Bučar Pajek, 2003), zato nas je zanimalo v kakšni meri učitelji na osnovnih šolah realizirajo gimnastične vsebine. Z raziskavo smo želeli ugotoviti kakšna je realizacija gimnastičnih vsebin iz učnega načrta za športno vzgojo v tretjem triletju za osnovne šole v Sloveniji. Vzorec merjencev predstavlja 147 učiteljic in učiteljev športne vzgoje, ki so v letu 2004/2005 poučevali v tretjem triletju slovenskih osnovnih šol. Vzorec spremenljivk predstavlja anketni vprašalnik z naslovom »Izpeljava učnega načrta pri gimnastiki v tretjem triletju osnovne šole«. Izračunali smo frekvence skladno s ciljem raziskave. Rezultati kažejo, da učitelji v tretjem triletju gimnastičnim vsebinam namenijo v povprečju izpeljati le 9,8 ur gimnastike v celem šolskem letu. Učitelji realizirajo predvsem prvine, ki so z vidika tehnike lažje izvedljive (preval naprej, preval nazaj, stoja na rokah, premet v stran, hoja po gredi …), kjer varovanje ni nujno in so možnosti poškodb in padcev manjše. Prvine, ki imajo v svoji strukturi gibanja fazo leta, obrat ali kjer pride do zmanjšanja podporne površine, pa domnevno predstavljajo učiteljem večje težave za poučevanje in se jim zdijo tudi manj primerne.

Ključne besede: gimnastika, anketa, tretje triletje, osnovna šola

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Lurdes Ávila-Carvalho, Maria da Luz Palomero, Eunice Lebre

TEŽAVNOST PRVIN Z REKVIZITI PRI VRHUNSKIH RITMIČNIH SKUPINSKIH SESTAVAH NA TEKMOVANJU ZA SVETOVNI POKAL V PORTIMÃOU LETA 2009

Cilj raziskave je bil ugotoviti ali obstajajo oblike vrste gibanj glede na rekvizit, katere izbirajo ritmičarke pri skupinskih sestavah. Značilnosti šestindvajset skupinskih sestav (5 obročev in 3 trakovi z 2 kolebnicama) 13 skupin ritmičark na svetovnem pokalu v Portimãoo leta 2009 je bilo razčlenjenih. Rezultati: (a) meti (i) vse skupine največkrat uporabljajo mete med letom; (ii) pri treh trakovih in 2 kolebnicah se lovljenja največkrat izvajajo pri prvinah z vrtenjem, medtem ko se pri 5 obročih lovljenja največkrat izvajajo brez pomoči dlani; (iii) obvezna vrtenja so bila najbolj pogoste prvine pri 5 obročih, prav tako so bila dodatna vrtenja pri 3 trakovih in dveh kolebnicah. (b) prvine brez meta (i) vrtenja in spretna ravnanja so bila najpogostejša pri 5 obročih, medtem ko so bila valovanja in spirale najpogostejša pri 3 trakovih in 2 kolebnicah (ii) prvin tveganja brez meta ni bilo (c) sodelovanje (COLL) največkrat je bilo izvedeno sodelovanje COLL RR1 (to vsebuje velike mete s tveganjem izgube vidnega nadzora nad rekvizitom med njegovim letom kakor tudi mete preko, pod ali skozi en ali več rekvizitov ali ritmičark med letom rekvizita pri 5 obročih ter COLL z meti 3 trakov in 2 kolebnic. Pokazalo se je, da ima vsaka sestava svoje značilnosti po strukturi vsebine.

Ključne besede: ritmika, skupinske sestave, težavnost, ocene, izvedba.

Thomas Heinen, Pia Vinken in Patrick Ölsberg

VAROVANJE V GIMNASTIKI

Čeprav je varovanje v gimnastiki zelo razširjeno in uporabljano, je malo znanega o vplivu varovanja na kinematične značilnosti izvedbe gibanja varovane osebe. Cilj raziskave je bil oceniti vplive dveh načinov varovanja premeta nazaj in salta nazaj, skrčeno na parterju. Na osnovi izkušenj vrhunskih trenerjev je bilo pričakovati, da bo imelo varovanje za trebuh in hrbet v primerjavi z varovanjem za hrbet in zadnjo stran stegna drugačen vpliv na kinematične značilnosti izvedbe prvin. Šest telovadk je izvedlo prvine brez in z obema načinoma varovanja. Varovanje je pomembno vplivalo na spremenjene kinematične značilnosti pri obeh prvinah. Kombinacija obeh načinov varovanja je najboljša.

Ključne besede: športna gimnastika, varovanje, premet nazaj, salto nazaj, kinematika

Ivan Čuk in Warwick Forbes

VPLIV TEŽAVNOSTI SESTAV NA KONČNI REZULTAT V MOŠKEM MNOGOBOJU

Na vzorcu 49 telovadcev v mnogoboju na Evropskem prvenstu leta 2009 smo ugotavljali povezanost med težavnostjo sestav in rezultatom v mnogoboju. Na osnovi regresijske analize, taksonomske analize in ANOVA smo ugotovili, da obstajo tri skupine telovadcev, od katerih ima le ena možnost za osvojitev odličja. Težavnosti sestav med orodji so različne, največjo napovedno vrednost za uspeh v mnogoboju ima težavnostna stopnja sestave na bradlji.

Ključne besede: moška športna gimnastika, mnogoboj, strategija.

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