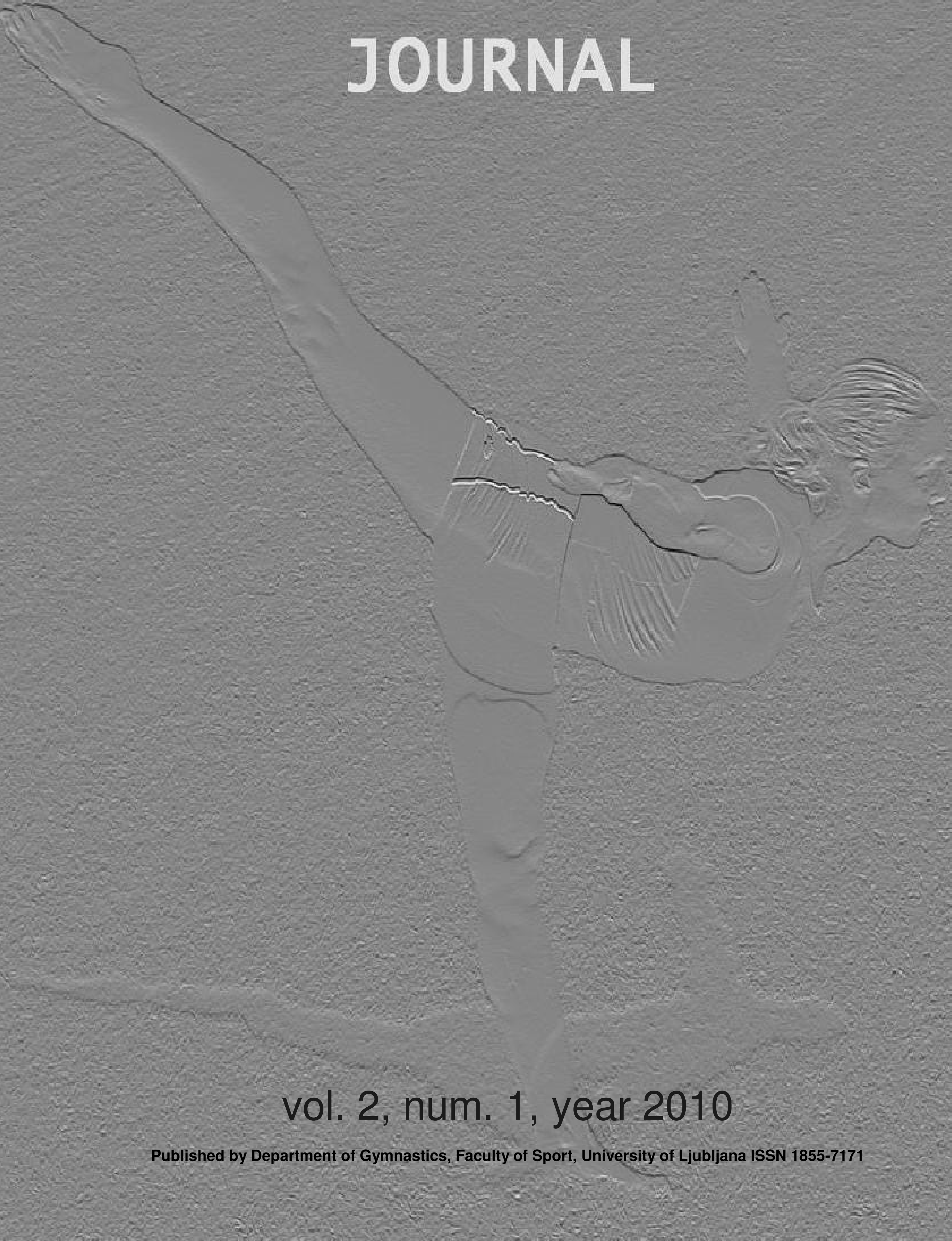
SCIENCE OF GYMNASTICS JOURNAL



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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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EDITORIAL

Dear friends,

Four months have passed since our first issue of the Science of Gymnastics Journal. The editorial board was not asleep during this time nor were our readers. Many things have happened and below is a short report of these events.

When we set out to start this journal we hoped we would attract some attention from the gymnastics community by promoting science and research in gymnastics. From 1 October to 31 December 2009 more than 3000 visitors from 64 countries visited our website at www.scienceofgymnastics.com. A great deal of thanks for such numbers goes to those who passed on the information about our journal. Let me take this opportunity to thank the International Gymnastics Federation (www.fig-gymnastics.com), the International Gymnast Magazine (www.internationalgymnast.com), www.gymnasticscoaching.com, and www.gymnastics.bc.ca in particular, and many others who have sent our address to their friends.

It is worth noting that we had visitors from all six inhabited continents of the world: from Europe, North and South America, Africa, Asia and Australia. Visitors came from places where gymnastics is an established sport as well as from places where they are just making their first tentative steps into this area.

A lot of our efforts in the last four months has gone in the improvement of the status of our Journal in international databases. Our articles are visible on Google Scholar. We have been accepted into the SIRC database of sport journals, our entry in the EBSCO SportDiscus database is pending and we have started working on acquiring a Thomson Reuter's impact factor.

The new issue starts with an article by German authors Thomas Heinen, Pia Vinken, and Konstantinos Velentzas addressing a very interesting dilemma of twist directions. The second article is the contribution by Trevor Dowdell from Australia who is exploring characteristics of coaching. The third article is about the reliability of judging in men's artistic gymnastics at the University Games in Belgrade 2009, written by a group of authors from Slovenia and Hungary: Bojan Leskošek, Ivan Čuk, Istvan Karacsony, Jernej Pajek and Maja Bučar. The fourth article comes from Slovenian author Matjaž Ferkolj who has researched kinematic characteristics of Roche vault on vaulting table. The second issue of our journal concludes with an article from Portugal in which José Ferreirinha, Joana Carvalho, Cristina Côrte-Real and António Silva analyze the evolution of flight element on uneven bars from 1989 to 2004.

Dear friends, please don't forget that this journal is open for submissions from all over the world. Do not hesitate to send an article as long as it is gymnastics related and follows our guidelines published on our web site. Your comments on any of the published articles or any queries you might have are also always welcome.

The Editorial Board wishes you a good reading.

Ivan Čuk

Editor-in-Chief

DOES LATERALITY PREDICT TWIST DIRECTION IN GYMNASTICS?

Thomas Heinen, Pia Vinken, Konstantinos Velentzas

German Sport University Cologne, Germany

Original research article

Abstract

Although twisting is a key element in many gymnastics skills, little is known about the relationship between twist direction in skills with different functional demands and other factors, like lateral preference. We explored relationships in twist direction between different gymnastics skills, and sought for significant predictors of preferred twist direction from measures of laterality. N = 44 gymnasts performed four different gymnastic skills. We analyzed gymnast's twist direction and lateral preference. We found that gymnasts, who twist left in upright stance, twist more often right during round-off, $\chi^2 = 13.09$, $p < .01$, *and more often left during twisting somersault backwards,* $\chi^2 = 17.79$, $p < .01$. *Gymnasts who were either left consistent or inconsistent in eyedness showed more often a leftward turning preference in upright stance,* $F(1, 42) = 10.71$, $p < .01$, *and gymnasts who were more left consistent in eyedness,* $F(1, 42) = 15.75$, $p < .01$, *or more right-consistent in footedness,* $F(1, 42) = 6.07$, $p = .02$, *showed more often a rightward turning preference in the round-off. We state that as a gymnast progresses in learning, it may be wise to experiment with both twist directions to ensure that the gymnast can explore his or her turning preference with regard to lateral preference.*

Keywords: *turning preference, lateral preference, round-off, twisting somersault backwards, straight jump with full turn, handstand with full turn.*

INTRODUCTION

Twisting and somersaulting make up the majority of gymnastics skills. Gymnasts decide at a very early age whether to turn to the left or to the right, and usually maintain this preference throughout their career (Arkaev and Suchilin, 2004).

While it is generally accepted in the coaching literature that an athlete should maintain his or her turning preference, one problem arises from a misperception of turning direction when being upside down, that is likely to develop in young gymnasts (Arkaev and Suchilin, 2004). One *feels* turning leftwards but is turning rightwards instead, because the vestibular system is placed upside down during an overhead phase in a particular skill. This misperception often causes problems of learning more complex skills, like a twisting somersault. Because the turning preference is often determined from self-reports of young gymnasts, indicating the direction in which they *feel good* when performing a particular skill, the actual twist direction is likely to be different between skills with different functional demands (Sands, 2000). It is furthermore likely to assume that gymnasts choose their preferred twist direction in favor of other factors, like lateral preference (Golomer, Rozey, Dizac, Mertz, and Fagard, 2009).

The purpose of this study was twofold. First, we sought to explore relationships in twist direction between different gymnastics skills with regard to turning preference in gymnasts, and second, we sought for significant predictors of preferred twist direction from measures of laterality.

There is comprehensive work done on turning preference in general and with regard to specific sports. Lenoir, Van Overschelde, De Rycke, and Musch (2006) observed for instance turning behavior in n = 107 adolescents while they ran and walked back and forth between two lines. The authors found a general preference for turning leftwards that was dependent on the experimental task. They concluded that turning preference in humans is the result of a complex interaction between intrinsic preferences and externally imposed task constraints. Golomer et al. (2009) observed the preferred direction for executing spontaneous whole-body turns. The authors recruited n = 45 untrained girls and n = 36 professional dance students. While 58% of the untrained girls showed a leftward turning bias, the remaining girls showed a rightward turning bias, independent of vision or lateral preference. The majority of dance students showed a rightward turning bias that may be explained by the influence of classical dance training. This may especially be the case because children's vestibular system is not fully mature before the age of 15 (Hirabayashi and Iwasaki, 1995), so that a "strict" training may also provoke a shift in turning preference at an early age.

Given, that there is a tendency for a leftward turning preference in humans that is, however, strongly dependent on task constraints and intrinsic factors (Lenoir et al., 2006), the question arises if such a preference can also be found in gymnastics. Sands (2000) conducted a survey on coaches, who then provided information for n = 244 gymnasts on 8 different competitive levels regarding twist direction in 5 different gymnastics skills. These skills were backward and forward twisting somersault, jump turn, pirouette, and round-off. The author found no significant difference between left and right direction of twist in any of the skills. However, the twist direction of the round-off was a significant predictor for the twist direction of the remaining four skills. Gymnasts who twist to the right during a round-off twist more often (about 74% in total) to the left in the four remaining skills and vice versa (about 64% in total). However, Sands (2000) calculated the frequencies in preferred turning directions for different skills but did not assess other parameters that may be related to twist direction.

From the coaches' perspective, restricting the turning direction for each individual gymnast does not necessarily make sense, because almost all gymnastic skills can be performed with either left or right rotation. As mentioned above, gymnasts decide at a very early age to either turn to the left or to the right, and one constituting factor for this decision could be lateral preference (Martin and Proca, 2007) because learners in general choose movement strategies in new tasks in favor of their lateral preference (Serrien, Ivry, and Swinnen, 2006). However, there is no clear evidence on the influence of lateral preference on turning preference in athletes. Brown, Tolsma, and Kamen (1983) conducted for instance a study to determine the relationship between eyedness and handedness and preferred direction of rotational movements. The authors recruited n = 120 non-athletes and n = 51 college-level gymnasts and observed turning preference in four gymnastics skills, a jump turn, a cartwheel, the swivel-hips and the seat-drop-full twist on the trampoline. Brown et al. (1983) found no consistent correlations between twist direction, and either eyedness or handedness in either experienced gymnasts or non-athletes. Golomer et al. (2009) also assessed lateral preference in their study mentioned above. Their results showed no significant relationships between turning bias and any measure of lateral preference (handedness, eyedness, footedness) in untrained girls or professional dance students. In this context, Mohr Brugger, Bracha, Landis, and Viaud-Delmon (2003) concluded, that side preferences in lateralized whole-body movement tasks are neither comparable between tasks nor within subjects.

For instance in gymnastics, round-offs are among the first skills that a young gymnast learns. In this skill, the gymnast places one hand down while simultaneously bending his or her knee of the supporting leg. Together with the placing of the hand the supporting leg is extended, the second hand touches the ground, and the other leg is swung upwards to support the rotation. The selection of the appropriate hand together with the supporting leg is an important consideration, due to the fact that it determines the twist direction in a round-off. Results from the literature indicate, that for instance foot preference to support the body may be dependent on the context of the task rather than on lateral preference (Golomer et al., 2009; Hart and Gabbard, 1997). However, there is only marginal evidence for the choice of the supporting leg with regard to lateral preference or task context in gymnastics, so that we can only speculate about the relationship.

Our first assumption was that twist direction in upright stance (straight jump with full twist) and twist direction of round-off and handstand are inversely related in such a way that gymnasts who twist right in upright stance twist left when performing the round-off and the handstand and vice versa (Sands, 2000). Our second assumption was that twist direction in upright stance and twist direction of a somersault backwards with a full turn are related in such a way that gymnasts who twist right in upright stance twist also right when performing the twisting somersault and vice versa (Arkaev and Suchilin, 2004). Our third assumption was that lateral preference could predict preferred twist direction in gymnasts (Golomer et al., 2009).

METHODS

N = 44 female gymnasts (age: 12.3 ± 1.9 years) with more than four years of competitive experience were recruited to participate in our study. To control for possible influences on turning preference, we recruited n = 22 gymnasts, reporting a leftward turning preference in upright stance and another n = 22 gymnasts, reporting a rightward turning preference in upright stance. All gymnasts had experiences in performing single and double forward and backward somersaults with either one or two twists. The study was conducted with regard to the ethical guidelines of the German Sport University Cologne.

Gymnasts were asked to perform four different skills on the floor, as they would do in a normal training session. The four skills were: 1) straight jump with full turn, 2) round-off, 3) handstand with full turn, and 4) twisting somersault backwards on the floor (performed after a round-off and back handspring). There was neither time pressure put on the gymnasts nor additional instructions given to them. All performances were videotaped for later analysis (50 Hz digital video). Two independent expert coaches were shown the videotaped performances of all gymnasts. Their task was to judge the twist direction in all four skills of all gymnasts. Video sequences were shown on a laptop computer with the option to play backward and forward each performance frame by frame. Judged twist direction always referred to gymnast's longitudinal axis. For instance, a round-off performed with the left hand put first on the floor reflects a rightward twist about the longitudinal axis (see Figure 1).

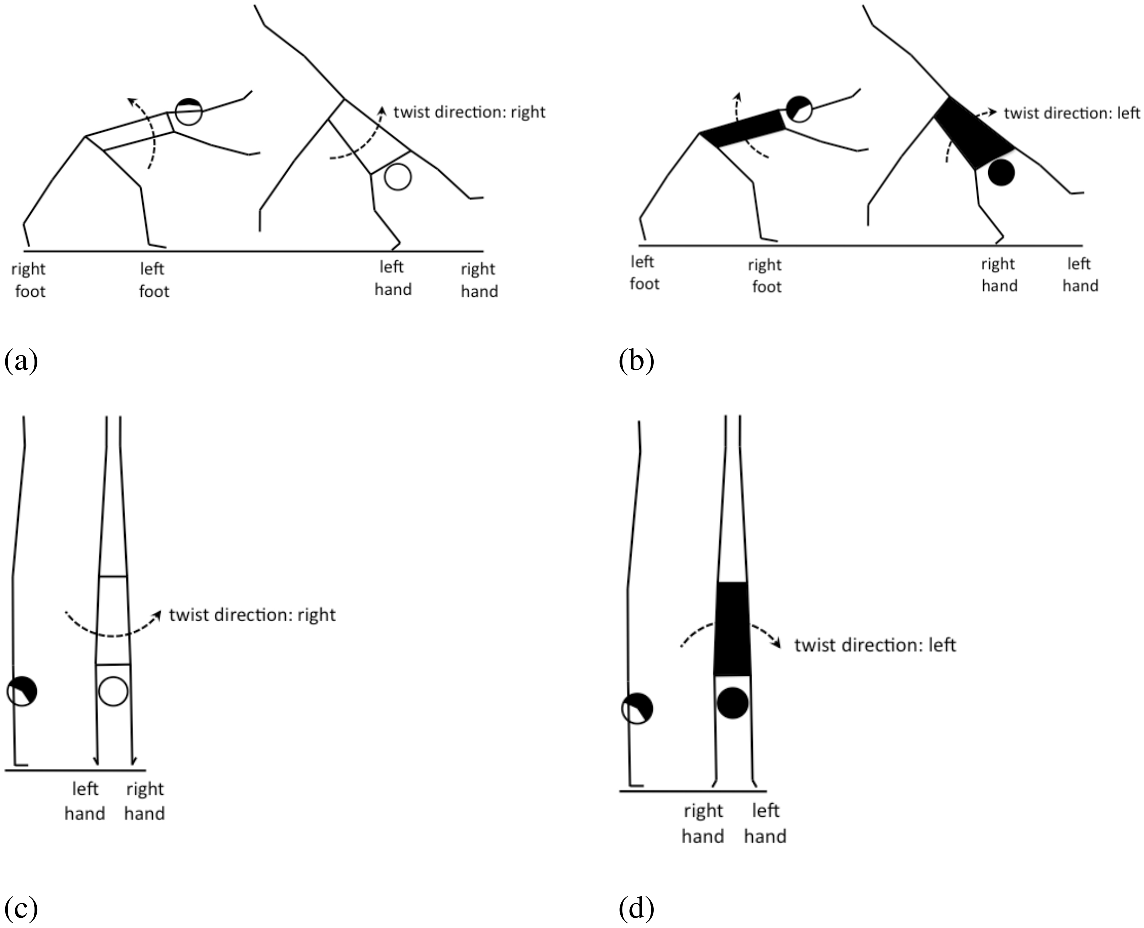

Figure 1. *Stick-figure diagrams illustrating the twist direction about the longitudinal axis (left and right) in both, the round-off (a and b) and the handstand (c and d). Notice that the back of the schematized gymnast is shown as a black area, while the front is shown as a white area.*

Inter-rater reliability between both coaches was 100%, so that twist direction of every single performance could be unambiguously classified as either left or right. Gymnast's reported turning preference in upright stance was cross-checked with their twist direction when performing a straight jump with a full turn, and matched in 100% of the cases.

Lateral Preference Inventory (LPI). To evaluate lateral preference we used a German version of the *Lateral Preference Inventory* (Coren, 1993; Ehrenstein and Arnold-Schulz-Gamen, 1997). This questionnaire assesses lateral preference in four dimensions: 1) eyedness, 2) earedness, 3) handedness, and 4) footedness. Participants are asked to respond to 16 questions related to the aforementioned dimensions, indicating their corresponding lateral preference (left vs. right). Four items assess each dimension. An example for a question related to the dimension of eyedness is: "Which eye would you use to look through a telescope?" When testing the LPI on test-retest reliability, Büsch, Hagemann, and Bender (2009) found a response consistency of 98%. The LPI takes about 10 minutes to complete. The LPI classifies a person as right-consistent, inconsistent, or left-consistent on each of the four dimensions. Additionally a sum score for each dimension can be calculated, ranging from -4 (left-consistent type) to 4 (right-consistent type) with a zero value indicating an inconsistent type.

The procedure of our study consisted of three phases. In the first phase, the gymnasts arrived at the gymnasium and were introduced to the purpose of the study.

After given their written, informed consent, they were asked to warm-up and prepare themselves for a floor training session, like they would do in normal training. In the second phase, and after warming-up, gymnasts were asked to perform the aforementioned four gymnastics skills in their preferred sequence. They could rest at free will and there was no time pressure put on them. During performance, they were videotaped. In the third phase, and after performing all skills, gymnasts were asked to complete the LPI. After completing the LPI, gymnasts were debriefed and received a chocolate bar for their participation. The complete investigation took about 30 minutes for each participating gymnasts.

An overall significance criterion of α = 5% was established for all results reported. To examine relationships between preferred twist direction in different gymnastic skills, we conducted separate frequency analyses, taking the twist direction frequencies of upright stance, round-off, handstand, and twisting somersault backwards as dependent variables. Because we calculated χ^2–tests of every combination of two of the aforementioned skills, this resulted in six separate analyses. To examine differences in measures of laterality with regard to twist direction, we calculated separate multivariate analysis of variance (MANOVA) for preferred twist direction in each of the aforementioned gymnastic skills, taking the laterality scores for eyedness, earedness, footedness, and handedness as dependent variables. In case, the MANOVA showed a significant overall effect, we calculated the separate univariate ANOVAs for each of the dependent variables to explore the structure of the overall effect.

RESULTS

Preferred Twist Direction and Gymnastic Skills

Our first assumption was that twist direction in upright stance (straight jump with full twist) and twist direction of round-off and handstand are inversely related in such a way that gymnasts who twist right in upright stance twist left when performing the round-off and the handstand and vice versa. Our second assumption was that twist direction in upright stance and twist direction of a somersault backwards with a full turn are related in such a way that gymnasts who twist right in upright stance twist also right when performing the twisting somersault backwards and vice versa.

(f).

We conducted separate frequency analyses, taking the twist direction frequencies of upright stance, round-off, handstand, and twisting somersault as dependent variables. The analysis revealed a significant effect for twist direction in round-off, χ^2 = 13.09, $p < .01$, confirming our first assumption. Gymnasts, who twist left in upright stance, twist more often right during round-off and vice versa (see Figure 2a).

Unexpectedly the analysis revealed no significant effect when comparing twist direction in upright stance and in handstand, χ^2 = .09, p = .76. Gymnasts, who twist left in upright stance, do not twist more often right during handstand and vice versa (see Figure 2b). The analysis revealed another significant effect, when comparing twist direction in upright stance with twist direction in twisting somersault, χ^2 = 17.79, $p < .01$. Gymnasts, who twist left in upright stance twist more often left during twisting somersault backwards and vice versa (see Figure 2c).

When comparing twist direction in round-off with twist direction in handstand or in a twisting somersault, we found no significant effects, χ^2 = .82, p = .36, and χ^2 = 3.27, p = .07 respectively (Figure 2d and 2e).

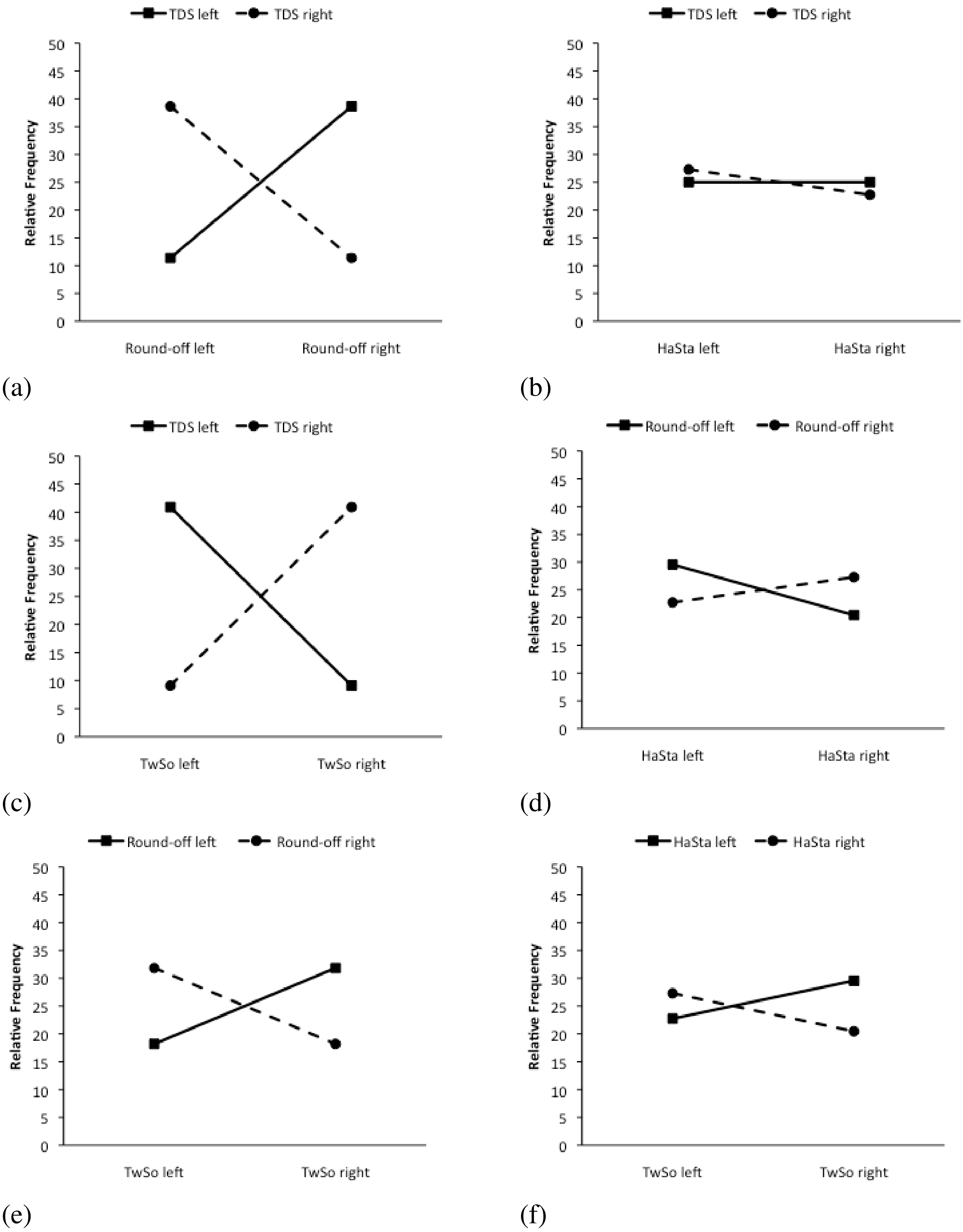

Figure 2. *Relative frequencies of gymnast's twist directions in upright stance (straight jump with full turn, TDS) compared to their twist direction in the round-off (a), the handstand (HaSta, b), and in the twisting somersault (TwSo, c), twist direction in round-off compared to handstand (d), twisting somersault (e), and twist direction in handstand compared to twisting somersault*

Finally, when comparing twist direction in handstand with twist direction in a twisting somersault, we found no significant effect, $\chi^2 = .82$, $p = .36$ (see Figure 2f).

Laterality and Preferred Twist Direction

Our third assumption was that laterality could predict preferred twist direction in gymnasts. A multivariate analysis of variance (MANOVA) was conducted for preferred twist direction in each of the aforementioned skills, taking the laterality scores (LPI) for eyedness, earedness, footedness, and handedness as dependent variables. The MANOVA for preferred twist direction in upright stance showed an overall effect, Wilk's $\lambda = 0.76$, $F(4, 39) = 3.19$, $p = .02$. However, when inspecting the separate univariate ANOVAs, the effect occurred only for eyedness, $F(1, 42) = 10.71$, $p < .01$, but neither for footedness, handedness, nor earedness. The MANOVA for preferred twist direction in round-off showed an additional overall effect, Wilk's $\lambda = 0.67$, $F(4, 39) = 4.74$, $p < .01$, that occurred for eyedness, $F(1, 42) = 15.75$, $p < .01$, and footedness, $F(1, 42) = 6.07$, $p = .02$. The MANOVAs for preferred twist direction in handstand or twisting somersault reached no statistical significance, Wilk's $\lambda = .97$, $F(4, 39) = 0.22$, $p = .92$, and Wilk's $\lambda = .89$, $F(4, 39) = 1.12$, $p = .34$.

Gymnasts who were more left consistent or inconsistent in eyedness showed more often a leftward turning preference in upright stance whereas gymnasts who were more right-consistent in eyedness exhibited more often preference for rightward rotations. Gymnasts who were more left consistent in eyedness or more right consistent in footedness showed more often a rightward turning preference in the round-off.

CONCLUSION

The purpose of our study was twofold. First, we sought to explore relationships in twist direction between different gymnastics skills with regard to turning preference in gymnasts, and second, we sought for significant predictors of turning preference from measures of laterality. We recruited female gymnasts with more than four years of competitive experience, and observed their twist direction in four different gymnastic skills together with their lateral preference in four dimensions. We found that gymnasts who twist left in upright stance, twist more often right during round-off, and more often left during twisting somersault backwards and vice versa. There was no relationship between twist direction in upright stance and in handstand. Gymnasts who were either left consistent or inconsistent in eyedness showed more often a leftward turning preference in upright stance whereas gymnasts who were more right-consistent in eyedness exhibited more often preference for rightward rotations. Gymnasts who were more left consistent in eyedness or more right consistent in footedness showed more often a rightward turning preference in the round-off.

Extending the results of Sands (2000), there is a clear pattern of preferred twist direction between different skills that may in part be explained by perceptual similarity and lateral preference. Perceptual similarity may explain the relationship of twist direction between round-off, twisting somersault and straight jump with full turn with regard to the learning process in gymnastics (Arkaev and Suchilin, 2004). Both, the round-off and the straight jump with full turn are learned early in a gymnast's career. Perceptual similarity may occur when a gymnast rotates to the left in upright stance and to the right when being in an overhead position, so that the vestibular information is similar (Von Laßberg, Mühlbauer, and Krug, 2003). The gymnast *feels* that he or she maintains twist direction but instead rotates in different directions in both skills.

The same mechanism can explain the relationship between twist direction in a straight jump with full turn and in the twisting somersault. Especially in artistic gymnastics a twisting somersault is learned in such a way that the gymnast initiates the twist in the first half of the flight phase (before reaching an overhead position), again, the vestibular signal regarding the longitudinal axis is similar in both skills, this time indicating the same twist direction. However, there was no clear relationship between twist direction in a straight jump with full turn and a handstand, between twist direction in handstand and round-off, nor between twist direction in handstand and twisting somersault. Because the handstand with a full turn is a more static skill in which the gymnast has the goal to maintain equilibrium, he or she may rely to a lesser degree on vestibular information, but rather on information from other sensory sources, so that a clear relationship between the twist direction in more dynamic skills and the handstand with a full turn may not emerge in the learning process (Asseman and Gahéry, 2005).

According to lateral preference we found significant relationships for eyedness and the preferred twist direction in upright stance as well as for eyedness and footedness and the preferred twist direction in round-off. These results are contrary to the findings of Brown et al. (1983) or Golomer et al. (2009) who found no clear relationships between lateral preference and turning preference in athletes. Especially in gymnastics, athletes decide at a very early age to either turn to the left or to the right or usually maintain this preference throughout their whole career. One constituting factor for this decision could be lateral preference (Martin and Proca, 2007), because learners in general choose movement strategies in new tasks in favor of their lateral preference (Serrien, Ivry, and Swinnen, 2006). Furthermore, specific dimensions of lateral preference are already developed before gymnasts start to learn more complex movements. Apparently other extrinsic or intrinsic factors may also explain the selection of twist directions in different skills (Hart and Gabbard, 1997; Previc, 1991). However, the emergence of laterality is for instance linked to vestibular asymmetry and may be one constituting factor in choosing to rotate either left or right in specific gymnastic skills.

There are several limitations of our study so far and we want to highlight two specific aspects. First, we recruited our sample in such a way that 50% of the participants showed a leftward turning preference in upright stance while the remaining 50% of the participants showed a rightward turning preference. This selection does not assure that also lateral preference is equally distributed throughout the sample. However, we used the LPI that does not only classify participants as either left- or right-consistent on a specific factor but rather a distinct score is calculated, that indicates lateral preference on a continuum ranging from -4 (left-consistent) to 4 (right-consistent), allowing for gradual judgments according to laterality even if a sample is not equally in lateral preference (Büsch et al., 2009). However, if we would for instance equally select left- and right-handed gymnasts in another sample of the same expertise level and search for differences in turning preference, the effect should be even stronger.

Second, we acknowledge that our study is very exploratory in nature by describing relationships between preferred twist direction in different skills and lateral preference. However, there is still a fundamental discussion if an experimental manipulation of preferred twist direction should at all be conducted in gymnastics, because this could lead to negative developments for the individual gymnast if this manipulation significantly constrains his or her spatial perception in complex skills. From this point of view it is more beneficial to explore the relationships between a naturally selected preferred twist direction and the underlying factors. This could, in a subsequent step, be done in twins who practice in gymnastics but who show for instance a different turning or lateral preference. The ultimate goal could be the development of a complex test series to predict the optimal configuration of twist directions in different gymnastics skills for each individual gymnast on the basis of his or her characteristics in different factors, like lateral preference.

There are some practical implications of our study so far. First, according to our results, turning preference in gymnastics depends on the demands of the task and, in part, on lateral preference. With regard to the long-term training schedule the coach should carefully decide when to intervene in the development of twisting preference. For instance on the vault, the Tsukahara and the Kasamatsu begin with a round-off like movement to a support phase on the vaulting table, followed by either a counter-rotation or a continued rotation about the longitudinal axis. With regard to the learning history of an individual gymnast, either the Tsukahara or the Kasamatsu will be easier for him or her to acquire because he or she can maintain his or her preferred twist direction in the after flight phase.

We further acknowledge that the relationships we found are not applicable to all gymnasts, and therefore do not allow rule-like assessment. We agree with Sands (2000), stating that as a gymnast progresses in learning, it may be wise not to constrain twist direction but rather to experiment with both directions to ensure that the gymnast has the opportunity to *explore* his or her (natural) preference. It could furthermore be wise to explain the gymnast the potential misperception when being overhead and confront him or her with videotape replays of his or her performance so that he or she can relate his or her perceived twist direction with the actual twist direction.

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CHARACTERISTICS OF EFFECTIVE GYMNASTICS COACHING

Trevor Dowdell

School of Education and Professional Studies, Griffith University, Brisbane, Australia

Original research article

Abstract

This study is investigating the characteristics of effective sports coaching. The breadth of study method has allowed a progressively greater and a more "grounded" understanding of the characteristics of effective gymnastics coaching. The use of different information retrieval methods moving from literature review through surveys, discourse analysis and, finally, eliciting expert practitioner's overt and tacit knowledge represents a more integrated attempt to understand the characteristics of effective coaching. The use of multiple methods of knowledge elicitation was recommended to constrain the effects of knowledge type (e.g. representations versus declarations; overt versus tacit understandings) and task-method-investigator moderators. This study produced a key list of gymnastic coaching attributions, these being planning, effective teaching, having sport specific knowledge, goal setting and "envisioned" excellence in an integrated practice. Other identified common tasks reflected learned practices while on-the-job. These tasks were inter-personal communication, leadership, "spotting", being able to visually analyze skill practice, predict desired outcomes and monitoring students.

Keywords: *gymnastics, effective coaching, key list.*

INTRODUCTION

This study is the third in a series of pilot studies investigating the characteristics of effective sports coaching. Each of the three pilot studies has investigated the characteristics of effective gymnastic coaching using different data collection and analytical methods. The breadth of study method has allowed a progressively greater and a more "grounded" understanding of the characteristics of effective coaching. This highlights the relevance of the use of a range of research paradigms that can reveal more findings about phenomena, than would a reliance on a single research perspective (Schulman, 1986).

The initial study comprised a survey of over 120 gymnastic coaches Australia wide and an extensive review of the Literature. The Literature Review list of characteristics of effective coaching was, in the main, a list of *tasks* of coaching. The Literature review gleaned representational data (a list of tasks in context).

The second study investigated the opinions of a sample of expert coaches and their athletes from a group of top performing clubs in the State of Queensland. Data was collected via interview and the transcripts were analyzed using the Member Categorization Analysis (MCA) technique as described by Baker (1997) and Silverman (1993). The attributions derived from the second's study's interview analysis present a different perspective of effective coaching in sports classes. The coaches placed importance on the *representative core culture of their classes,* as well as *the committed and inspirational nature of the* *coach*. Many of the less highly ranked attributions (but never the less identified through the interviews) such as *parents and gymnast are happy, gymnast & coaches having fun,* and *gymnast respecting coaches* suggest the importance of an effective social and psychological climate to effective gymnastic classes.

This present study continues with the same sample of expert coaches as in the previous study, but elicits their tacit knowledge of the characteristics of effective gymnastics coaching using concept mapping and the use of repertory grid analysis. There is a reasonably large field of representational literature on what accounts for effective coaching, but very few examples found of a constructivist approach to studying coaching knowledge and experience (McGaha 2000, Spencer 2001 and Turner 2001). These few studies using a variety of qualitative methods (observation, reflective journals, interviews via the "Delphi" method, and stimulated recall) have led to some evident suggestions for better or more effective coaching competencies and concomitant education. Practical experience as opposed to knowledge of soccer, and the use of teaching cues was found to be important by soccer coaches (Turner, 2001), while conversely knowledge of sport regulations and event management was deemed critical by cheerleaders (Spencer, 2001). McGaha (2000) described coach behaviors as being similar to expert physical educators and highlighted the use of silence as an effective coaching behavior. This current study is the first to consider the question of effective gymnastic coaching by eliciting expert's knowledge via concept mapping and the use of repertory grid analysis.

The aim of this project is to use concept mapping and repertory grid analysis to identify what expert coaches of top performing gymnastic clubs consider are the characteristics of effective coaching.

1. To describe what characterizes effective sports (gymnastic) coaching based on the hierarchical outcomes of concept maps created by expert coaches.
2. To describe what characterizes effective sports (gymnastic) coaching based on the cluster analysis of repertory grids created by expert coaches.
3. To compare and contrast the described characteristics (attributions) with those of effective coaching presented in the previous pilot studies

A "user-pays" proviso for sports class participation is a recent and pervasive development that consequently demands positive results for the participating gymnasts.. Providing effective instruction for the student's potential growth through competitive gymnastics is a primary goal of each gymnastic club. Expectations may be varied, but it might be assumed that parents expect value for money, and that their child learns while having fun. The importance of the question of what constitutes effective coaching has not diminished, but increased over time.

Gymnastics class activity is heavily reliant on coach locus of control. Gymnastics is among the most complex (if not the most complex) of human physical endeavors (Salmela, Petiot, Halle and Regnier, 1980). A gymnastics coach is responsible for a lengthy period of instructing hundreds upon hundreds of varied and intricate skills to each of their students. The mastery of these skills would be impossible without the integrated control of the coach. (Dowdell, 2002a). It can be suggested that an "effective" coach can have a positive influence on class (skill learning) outcomes.

Often, an expert gymnastic coach is not fully aware of their tacit knowledge of effective coaching. A gymnastics coach's tacit knowledge, as well as their explicit (or easily verbalized) knowledge can be of great value to other practitioners. Effective transfer of tacit knowledge generally requires personal contact and trust. Eliciting expert gymnastic coach's knowledge of effective coaching via concept mapping and the use of repertory grid analysis can play an important role in defining what is effective gymnastic coaching.

Knowledge is central to human performance, and eliciting this knowledge is critical to understanding human performance. The traditional model of applying theory into practice in a "real-world" trial application has been progressively challenged. McMeniman, Cumming, Wilson, Stevenson, and Sim (2002) suggest that this applied research model may not be in accord with the realities of practice. They support a theory-practice model that is reflective of and informs about actual practice settings. Hence the use of "knowledge-in-action" investigative methods.

Research into sports' performance and training behavior over the second half of the twentieth century has been heavily influenced by positivist research methodology and a coach or athlete centered construct. Sport skill was to be "coached" and must therefore draw heavily on physiological and bio-mechanical review, with scant regard for the social psychology of the sport experience (Potrac, Brewer, Jones, Armour and Hoff 2000; Jones, Armour, and Potrac, 2002). The paucity of constructivist examinations of effective sports classes and teaching may have been a result of the popularity of personality surveys and quantitative measurement in sports settings. This is not to say that such investigations have been without merit - on the contrary. However, more varied methods of investigation of sports class settings; such as the case study approach, discursive analysis, and knowledge elicitation protocols may enrich the explanation of what constitutes effective sports coaching.

The variety of tools to elicit and model knowledge-in-action brings with them context, process and interpretative limitations. Interviews and observations, among the most frequently used of all methods, are useful for understanding broad aspects of knowledge-in-action. Stimulated re-call through use of video playback allows the knowledge elicitation process to be enhanced by a delving into the "cognitive world" of the reflective practitioner. The use of multiple methods of knowledge elicitation is recommended to constrain the effects of knowledge type (e.g. representations versus declarations; overt versus tacit understandings) and task-method-investigator moderators (Cooke, 1999). Examples of these moderators to valid investigation can be interpretation of observed practice versus practitioner recall, and sequence and content limitations of interviews.

In this series of pilot studies the use of very different information retrieval methods moving from literature review through surveys, discourse analysis and, finally, eliciting expert practitioner's overt and tacit knowledge represents a more integrated attempt to understand the characteristics of effective coaching. Concept mapping and the use of repertory grids continue this process of connecting to the understandings and knowledge-in-action of competent practitioners. Concept mapping is a technique for externalizing concepts (in the form of propositions), and the relationships between concepts (Novak and Gowin, 1984). Simply put, concept mapping can show how an expert practitioner "organizes" their knowledge (Artiles and McClafferty, 1998). Concept mapping has been used to assess the veracity of recently acquired knowledge, to discover the links between "old" and "new" knowledge, as an evaluation tool, as a tool for reflection of changes in knowledge based on experience, and as a method for eliciting the expert's linked propositions about a topic or phenomena.

The basis for the use of repertory grid knowledge elicitation can be found in the work of Kelly's personal construct theories (1955). His essential conjecture was that; "A person's processes are psychologically channeled by the way in which he anticipates events" (Kelly, 1955, p.46). Kelly suggested that we all develop dichotomous "constructs" which are the basis for distinctive behavior. The repertory grid introduces a means of eliciting a respondent's knowledge by having them classify a set of significant other persons in terms of the respondent's personal constructs (Gaines and Shaw, 2002, 2007). This method attempts to elicit conceptual structures about phenomena indirectly. That is to say, without overtly eliciting concepts and their relationship. This tacit elicitation of knowledge is a useful addition to an integrated approach to understanding practitioner knowledge-in-action.

METHODS

The settings for this study were five gymnastic training organizations. Selection of these clubs was dependent on being ranked in the top dozen clubs (from approximately 90 women's gymnastics clubs in number) in the State and ease of entry and ability to interview key staff. One of the clubs is based in a regional area, while the other four are in the metropolitan area of south-east Queensland, Australia.

Each expert coach was given sufficient, but brief, instructions on constructing a concept map to answer the given question, "What do you understand as the important characteristics of effective gymnastics coaching?" The expert's conceptualizations were augmented with brief interviews conducted during the concept map constructions. Data from the concept maps were analyzed to identify commonalties. Concepts were, in the main, hierarchically presented as super-ordinate, ordinate and sub-ordinate concepts. This allowed a weighted comparison to be made between the five expert's concept maps.

The repertory grid protocol was administered as described by Hopper (1999). The WebGrid-2 software (Gaines and Shaw, 2002) was used to produce a cluster analysis (correlation) among the elements that described the five constructs of sample coaches. The characteristics of the "coach I want to become" gives a potential list of effective coaching characteristics that may otherwise not be elicited by more representative means.

In previous pilot studies, a literature review of effective sports coaching and teaching articles from 1973 to 1995 was carried out by the author for publication (Dowdell, 2002b). Key effective coaching characteristics were collated and tabled. The question of the characteristics of effective coaching was again put to a cohort of expert coaches (five of who participated in this current study). Their interviews were tape-recorded, transcribed and analyzed using the Member Categorization Analysis (MCA) technique as described by Baker (1997). Each coach interviewee ranked the list of randomly ordered effective class attributions. The rankings were weighted so as to allow the addition of each to achieve a final score total (weighted ranking 1st= x17, 2nd= x16, 3rd= x15, 4th= x14, 5th= x13, 6th= x12, and so on) and a hierarchical list of effective coaching attributions.

The characteristics of effective gymnastics coaching discovered in the knowledge elicitation protocols of this study are tabled with information gleaned from the literature review and MCA.

The selection of expert coaches was non-random, and is a limitation in research method. The small number of expert coach respondents limits the generalizability of the report's findings. The absence of formalized and transcribed interviews with each of the expert practitioners following the development of their concept map has limited the depth of analysis of the concept maps.

RESULTS

The given super-ordinate concepts of effective coaching were of a coaching practice that is *value-based and "vision" driven*, with a clear grasp of the all-encompassing *implementation* of the process. Included are the ordinate concepts of having *sport-specific knowledge, being an effective teacher, being well planned and organized, and leading.*

Table 1. *Listed and ranked weighted effective coaching concepts in descending order compared with the list of attributions of effective coaching discovered from a previous MCA study and the Literature review of effective coaching.*

Listed and ranked (weighted) effective coaching attributions from practitioner's concept maps	Final ranking of Attributions of an effective sport (gymnastic) class – from MCA (Dowdell, 2002)	Attributions of effective sport coaching – from a Literature review (Dowdell, 2002)
1. Planning	1. Classes demonstrate core culture (represents Goals/Objectives, Values)	1. Provision of a totally planned system (11)
2. Effective (Competent) Teaching	2. Coach is enthusiastic, inspirational and committed to excellence	2. Good (interpersonal) communication (10)
3. Sport specific knowledge (=2nd)	3. Coach prepares Programs well	3. Knowledge of the specific sport (9)
4. Goal setting	4. Coach committed to measurable class change & outcomes	4. Transfer of control to the group/athlete (8)
5. Has Big Picture (=4th)	5. Coach In control & In charge	5. Maximization of the instructional process (7)
6. "Do" - implementation	6. Set and review fitness-skill goals	6. Maximization of direction (6)
7. Has a vision of excellence (=6th)	7. Adjust or re-do program to meet class needs	7. High levels of control (6)
8. Inter-personal communication	8. Students demonstrates changing performance	8. Maximization of productivity (6)
9. Gives and accepts feedback (=8th)	9. Maximum activity & participation	9. Maximization of progress information / feedback (6)
10. Organized (=8th)	10. Coaches provide feedback to every student	10. Skill analysis (6)
11. Leadership	11. Gymnast respect coaches and show positive attitude	11. Knowledge of sports sciences (5)
12. Knowledge and use of good physical environment (=11th)	12. Gymnasts treated as individuals	12. Maximization of positive experiences (5)
13. Understands and correct performance technique (=11th)	13. Parents happy with and enjoying service	13. Enthusiasm and energy in coaching (5)
14. Visually analyses (models) (=11th)	14. Same kids attending happy - not demoralized	14. Maximization of athlete's intrinsic motivation (4)
15. Programming	15. Gym uncluttered and neat	15. Philosophy (of program) reflected in objectives (4)
16. "Spotting"	16. Gymnast and coaches having fun	16. Set objectives (4)
17. Monitor and evaluate students	17. Low Noise level	17. Dedicated coach (3)
		18. Empathetic coach (3)

Listed and ranked weighted effective coaching concepts in descending order are listed in Table 1 and compared with the list of attributions of effective coaching discovered from the previous MCA study and the Literature review of effective coaching. Each of the expert coaches expressed particular characteristics of the "coach they would like most to become" in the repertory grid responses. Common effective coaching attributions were *being sport knowledgeable, being well planned, predicting and getting results, hard working, and being able to visually analyze (skills).* The repertory grid cluster analysis of these responses is shown in Table 2.

Table 2. *Elements of effective gymnastics coaching showing higher correlation.*

	Elements that correlate 100%, 95%, 90% and the lowest correlation of 80% or less			
COACH	100%	95%	90%	80% or less
Expert coach #1	Well-planned AND Adaptive	Skilled AND Inspirational	Knowledgeable AND Skilled and Inspirational AND Well-planned, Adaptive	Confidence and Energetic, AND All others
Expert coach #2	Analytical eye AND Predict and achieve results	Useful planning AND Analytical eye Predict and achieve results	Useful planning, analytical eye, Predict and achieve results AND Knowledgeable Prevents injuries, Creates champion thinking AND Open to ideas.	NA
Expert coach #3	Initiative, thorough knowledge AND life long learning Being committed AND hard-working	Complete planning commitment and hard work AND A quality character	NA	NA
Expert coach #4	NA	Seeks knowledge AND motivational	Good visual analysis AND successful Humorous and assertive	NA
Expert coach #5	Structured lessons, good class controls and outcome oriented	Hard working AND Structured lessons, good class control and outcome oriented	Good time management AND clear short instructions. Hard working AND clear short instructions	Good time management AND Relates well to children

DISCUSSION

The selected coach practitioners are each similarly expert in the field of gymnastics coaching. However, each "organized" differently their concepts of the important characteristics of effective gymnastics coaching. Coach #1, #2, and #4 clearly saw coaching practice as integrated and vision driven, while coach #3 saw key values predicating practice in a simple map beginning with "Being" and "Doing" the role of an effective coach. Coach #5 reflected a three-dimensional model that was difficult to justify in a two-dimensional concept map. This coach (the business owner) reflected the ownership and responsibility of the business of gymnastic coaching more so than the other coaches who were staff or consultants.

The weighting of concepts via hierarchical levels produced a key list of effective coaching attributions being *planning, effective teaching, having sport specific knowledge, goal setting* and *"visioned" excellence in an integrated practice.* This list corresponds with the literature review and survey findings that suggests *totally planned systems, sport specific knowledge,* and *maximization of the instructional process* are among the top five characteristics of effective coaching.

However, it is the differences between the three lists in table 1 that are enlightening. The Literature Review list of characteristics of effective coaching is mainly a list of tasks of coaching. Only numbers 2 and 18 refer directly to the interactional nature of coaching. The attributions derived from the MCA and concept mapping present a different perspective of the "world" of effective gymnastic classes. There are common tasks between the Literature Review findings and the MCA findings highlighted as important, such as a well-planned coaching program. However, the MCA outcomes stress more of the social-psychological interactions among coach, student and class. For example, inter-personal communication, inspired leadership, "spotting" and monitoring students are aspects of learned practice that cannot be accomplished outside the world of practitioner experience.

This difference may point to the Literature review gleaning representational data (list of tasks out of context), while the methods used in this study brought forth the practitioner's everyday understandings of their "world" of gymnastic coaching. Interestingly, the expert coaches repertory grid -responses to the question "the coach I would like most to become" showed a commonality among coaching attributions. Being *knowledgeable* and having a *complete and useful coaching plan were* common to four coaches. The ability to *visually analyze skill practice* and *predict desired outcomes*, as well as *being hard working* was common in at least two of the five practitioners.

The cluster analysis of elements (results in Table 2) grouped comprehendible (even predictable) attributions. Examples are "well planned" and "adaptive" (coach #1), and "good time management" and "clear short Instructions" (coach #5). Of interest is some correlation between attributions that may bear future scrutiny. These are "skilled' and "inspirational" from coach #1, "prevents injuries" and "creates champion thinking" from coach #2, and "humorous" and "assertive" from coach #4. Future analysis of this type would benefit greatly by post grid response interviews as to why the practitioners selected particular bi-polar constructs and why these constructs clustered together as they did.

This current study is the first to consider the question of effective coaching by eliciting expert's tacit knowledge via concept mapping and the use of repertory grid analysis. These knowledge elicitation methods seem ideally suited to coach practitioners, as "real-world" practice is more than often reflective rather than representative of theoretical models. Past constructivist methods of effective sports practice investigation have been mostly representational (observations and document analysis) with little applicability to expert "reflection in practice" (Byra and Karp, 2000). The current knowledge-in-action protocols are ideally suited to further probing of the overt and tacit knowledge of expert coach practitioners. The list of attributions of effective gymnastic coaching both confirms past studies and provides a more comprehensive view by adding some key learned practices such as visual analysis of skills, "spotting", outcome predication and monitoring students.

CONCLUSION

This study is the third in a series of a pilot group of studies investigating the characteristics of effective gymnastics coaching. These studies are to establish dimensions of coaching behavior relevant to a key study to produce a measuring instrument for sports class learning climate.

Each of the three pilot studies has investigated the characteristics of effective sports (gymnastic) coaching using different data collection and analytical methods. The breadth of study method allows a progressively greater and a more "grounded" understanding of the characteristics of effective coaching. The use of very different information retrieval methods moving from literature review through surveys, discourse analysis and, finally, eliciting expert practitioner's overt and tacit knowledge represents a more integrated attempt to understand the characteristics of effective coaching. The use of multiple methods of knowledge elicitation is further recommended to constrain the effects of knowledge type (e.g. representations versus declarations; overt versus tacit understandings) and task-method-investigator moderators.

This study produced a key list of gymnastic coaching attributions, these being *planning, effective teaching, having sport specific knowledge, goal setting* and *"envisioned" excellence in an integrated practice.* Other identified common tasks reflected learned practices while on-the-job. These tasks were *inter-personal communication, leadership, "spotting", being able to visually analyze skill practice*, *predict desired outcomes* and *monitoring students*. Future analysis of this knowledge-in-action elicitation type would benefit greatly by post response interviews as to why the practitioners selected particular constructs and why these constructs clustered together as they did.

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RELIABILITY AND VALIDITY OF JUDGING IN MEN'S ARTISTIC GYMNASTICS AT THE 2009 UNIVERSITY GAMES

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Abstract

Ensuring reliability and validity of judging at artistic gymnastics competitions is difficult. Despite the FIG Men's Code of Points being changed, there is little evidence to show that these changes have had an effect on judging standards. After the last change to the Code of Points (2008) the second biggest men's artistic gymnastics competition took place in 2009 - University Games in Belgrade. Data based on judges' scores were analysed. By last change of the Code of Points the sum of the Difficulty score and the Execution score form the Final score. For the Execution score, which is evaluated by 4 or 6 judges (4-in qualifications and all around, 6 in finals) reliability and validity were calculated (intraclass correlation coefficient, Cronbach's alpha, Kendall coefficient of concordance W, and a theta coefficient; differences in mean E scores between judges were tested using repeated measures ANOVA. All data was analyzed using SPSS Statistics 17.0. Results show very high reliability (e.g. Cronbach alfa range from 0.92 up to 0.99). Systematic bias in individual judge's scores and judges' panels were frequent. Invalidity tends to decrease as competitor numbers increase. Despite good reliability and satisfactory validity of judging at the University Games it should be emphasized that judging quality differs between apparatus, sessions and judges.

Keywords: *men's artistic gymnastics, judging,reliability, validity, university games.*

INTRODUCTION

Evaluation of artistic gymnastics exercises has a long tradition. A gymnasts result is determined by a panel of judges, which should evaluate a gymnastic exercise according to clearly defined rules. Although these rules objectively specify how exercises should be evaluated, evaluation is prone to judges' errors. These errors may be unintentional or sometimes intentional, e.g. at OG 2004 in Athens where head judge was punished for biased decision in men's all around finals. In elite gymnastics the difference between competitors, especially those running for medals, is usually small and small errors can result in a big difference to the final rank of a competitor. Competitors, coaches, spectators, and the media are therefore concerned that judging is of a high standard. The Fédération Internationale de Gymnastique (FIG), which is responsible for the development of sport internationally, is continually trying to implement "fair" rules, which are interpreted by carefully chosen, well educated judges with high ethical standards (FIG, 2009a, 2009b). Some of the most important endeavors of the FIG in this direction were major changes made to the Code of Points in 2006 and the IRCOS project, which allow for evaluation of judge's performances through video analysis.

At the beginning of gymnastics judging only one judge evaluated each gymnast, today this has risen to eight judges evaluating each gymnast (FIG, 2009c). Women's artistic gymnastics started with the World championships in 1950 following the men's tradition. Today, the Code of Points is similar for women and men in terms of the judges' panel structure and general evaluation guidelines. Both sports have 6 (or 4 for competitions at lower levels than Olympic Games or World Cup) judges evaluating exercise presentations – which results in an E (execution) score and 2 judges evaluating the exercise content – resulting in a D (difficulty) score. The E score decreases from 10 points in decrements of 0.1 point and the D score increases from 0 points up in 0.1 increments. The D score is ratio scale, while the E score is interval scale. Both scales can be used with multivariate analysis, as though especially right censoring (at 10 points) of E score may cause problems in analysis requiring multivariate normal distribution of data.

Due to the D score being a combination of two judges' evaluations reliability and validity cannot be calculated. It is however, possible to calculate reliability and validity for the E score – the average of the middle four (or two). Reliability (also called consistency or repeatability) can be defined as achieving the same results with several measurements of the same subject under identical conditions. A special case of reliability, called inter-rater reliability or objectivity is defined as achieving same results from different persons (judges, assessors, raters, observers) who evaluate the *same* performance. This later aspect of reliability is especially important in gymnastics. As most of the reliability measures are based on interitem (interobserver) correlations, they could not detect validity of judging, i.e. if there is any systematical bias in judging, e.g. systematical under- or overestimation of particular judge or competitors of certain nationalities.

Several authors have tried to evaluate the quality of judging at different competitions. Ansorge, Scheer, Laub, and Howard (1978) found bias in scores induced by the position in which female gymnasts appear in their within-team order. Ansorge and Scheer (1988) found biased judging towards judges' own national team and against immediate competitors' teams. Hraski (1988) analyzed judging at the World Cup in 1982 in all male disciplines; judging for floor exercises was deemed to be the poorest discipline, while still being of an acceptable standard. Duda, Brown, Borysowicz, and St. Germaine (1996) analyzed stress factors of judging; one of many concerns identified was related to the objectivity and reliability of judging. In rhythmic gymnastics, Popović (2000) found biased judging where judges scored gymnasts of their own nationality more favorably. Plessner and Schallies (2005) were determining parallax problems evaluating rings positions; experts were better evaluating position than others. Boen, Van Hoye, Auweele, Feys, and Smits (2008) found that if judges knew other judges scores it resulted in them correcting and adjusting their scores. The FIG Technical Committee is evaluating the quality of judging after all major events. In the past the ranking of gymnasts was the most important information. With the changes to the Code of points resulting in two scores – E and D – in 2006, they started to evaluate E judges by calculating the difference between the final score (average score of middle 4 or 2 judges) and the individual judges score. The 2009 Code of Points (FIG, 2009c) states that judges cannot see other judge's scores before or after they give their own score, but they do see the final E score. The aim of our research was to analyze the reliability and validity of judges' E scores on all apparatus for all sessions (qualification, all round finals, and apparatus finals) at the 2009 World University Games (Universiade) in Belgrade.

METHODS

Judges E scores were obtained from the game's official book of results. To protect judges anonymity we randomly changed their position in the analysis from the book of results. Three analyses were carried out, one for each session of the competition. The first analyses used data from the qualification sessions on each apparatus. There were four judges for each apparatus. In the qualification session 93 gymnasts performed on the floor, 91 on the pommel horse, 91 on the rings, 113 on the vault, 94 on the parallel bars, and 89 on the high bar. The second analyses used data from the all round finals where 4 judges evaluated E score. In the all round finals 24 gymnasts competed. The third analyses used data from the apparatus finals where 6 judges evaluated E score. In the apparatus finals 8 gymnasts competed, providing 8 sets of scores for each apparatus other than the vault, where 16 sets of scores were available because each competitor performed twice. For each set of analysis we calculated statistics for the E score, item (individual judge) and scale (all judges together) scores. The following reliability and validity statistics were then calculated: intraclass correlation coefficient, Cronbach's alpha, Kendall coefficient of concordance W, and a theta coefficient (Armor, 1974), which is based on the first (largest) eigenvalue from the principal component analysis of the correlations between judges' scores. Differences in mean E scores between judges were tested using repeated measures ANOVA. All data was analyzed using SPSS Statistics 17.0 whenever possible, otherwise using Microsoft Excel.

RESULTS

Mean E scores (Table 1, Figure 1) vary between events, and for some events the data is not normally distributed due to extreme outliers (e.g. rings and high bar during qualification). There is also a large difference in the variability of scores. In general, the smallest variability in all three competition sessions is observed on vault, and the highest in pommel horse. There is a tendency of decreasing variability from first (qualification) to last (apparatus finals) session. The similar pattern of differences in variability between sessions and apparatuses is also evident in central tendency. In all three sessions vault has highest, while rings and pommel horse (except in apparatus finals) have the lowest mean and median values.

Table 1. *Distribution statistics of E score*

session	apparatus	N	M	Me	Min	Max	SD	IQR	Skew.	Kurt.
qualification	Floor	93	8.28	8.40	7.1	9.05	.47	.55	-.85	-.06
	Pommel horse	91	8.09	8.25	3.9	9.5	.90	1.00	-1.63	4.57
	Rings	91	7.69	8.00	0.35	8.85	1.07	.80	-4.03	24.27
	Vault	113	8.86	8.95	7.6	9.4	.36	.35	-1.36	1.58
	Parallel bars	94	8.46	8.60	6.35	9.5	.69	.98	-.84	.19
	High bar	89	8.06	8.30	0.65	9.35	1.08	.73	-4.29	25.78
all round finals	Floor	24	8.62	8.75	6.9	9.15	.44	.23	-2.90	10.65
	Pommel horse	24	7.61	7.85	5.1	8.75	.91	1.10	-1.18	1.36
	Rings	24	8.03	8.15	6.9	8.65	.46	.48	-1.14	.59
	Vault	24	8.89	8.90	7.95	9.6	.35	.40	-.65	1.68
	Parallel bars	24	8.43	8.53	7.6	9.15	.45	.85	-.15	-1.08
	High bar	24	8.22	8.43	6.5	9.15	.67	.89	-1.15	.64
apparatus finals	Floor	8	8.59	8.69	7.975	8.925	.31	.43	-1.13	.94
	Pommel horse	8	8.73	8.75	8.2	9.225	.39	.80	-.04	-1.57
	Rings	8	8.33	8.41	7.575	9.075	.48	.73	-.15	-.16
	Vault	16	9.06	9.15	8.025	9.425	.37	.26	-1.87	3.62
	Parallel bars	8	8.19	8.33	7.175	9.025	.61	.98	-.47	-.51
	High bar	8	8.39	8.60	6.75	8.85	.68	.30	-2.59	6.99

Legend: *N* – no. of performances; *M* – mean; *Me* – median; *Min*, *Max* – lowest and highest value; *SD* – standard deviation; *IQR* – Interquartile range; *Skew.*, *Kurt.* – coefficients of skewness and kurtosis.

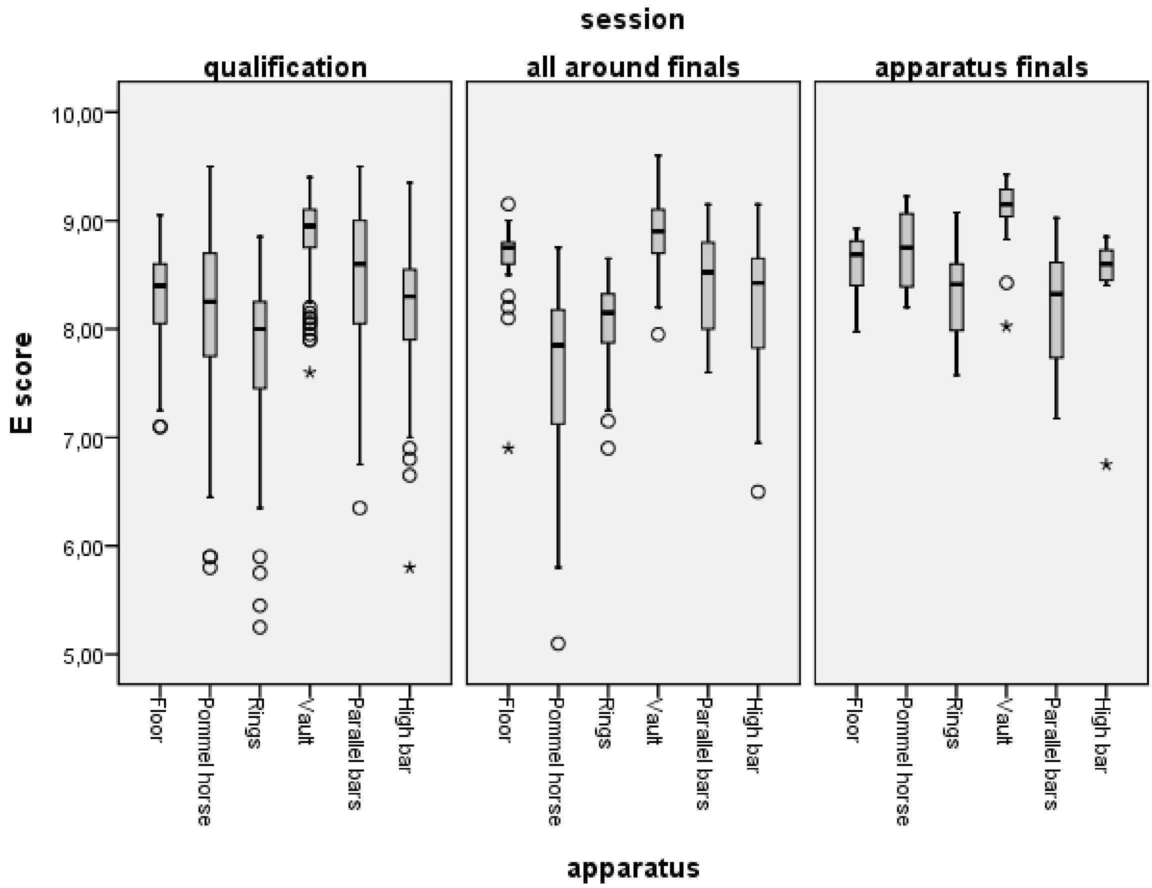

Figure 1. *Boxplots of E score. Note: in qualification, four extreme outliers (E score < 5) are excluded.*

Statistics of scores for individual judges is presented separately for each session and Distributional statistics (mean and standard deviation) was calculated for raw E scores and it's signed and absolute deviation from the final E score. These two forms of deviation are measures of bias (under/over estimation) and reliability of judge's scores.

They are also transformed to mean rank (R_{mean}), and it's deviation (dR_{mean}) from expected (unbiased) rank, calculated as follows: $(m+1)/2$, where m is the number of judges (4 in first two and 6 in the last session). Finally, corrected item-total correlation (r_{corr}) and Cronbach's alpha *if item deleted* ($alpha_{del}$) were calculated.

Table 2. *Statistics of individual judges in the qualification session*

		E score		Dev. E score		Dev. E score abs.					
apparatus	judge	M	SD	M	SD	M	SD	R_{mean}	dR_{mean}	r_{corr}	$alpha_{del}$
Floor	1	8.28	.55	-.01	.22	.16	.15	2.5	.0	.87	.93
	2	8.30	.47	.01	.17	.13	.10	2.5	.0	.89	.92
	3	8.26	.50	-.02	.18	.12	.13	2.4	.1	.88	.93
	4	8.31	.52	.03	.22	.17	.15	2.6	-.1	.85	.93
P. horse	1	8.04	1.04	-.05	.24	.17	.18	2.5	.0	.95	.94
	2	8.00	1.01	-.09	.27	.20	.20	2.3	.2	.94	.95
	3	8.07	.81	-.02	.38	.27	.26	2.5	.0	.87	.97
	4	8.14	.81	.05	.28	.21	.19	2.8	-.3	.92	.95
Rings	1	7.79	1.18	.11	.31	.25	.21	2.9	-.4	.95	.96
	2	7.43	1.00	-.26	.36	.34	.28	1.7	.8	.92	.97
	3	7.75	1.06	.07	.28	.20	.20	2.6	-.1	.94	.96
	4	7.75	1.11	.06	.25	.19	.18	2.7	-.2	.95	.96
Vault	1	8.93	.39	.07	.16	.13	.11	2.9	-.4	.85	.93
	2	8.83	.36	-.03	.14	.10	.10	2.2	.3	.86	.92
	3	8.91	.39	.05	.15	.11	.12	2.9	-.4	.88	.92
	4	8.78	.37	-.08	.16	.12	.14	2.0	.5	.85	.92
Par. bars	1	8.42	.74	-.04	.15	.12	.10	2.4	.1	.96	.96
	2	8.47	.71	.00	.15	.11	.10	2.5	.0	.96	.96
	3	8.54	.64	.07	.23	.17	.17	2.8	-.3	.92	.98
	4	8.43	.75	-.03	.21	.15	.16	2.3	.2	.94	.97
High bar	1	8.08	1.10	.02	.21	.16	.14	2.6	-.1	.97	.98
	2	8.07	1.15	.01	.19	.14	.13	2.6	-.1	.98	.98
	3	8.06	1.07	.00	.23	.17	.15	2.5	.0	.96	.98
	4	8.02	1.10	-.04	.25	.16	.20	2.2	.3	.96	.98

Legend: R_{mean} mean rank; dR_{mean} deviation of R_{mean} from expected rank; r_{corr} corrected item-total correlation; $alpha_{del}$ Cronbach alpha if item deleted

Table 3. *Statistics of individual judges in the all round finals*

		E score		Dev. E score		Dev. E score abs.					
apparatus	judge	M	SD	M	SD	M	SD	R_{mean}	dR_{mean}	r_{corr}	$alpha_{del}$
Floor	1	8.58	.54	-.04	.18	.13	.14	2.3	.2	.90	.94
	2	8.69	.45	.07	.14	.10	.12	2.9	-.4	.93	.93
	3	8.60	.46	-.02	.14	.09	.12	2.6	-.1	.90	.94
	4	8.56	.50	-.06	.22	.14	.18	2.2	.3	.85	.95
P. horse	1	7.40	1.16	-.20	.40	.30	.33	1.8	.7	.94	.96
	2	7.63	1.11	.03	.33	.25	.21	2.7	-.2	.94	.96
	3	7.65	.79	.05	.22	.16	.15	2.6	-.1	.96	.96
	4	7.70	.89	.10	.21	.18	.15	2.9	-.4	.94	.96
Rings	1	8.08	.61	.05	.31	.24	.21	2.9	-.4	.77	.93
	2	8.05	.47	.03	.21	.14	.16	2.7	-.2	.86	.89
	3	7.94	.50	-.09	.20	.17	.14	2.0	.5	.83	.90
	4	8.00	.45	-.03	.17	.14	.11	2.4	.1	.87	.89
Vault	1	8.88	.36	-.01	.14	.10	.10	2.6	-.1	.85	.89
	2	8.83	.31	-.06	.12	.10	.08	2.0	.5	.89	.89
	3	8.90	.36	.01	.21	.11	.18	2.4	.1	.75	.93
	4	8.96	.41	.07	.16	.14	.11	3.0	-.5	.84	.90
Par. bars	1	8.38	.56	-.05	.19	.14	.13	2.2	.3	.90	.89
	2	8.50	.39	.08	.25	.19	.19	2.9	-.4	.77	.94
	3	8.37	.49	-.06	.24	.18	.17	2.2	.3	.81	.92
	4	8.45	.46	.02	.11	.08	.08	2.7	-.2	.93	.88
High bar	1	8.25	.69	.03	.24	.20	.13	2.8	-.3	.89	.94
	2	8.27	.85	.05	.29	.23	.18	2.8	-.3	.93	.93
	3	8.12	.66	-.10	.22	.18	.15	2.1	.4	.91	.94
	4	8.19	.68	-.02	.26	.22	.15	2.3	.2	.86	.95

Legend: R_{mean} mean rank; dR_{mean} deviation of R_{mean} from expected rank; r_{corr} corrected item-total correlation; $alpha_{del}$ Cronbach alpha if item deleted

Table 4. *Statistics of individual judges in the apparatus finals*

		E score		Dev. E score		Dev. E score abs.					
apparatus	judge	M	SD	M	SD	M	SD	R_{mean}	dR_{mean}	r_{corr}	$alpha_{del}$
Floor	1	8.74	.41	.15	.24	.24	.13	4.5	-1.0	.72	.94
	2	8.48	.28	-.11	.11	.13	.10	2.6	.9	.91	.91
	3	8.39	.39	-.20	.22	.28	.08	1.8	1.8	.73	.93
	4	8.69	.39	.10	.16	.15	.10	4.4	-.9	.89	.91
	5	8.63	.17	.04	.18	.11	.14	3.6	-.1	.90	.93
	6	8.66	.40	.08	.12	.11	.08	4.1	-.6	.96	.90
P. horse	1	8.80	.38	.07	.12	.11	.09	4.0	-.5	.94	.91
	2	8.79	.23	.06	.23	.17	.16	3.4	.1	.82	.94
	3	8.85	.32	.12	.15	.15	.12	4.3	-.8	.91	.92
	4	8.74	.54	.01	.23	.21	.06	3.8	-.3	.88	.92
	5	8.59	.55	-.14	.27	.22	.20	2.9	.6	.80	.93
	6	8.49	.65	-.24	.33	.28	.29	2.6	.9	.89	.92
Rings	1	8.26	.40	-.07	.21	.14	.16	2.9	.6	.86	.96
	2	8.36	.48	.03	.19	.11	.14	3.4	.1	.89	.95
	3	8.39	.40	.06	.20	.16	.11	3.8	-.3	.88	.96
	4	8.24	.57	-.09	.24	.19	.16	3.1	.4	.88	.95
	5	8.25	.64	-.08	.25	.19	.17	3.6	-.1	.91	.95
	6	8.43	.53	.09	.15	.11	.14	4.1	-.6	.93	.95
Vault	1	8.94	.46	-.12	.17	.15	.14	2.7	.8	.92	.98
	2	9.11	.38	.04	.10	.09	.07	4.1	-.6	.95	.97
	3	9.06	.32	-.01	.11	.08	.07	3.2	.3	.94	.97
	4	9.02	.40	-.05	.11	.09	.08	2.8	.7	.94	.97
	5	9.13	.33	.07	.09	.09	.07	4.3	-.8	.95	.97
	6	9.10	.45	.04	.14	.10	.10	4.0	-.5	.94	.97
Par. bars	1	8.15	.63	-.04	.34	.24	.22	3.1	.4	.78	.96
	2	8.01	.67	-.18	.36	.26	.31	3.1	.4	.81	.96
	3	8.21	.84	.02	.30	.26	.11	4.2	-.7	.94	.95
	4	8.23	.62	.03	.14	.11	.09	3.6	-.1	.96	.95
	5	8.14	.64	-.06	.18	.16	.08	2.8	.7	.95	.95
	6	8.30	.56	.11	.22	.19	.15	4.3	-.8	.90	.95
High bar	1	8.45	.55	.06	.18	.13	.12	3.8	-.3	.97	.98
	2	8.44	.80	.04	.19	.14	.13	3.7	-.2	.97	.98
	3	8.28	.75	-.12	.20	.19	.12	3.0	.5	.94	.98
	4	8.51	.52	.12	.21	.16	.17	4.4	-.9	.96	.98
	5	8.49	.81	.09	.21	.16	.16	4.2	-.7	.96	.98
	6	8.20	.61	-.19	.15	.21	.13	1.9	1.6	.97	.98

Legend: R_{mean} mean rank; dR_{mean} deviation of R_{mean} from expected rank; r_{corr} corrected item-total correlation; $alpha_{del}$ Cronbach alpha if item deleted

Pearson's correlations between judges (Table 5) are, in the main, higher than .8. There are few exceptions, usually when the number of competitors in an event is low. One very low correlation (.39) in the floor apparatus finals between judges 1 and 3 is due to judge no. 3 awarding the highest score in this event to the competitor who finished in 7th (second last) place. Without this score correlation would be .81. Except for the vault qualifications and parallel bars all round finals, the floor has the lowest correlations between judges, with horizontal bar providing the highest correlations. In general, average correlation is the highest in qualification session and lowest in the all round finals, with two clear exceptions (high correlations in pommel horse all round finals and vault apparatus in the finals).

Table 5. *Pearson correlation coefficients between judges' E scores*

		qualification				all around finals				apparatus finals					
	judge	1	2	3	4	1	2	3	4	1	2	3	4	5	6
Floor	1		.85	.81	**.79**		.91	.89	.78		.65	**.39**	.73	.75	.87
	2	.85		.83	**.79**	.91		.84	.86	.65		.88	.79	.90	.90
	3	.81	.83		.82	.89	.84		.83	**.39**	.88		.75	.79	.71
	4	**.79**	**.79**	.82		.78	.86	.83		.73	.79	.75		.77	.90
	5									.75	.90	.79	.77		.84
	6									.87	.90	.71	.90	.84	
Pommel horse	1		.94	.87	.92		.90	.93	.91		.77	.86	.81	.88	.90
	2	.94		.85	.90	.90		.94	.92	.77		.92	.90	**.60**	.70
	3	.87	.85		.83	.93	.94		.94	.86	.92		.90	.71	.83
	4	.92	.90	.83		.91	.92	.94		.81	.90	.90		.70	.83
	5									.88	**.60**	.71	.70		.78
	6									.90	.70	.83	.83	.78	
Rings	1		.90	.93	.92		.73	**.69**	.75		.81	.85	.75	.86	.77
	2	.90		.88	.90	.73		.83	.83	.81		.75	.83	.82	.93
	3	.93	.88		.93	**.69**	.83		.81	.85	.75		.80	.85	.87
	4	.92	.90	.93		.75	.83	.81		.75	.83	.80		.86	.87
	5									.86	.82	.85	.86		.85
	6									.77	.93	.87	.87	.85	
Vault	1		**.80**	**.79**	**.79**		.82	.73	.78		.90	.90	.90	.87	.88
	2	**.80**		.83	**.77**	.82		.71	.87	.90		.89	.94	.93	.90
	3	**.79**	.83		.82	.73	.71		**.67**	.90	.89		.88	.93	.94
	4	**.79**	**.77**	.82		.78	.87	**.67**		.90	.94	.88		.93	.89
	5									.87	.93	.93	.93		.93
	6									.88	.90	.94	.89	.93	
Parallel bars	1		.95	.91	.92		.74	.79	.93		**.57**	.76	.86	.77	.70
	2	.95		.90	.93	.74		**.66**	.78	**.57**		.85	.81	.82	.71
	3	.91	.90		.88	.79	**.66**		.81	.76	.85		.90	.89	.89
	4	.92	.93	.88		.93	.78	.81		.86	.81	.90		.92	.91
	5									.77	.82	.89	.92		.95
	6									.70	.71	.89	.91	.95	
High bar	1		.96	.95	.94		.86	.88	.80		.95	.93	.94	.97	.94
	2	.96		.96	.96	.86		.90	.87	.95		.90	.93	.98	.96
	3	.95	.96		.94	.88	.90		.80	.93	.90		.97	.91	.94
	4	.94	.96	.94		.80	.87	.80		.94	.93	.97		.92	.94
	5									1	.98	.91	.92		.93
	6									.94	.96	.94	.94	.93	

Note: coefficients lower than .8 in qualification session, .7 in all around finals and .6 in apparatus finals are printed in bold

Table 6. *Reliability and validity measures of competition events*

Session	apparatus	Alpha	$ICC_{average}$	ICC_{single}	Armor's theta	Kendall W	ANOVA F
qualification	Floor	.94	.94	.81	.95	.01	.92
	P. horse	.96	.96	.87	.97	.02	<u>2.83</u>
	Rings	.97	.97	.88	.98	<u>.20</u>	<u>23.06</u>
	Vault	.94	.93	.77	.94	<u>.16</u>	<u>19.51</u>
	Par. bars	.98	.98	.91	.98	<u>.03</u>	<u>5.70</u>
	High bar	.99	.99	.95	.99	.02	1.25
all around finals	Floor	.96	.95	.84	.96	.06	2.08
	P. horse	.97	.97	.88	.98	<u>.14</u>	<u>3.92</u>
	Rings	.92	.92	.75	.93	.08	1.47
	Vault	.92	.92	.74	.93	<u>.13</u>	2.27
	Par. bars	.93	.93	.77	.94	.08	1.87
	High bar	.95	.95	.84	.96	.07	1.30
apparatus finals	Floor	.93	.91	.62	.95	<u>.36</u>	<u>3.92</u>
	P. horse	.94	.92	.67	.96	.13	2.49
	Rings	.96	.96	.80	.97	.06	1.01
	Vault	.98	.97	.86	.98	<u>.16</u>	<u>4.24</u>
	Par. bars	.96	.96	.81	.97	.12	.89
	High bar	.98	.98	.89	.99	.26	<u>2.92</u>

Note: coefficients W and F that are significantly different from zero at p<.05 are underlined.

DISCUSSION AND CONCLUSIONS

As many of the reliability measures of judges' performances are based on Pearson's correlations (*r*) it's important to evaluate these before evaluating derived measures. The size and sign of *r* can be heavily affected by the presence of outliers, especially if the number of outliers is high compared to the total number of cases e.g. in the high bar apparatus finals (8 competitors) *r* between the first two judges is .95; if we omit the outlier (competitor with score 7.1 and 6.5 given from first and second judge, respectively), *r* is not only much lower but also of negative sign (*r*=–.33). As a consequence of this, ICC changes from very high (.98) to moderate (.63).

Despite this, indices of reliability are generally quite high. In different sessions and apparatus all reliability measures (Cronbach's alpha, ICC, Armor's theta) are higher than .90. Those indices tend to be a little lower in the all round finals than in qualification and apparatus finals. There appears to be no systematic differences in reliability between apparatus. Vault scores tend to have lower reliability than other apparatus in qualification and all round finals, but not in apparatus finals. High bar scores have the highest reliability in qualification session and apparatus finals, but only average in all around finals.

Although these results are not directly comparable with results from the 1982 World Cup in Zagreb (Hraski, 1988) it seems that reliability is improving over time, and through the introduction of new rules, especially splitting judges' panel into judges for exercise presentation and exercise content. In Zagreb, only 20 gymnasts competed, all in one session; they were evaluated by 5 judges (head judge and four score judges), which were judging exercise difficulty and exercise presentation together; Armor's theta ranged from .92 (on the floor) to .98 (rings and high bar), whereas in Belgrade Armor's theta ranged from .93 (rings and vault all round finals) to .99 (high bar qualifications and apparatus finals).

High reliability of E scores is not always accompanied by high validity. Systematic bias in individual judge's scores (as measured by dR_{mean}, a deviation of mean rank from expected unbiased rank) and judges' panels (as measured by Kendall W and ANOVA F) were frequent.

Surprisingly, the second highest dR_{mean} (1.6) appeared in the event with the highest reliability (i.e. high bar finals). Poor validity tended to decrease as the number of competitors increased, this was particularly evident in the apparatus finals, where each judge only gives 8 scores (16 on vault). It's seems that in sessions with more competitors, judges have an opportunity to adjust their criterion of judgment after the first few competitors.

Despite good reliability and generally satisfactory validity of judging at the University Games it should be emphasized that the quality of judging differs between apparatus, sessions, and individual judges. There are numerous objective and subjective factors for these differences e.g. the number of competitors in a session, judge's seat positions and view angle to the gymnast, and the judge's experience. At the moment as there is only sum of deductions presented in the judge's score it would be advisable if E judges could be evaluated according to what deduction was taken in time of gymnast's exercise. Such a computerized system already exists (Čuk and Forbes, 2006) and it would be good if it could be tested to overcome significant differences in judge's scores.

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A KINEMATIC ANALYSIS OF THE HANDSPRING DOUBLE SALTO FORWARD TUCKED ON A NEW STYLE OF VAULTING TABLE

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Original research article

Abstract

At the 2001 world championships in Ghent, the FIG (The International Federation of Gymnastics) replaced the traditional horse with a new vaulting table. The new style table is wider and has a more elastic surface. This has resulted in an increase in the number of male gymnasts performing the forward handspring double salto tucked.. This study aimed to determine important kinematic variables during specific phases of the vault (trajectories, time, velocity, angular velocity, angles) that influence the quality of the handspring double salto forward tucked (Roche). The sample consisted of gymnasts that performed the handspring double salto forward tucked at the 2002 World Championship in Debrecen (N=9). Statistical analyses were carried out using SPSS 15.0, 98 kinematic variables were identified, we reported the most important variables identified during the handspring double salto forward tucked movement.. The handspring forward double salto tucked is becoming a basic element on which new derivations of vaulting movements are based (i.e. piked position, or with turns); it is therefore essential to understand its parameters. The results from this study provide useful information for competitors, coaches, and judges.

Keywords: *artistic gymnastics, vault, table, biomechanics, handspring, double salto tucked.*

INTRODUCTION

In competitive gymnastics, gymnasts can choose from five families of vaults: direct vaults (without passing handstand); vaults with a turn in the first flight phase; forward handspring, where the gymnast puts his hands directly forward onto the table; Tsukahara vault, where the gymnast completes a half twist before pushing off the table; and the Yurchenko style vault, where the gymnast does a round off onto the springboard and a backward handspring onto the table.

At the 2001 World Championships in Ghent the FIG (FIG, 2001) replaced the traditional style horse with a new style of vaulting table (Figure 1). This is the biggest change in gymnastics apparatus since the introduction of pre-tensioned apparatus in the 1950's.

The vaulting table is 95 cm wide and 95 to 105 cm long and 135 cm high. Wider and shorter tables are safer (McNeal, 2003). The upper area of the table is slightly inclined (5 degrees). The elastic characteristics of the new table has more advantages than the old style horse, with the wider and slightly inclined support area providing better support for the arms during take-off (Figure 2) (McNeal, 2003; Čuk and Karacsony, 2004).

Following the introduction of the new vaulting table, the number of male gymnasts who decided to perform the handspring double salto tucked has increased.

Several studies involving the vault have been carried out (Prassas, 2002; Sands, Caine, Borms, 2003; Penitente, Merni, Fantozzi and Franceshetti,2006), however few of these studies have examined the kinematics of the handspring vault, and none of them analyzed the vault handspring double salto forward tucked on the new vaulting table. Aim of the research was to do kinematic analyse of handspring double salto forward tucked on new vaulting table. The vaulting sequence was divided into seven phases: run, jump on springboard, springboard support phase, first flight, support on the table, second flight, and landing. In modern gymnastics the handspring double salto forward tucked is becoming the primary jump. Handspring double salto forward tucked is the base for further development with different body position and added turns. Therefore it is important to know the biomechanical characteristics of this movement.

Figure 1. *Vaulting table (Jenssen&Fritsen, 2003)*

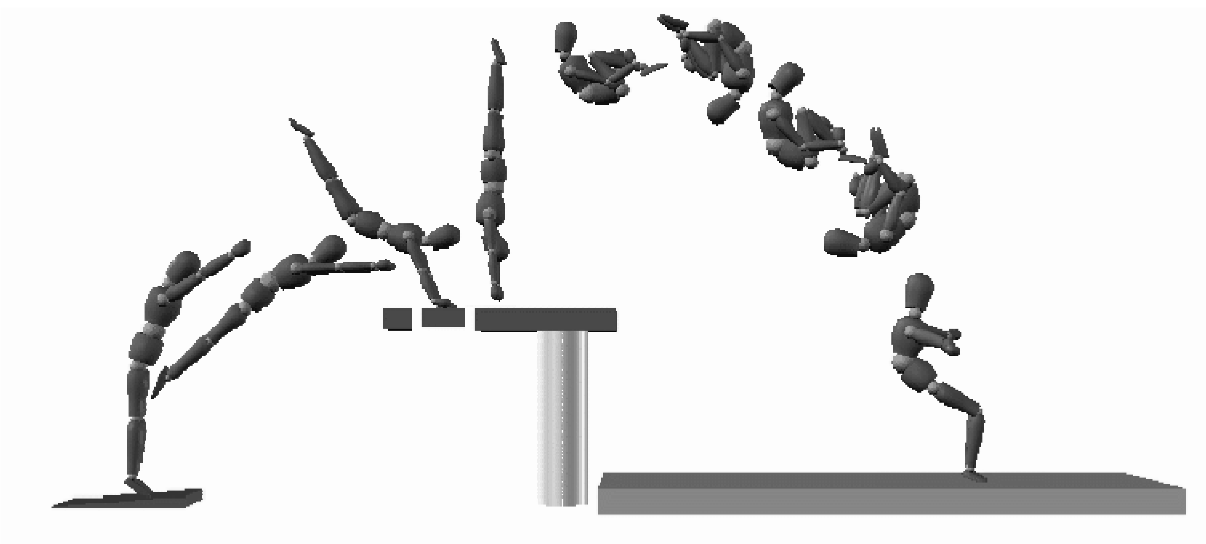

Figure 2. *Handspring and double salto forward tucked (Čuk and Karacsony, 2004)*

The first phase is a sprint towards the vault. This is an important phase because the following phases are dependent on it (Čuk, Bricelj, Bučar, Turšič and Atiković, 2007). The FIG`s Code of Points (FIG, 2006) states that the distance of the run for male gymnasts is 25 meters, measured from the edge of the table. After considering the springboard take-off and flight, this leaves gymnasts with 20 meters to make their approaching sprint. Most gymnasts cover this distance in 13 to 14 steps (Čuk and Karacsony, 2004). A fast approach sprint can be translated into horizontal velocity, combined with a successful take-off to result in a good vaulting movement. This research did not examine the first phase of the vaulting movement.

The jump on the springboard must be completed with minimum loss of sprint speed. Higher sprint speed can be maintained if the gymnast focuses their attention on the sprinting phase and not the vault ahead (Prassas, 2002). This has been shown through research carried out by Usenik (2006) with fourteen elite gymnasts. Čuk and Karacsony (2004) found that top gymnasts spent only 0.24 seconds to complete the take-off phase on the springboard following the sprint approach. In our research we didn`t investigate this phase in detail.

The others phases are represented in the results and discussion.

METHODS

The study sample consisted of elite gymnasts (n=9) that performed the handspring and double salto forward tucked at the 2002 World Championships in Debrecen.

Kinematic analysis was using the APAS-Ariel performance analyses system (Ariel Dynamics Inc., SanDiego, Ca). We used Sušanka, Otahal and Karas (1987) 15-segment body model defined with 17 points. All jumps were recorded during the competition using two orthogonal SVHS cameras at 50 frames per second. All data were smoothed with a digital filter of range 7. We calculated trajectories, velocities, time and angles of important positions in following phases of the vault: support on springboard, the first flight, support on the apparatus, the second flight, and landing. We identified 98 variables in total and have reported the most important ones. In results and discussion mean values are shown.

Statistic analysis was carried out using SPSS (Statistical package for the social sciences, 12.0, Chicago, IL, USA). For each variable we calculated descriptive statistics including mean, standard deviation, standard error, and minimum and maximum values.

RESULTS AND DISCUSSION

We divided the vault into seven phases. From these phases nine important positions have been identified positions for our analysis:

1. Touch down on springboard
2. Take off from the springboard
3. Touch down on table
4. Take off from the table
5. Maximum tuck position in salto
6. Maximum height of body center of gravity (BCG)
7. Finished first salto
8. Finished second salto
9. First contact at landing

Springboard support position

With our research we wanted to show kinematic variables at: springboard support phase, first flight, support on the table, second flight and landing.

Table 1. *Touch down on springboard*

	hBCGtds [m]	ltds [m]	ttos [s]	Vxtds [m/s]	Vytds [m/s]	Vxyztds [m/s]	stds [deg.]	etds [deg.]	htds [deg.]	ktds [deg.]	tttds [deg.]
X	**0.978**	**0.337**	**0.102**	**7.967**	**1.113**	**8.049**	**107.2**	**126.5**	**103.0**	**144.9**	**69.7**
MAX	1.059	0.496	0.120	8.350	1.350	8.459	124.2	147.5	111.9	158.9	73.2
MIN	0.912	0.100	0.100	7.575	0.725	7.624	95.3	83.7	92.6	135.6	65.9
SD	0.039	0.112	0.007	0.283	0.236	0.298	10.4	21.7	5.9	7.6	2.5
SE	0.070	0.118	0.029	0.188	0.172	0.193	1.1	1.6	0.9	1.0	0.6

hBCGtds – height of the BCG at touch down on springboard
ltds – distance from toes to the end of the springboard
ttos – time of take off from the springboard
Vxtds – BCG velocity in x axis at touch down on springboard
Vytds – BCG velocity in y axis at touch down on springboard
Vxyztds – BCG velocity in xyz axis at touch down on springboard
stds – shoulder angle at touch down on springboard
etds – elbow angle at touch down on springboard
htds – hip angle at touch down on springboard
ktds – knee angle at touch down on springboard
tttds – angle between trunk and x axis at touch down on springboard

The height of the gymnasts BCG at touch down on the springboard is 0.978 m (measured from the floor). Distance from toes to the end of springboard is 0.337 m. This is similar to previous findings from Čuk and Karacsony (2004) that showed male gymnasts took off 34 cm from the end of springboard.

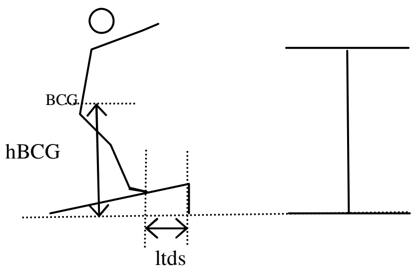

Figure 3. *Height of gymnasts BCG and distance from feet fingers to end of springboard at touch down on springboard*

Time of take off at springboard support phase is 0.102s. Velocity (in x axis) of gymnasts BCG at touch down on springboard is 7.967 m/s, velocity (in y axis) is 1.113 m/s, velocity (in xyz axises) is 8.049 m/s.

Shoulder angle at the moment of touch down on springboard is 107.2 degree, elbow angle is 126.5 degree, hip angle is 103.0 degree, knee angle is 144.9 degree, angle between trunk and x axis is 69.7 degree. Similar results for the angle between trunk and x axis were obtained by Prassas (2002) (handspring and Tsukahara vault), Pentiente et al (2006) (Yurchenko vault) and Takei (2007) (Handspring vault). After analyzing the angular kinematic data it is possible to deduct that the gymnasts used the hip joint and a body angle (angle between trunk and x axis) to generate a proper angular momentum. From the lower body angular data it is possible to conclude that the gymnasts don't use the hip joint for the take off actions (Penitente et al, 2006).

Lower angle of hip joint at the take off action could mean that the body is stiffer. Therefore the gymnasts can harness the elastic energy of the springboard.

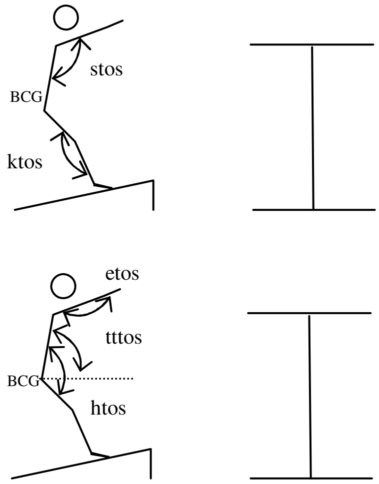

Figure 4. *Angles at the moment of touch down on springboard*

Table 2. *Take off from the springboard*

	hBCGtos [m]	Vxtos [m/s]	Vytos [m/s]	Vxyztos [m/s]	stos [deg.]	etos [deg.]	htos [deg.]	ktos [deg.]	tttos [deg.]
X	**1.165**	**5.042**	**4.654**	**6.868**	**142.2**	**165.6**	**139.4**	**172.7**	**45.6**
MAX	1.226	5.625	4.725	7.346	155.5	174.1	150.6	176.2	50.2
MIN	1.119	4.525	4.300	6.475	125.1	153.2	129.7	165.5	37.8
SD	0.032	0.328	0.138	0.244	10.3	6.2	7.1	3.3	3.9
SE	0.063	0.202	0.131	0.175	1.1	0.9	0.9	0.6	0.7

hBCGtos – height of the BCG at take off from the springboard
Vxtos – BCG velocity in x axis at take off from the springboard
Vytos – BCG velocity in y axis at take off from the springboard
Vxyztos – BCG velocity in xyz axis at take off from the springboard
stos – shoulder angle at take off from the springboard
etos – elbow angle at take off from the springboard
htos – hip angle at take off from the springboard
ktos – knee angle at take off from the springboard
tttos – angle between trunk and x axis at take off from the springboard

The mean height of the gymnasts BCG (body centre of gravity) at take off from the springboard was 1.165 m. Velocity (in x axis) of gymnasts BCG at touch down on the springboard was 5.042 m/s. velocity (in y axis) is 4.654 m/s, velocity (in xyz) is 6.868 m/s. From the analyses it is possible to affirm that during the springboard phase gymnasts exploit the decrease in the horizontal velocity to increase the vertical component of the velocity. This is essential for a successful contact with the table, and to set up the following phases of the vault properly (Penitente et al, 2006). The vertical component initially decreases the vertical velocity and subsequently generates the upward velocity. Such combination of the velocity is required, so that the gymnast has sufficient angular and radial velocity and sufficient body angle. With regard to rotation, the vertical force promotes angular momentum only when the BCG passes over the base of support (feet) (Prassas, 2002).

The mean shoulder angle at the moment of take off from the springboard was 142.2 degrees, the mean elbow angle was 165.6 degrees, the mean hip angle was 139.4 degrees, the knee angle was 172.7 degrees, and the mean angle between the trunk and the x axis was 45.6 degrees.

The first flight

Table 3. *The first flight*

	dft [m]	tff [s]
X	**1.555**	**0.136**
MAX	1.819	0.160
MIN	1.279	0.100
SD	0.191	0.024
SE	0.155	0.055

dft – distance from feet fingers to touch down on table
tff – time of first flight

Distance from the toes on springboard to touch down on the table is 1.555 m. The mean time of first flight was 0.136 s.

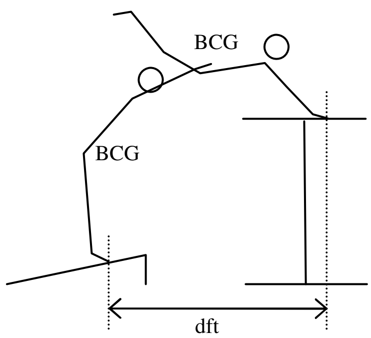

Figure 5. *Distance from the feet fingers on springboard to touch down on the table*

The time of the first flight depends on the relationship between horizontal and vertical velocity (Prasas, 2002). The time of the first flight also depends on the type of vault. The shortest first flight times are recorded on the Tsukahara vault, followed by the Yurchenko and handspring vault. The longest time of the first flight are recorded when turns are carried out in the first flight (Čuk, Karacsony, 2004).

Table 4. *Time of first flight (World Championship in Debrecen 2002) (Čuk and Karacsony, 2004)*

Vault	**Time [s]**	**N**
Tsukahara vault	0.06	37
Handspring vault	0.10	27
Yurchenko vault	0.13	11
Nemov vault	0.10	2
AVERAGE	***0.09***	***77***

Support on the table

Table 5. *Touch down on the table*

	hBCGtdt [m]	**wstdt [m]**	**wwtdt [m]**	**tst [s]**	**Vxtdt [m/s]**	**Vytdt [m/s]**	**Vxyztdt [m/s]**	**stdt [deg.]**	**etdt [deg.]**	**htdt [deg.]**	**ktdt [deg.]**	**tttdt [deg.]**	**ahttdt [deg.]**	**atBCGtdt [deg.]**
X	**1.710**	**0.429**	**0.439**	**0.162**	**5.229**	**3.267**	**6.175**	**114.7**	**166.3**	**152.3**	**153.7**	**15.4**	**47.0**	**25.0**
MAX	1.799	0.451	0.490	0.180	5.575	3.650	6.320	133.5	176.0	167.2	177.1	24.5	55.7	33.1
MIN	1.558	0.404	0.325	0.140	4.500	2.475	5.642	101.6	152.1	132.7	121.6	4.4	38.2	15.5
SD	0.083	0.015	0.054	0.012	0.307	0.364	0.212	13.0	8.1	11.9	17.9	7.5	7.1	6.7
SE	0.102	0.043	0.082	0.039	0.196	0.213	0.163	1.3	1.0	1.2	1.5	1.0	0.9	0.9

hBCGtdt – height of the BCG at touch down on the table
wstdt – width of shoulders at touch down on the table
wwtdt – width of wrist at touch down on the table
tst – time of support on the table
Vxtdt – BCG velocity in x axis at touch down on the table
Vytdt – BCG velocity in y axis at touch down on the table
Vxyztdt – BCG velocity in xyz axis at touch down on the table
stdt – shoulder angle at touch down on the table
etdt – elbow angle at touch down on the table
htdt – hip angle at touch down on the table
ktdt – knee angle at touch down on the table
tttdt – angle between trunk and x axis at touch down on the table
ahttdt – angle between hand and table at touch down on the table
atBCGtdt – angle between table and BCG at touch down on the table

The mean height of the gymnasts' BCG at touch down on the table was 1.710 m, the width of the shoulders at touch down on the table was 0.429 m, width of the wrists was 0.439 m. As we expected, on the new vaulting table the gymnast's arms were almost parallel and orthogonal; this is the most efficient support position, generating higher take off power.

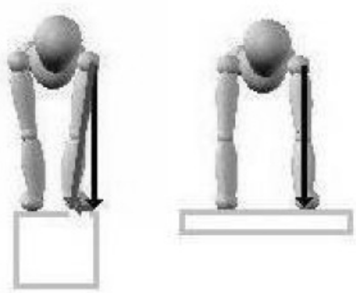

Figure 6. *Support position on old horse (left), support position on new vaulting table (right) (Čuk, Karacsony, 2004)*

The average time gymnasts spent in the support position was 0.162 seconds.

Table 6. *The time of support on the table (World Championship in Debrecen 2002) (Čuk andKaracsony, 2004)*

Vault	Time [s]	N
Handspring vault	0.19	27
Tsukahara vault	0.26	37
Yurchenko vault	0.21	11
Nemov vault	0.20	2
Average	***0.23***	***77***

Velocity (in x) of gymnast's BCG at the moment of support on the table was 5.229 m/s, velocity (in y) was 3.267 m/s, and the velocity (in xyz) was 6.175 m/s.

Shoulder angle at the moment of support on the table was 114.7 degree, the elbow angle was 166.3 degrees, the hip angle was 152.3 degrees, the knee angle was 153.7 degrees, the angle between the trunk and the x axis was 15.4 degree, the angle between the hand and table was 47.0 degree, the angle between the table and the BCG was 25.0 degree.

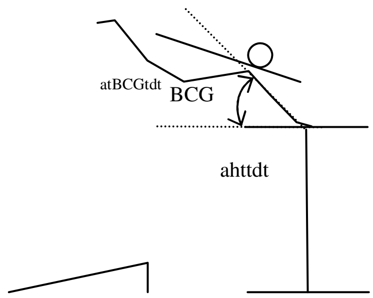

Figure 7: *Angle between hand and table and angle between table and BCG*

Table 7. *Take off from the table*

	hBCGtot [m]	Vxtot [m/s]	Vytot [m/s]	Vxyztot [m/s]	stot [deg.]	etot [deg.]	htot [deg.]	ktot [deg.]	tttot [deg.]	ahttot [deg.]	atBCGtot [deg.]
X	**2.317**	**3.929**	**4.146**	**5.724**	**145.3**	**167.6**	**160.8**	**139.5**	**108.9**	**99.5**	**86.0**
MAX	2.402	4.675	4.425	6.235	163.2	174.0	173.5	167.8	130.6	109.2	96.4
MIN	2.168	3.225	3.900	5.257	123.7	157.7	141.4	81.3	95.4	90.0	77.0
SD	0.075	0.438	0.183	0.286	13.2	6.2	10.3	27.0	11.1	8.3	6.6
SE	0.097	0.234	0.151	0.189	1.3	0.9	1.1	1.8	1.2	1.0	0.9

hBCGtot – height of the BCG at take off from the table
Vxtot – BCG velocity in x axis at take off from the table
Vytot – BCG velocity in y axis at take off from the table
Vxyztot – BCG velocity in xyz axis at take off from the table
stot – shoulder angle at take off from the table
etot – elbow angle at take off from the table
htot – hip angle at take off from the table
ktot – knee angle at take off from the table
tttot – angle between trunk and x axis at take off from the table
ahttot – angle between hand and table at take off from the table
atBCGtot – angle between table and BCG at take off from the table

The mean height of the gymnasts' BCG at take off from the table was 2.317 m. Velocity (in x) of gymnasts BCG at the moment of take off from the table was 3.929 m/s, velocity (in y) is 4.146 m/s, velocity (in xyz) is 5.724 m/s. From the table we can see that the velocity in x axis by the touch down on the table was higher, while at take off from the table the velocity in y axis was higher. This relationship between velocity components enables high take off, so that after the jump the gymnast can always land on his legs.

Shoulder angle at the moment of take off from the table is 145.3 degree, elbow angle is 167.6 degree, hip angle is 160.8 degree, knee angle is 139.5 degree, angle between trunk and x axis is 108.9 degree, angle between hand and table is 99.5 degree, angle between table and BCG is 86.0 degree.

Studies have shown Prassas (2002), Takei (2007), Čuk and Ferkolj (2007) that it is within a gymnast`s capability to increase the angular momentum during this phase. This requires a slightly different body position, specifically greater shoulder joint extension and a smaller hip joint angle at the vaulting table contact phase, as well as a higher angular velocity at vaulting table impact (Prassas, 2002).

The second flight

Table 8. *Maximum tuck position*

	hBCGmtp [m]	dsf [m]	tomtp [m]	tsf [s]	Vxmtp [m/s]	Vymtp [m/s]	Vxyzmtp [m/s]	smtp [deg.]	emtp [deg.]	hmtp [deg.]	kmtp [deg.]	ttmtp [deg.]
X	**2.957**	**4.241**	**0.230**	**1.056**	**3.629**	**1.633**	**4.006**	**46.6**	**138.7**	**36.5**	**46.0**	**141.8**
MAX	3.053	4.913	0.240	1.080	4.550	2.100	4.757	56.4	154.1	43.3	52.5	159.8
MIN	2.810	3.879	0.220	1.000	3.025	1.050	3.344	34.6	115.1	27.150	37.400	130.6
SD	0.067	0.428	0.011	0.024	0.467	0.291	0.424	6.8	14.1	4.744	5.794	9.8
SE	0.091	0.207	0.036	0.055	0.242	0.191	0.230	0.9	1.3	0.770	0.851	1.1

hBCGmtp – height of the BCG at maximum tuck position
dsf – distance of second flight
tomtp – time from take off from the table to maximum tuck position
tsf – time of second flight
Vxmtp – BCG velocity in x axis at maximum tuck position
Vymtp – BCG velocity in y axis at maximum tuck position
Vxyzmtp – BCG velocity in xyz axis at maximum tuck position
smtp – shoulder angle at maximum tuck position
emtp – elbow angle at maximum tuck position
hmtp – hip angle at maximum tuck position
kmtp – knee angle at maximum tuck position
ttmtp – angle between trunk and x axis at maximum tuck position

The mean height of the gymnasts' BCG at maximum tuck position was 2.957 m. The mean distance of the second flight (from support position to landing) was 4.241 m. The mean duration of the second flight was 1.056 s.

The duration of the second phase and the maximum height of the vault are dependant on the vertical velocity (y axe) at take off from the table. Greater vertical velocity results in a longer flight time and therefore a higher vaulting movement.

The time from take off from the table to maximum tuck position is 0.230 second.

Analyses from Čuk and Karacsony (2004) gave similar results.

Velocity (in x axis) of gymnasts BCG at the moment of maximum tuck position is 3.629 m/s, velocity (in y axis) is 1.633 m/s, velocity (in xyz) is 4.006 m/s.

Shoulder angle at the moment of maximum tuck position is 46.6 degree, elbow angle is 138.7 degree, hip angle is 36.5 degree, knee angle is 46.0 degree, angle between trunk and x axis is 141.8 degree. Similar results were obtained also by Takei (2007).

Table 9. *Maximum height of BCG*

	hBCGmh [m]	Vxmh [m/s]	Vymh [m/s]	Vxyzmh [m/s]	smh [deg.]	emh [deg.]	hmh [deg.]	kmh [deg.]	ttmh [deg.]
X	**3.125**	**3.725**	**0.100**	**3.735**	**36.0**	**118.2**	**50.7**	**55.8**	**101.8**
MAX	3.234	4.275	0.200	4.294	43.1	137.9	62.0	61.3	141.0
MIN	3.028	2.875	0.000	2.878	27.5	93.4	36.3	49.4	76.5
SD	0.070	0.436	0.073	0.441	5.3	11.7	8.2	3.4	21.3
SE	0.093	0.233	0.095	0.235	0.8	1.2	1.0	0.6	1.6

hBCGmh – height of the BCG at maximum high of BCG
Vxmh – BCG velocity in x axis at maximum high of BCG
Vymh – BCG velocity in y axis at maximum high of BCG
Vxyzmh – BCG velocity in xyz axis at maximum high of BCG
smh – shoulder angle at maximum high of BCG
emh – elbow angle at maximum high of BCG
hmh – hip angle at maximum high of BCG
kmh – knee angle at maximum high of BCG
ttmh – angle between trunk and x axis at maximum high of BCG

The mean maximum height recorded for a gymnast's BCG was 3.125 m.

The velocity (in x axis) of the gymnast's BCG at the highest point was 3.725 m/s, velocity (in y axis) was 0.100 m/s, and velocity (in xyz) was 3.735 m/s.

The shoulder angle at the highest point of the vaulting movement was 36.0 degrees the elbow angle was 118.7 degrees, the hip angle was 50.7 degree, the knee angle was 55.8 degree, and the angle between the trunk and x axis was 101.8 degrees.

Table 10. *Finished the first salto*

	hBCGfs [m]	ttofs [s]	Vxfs [m/s]	Vyfs [m/s]	Vxyzfs [m/s]	sfs [deg.]	efs [deg.]	hfs [deg.]	kfs [deg.]	ttfs [deg.]
X	**3.098**	**0.480**	**3.979**	**0.438**	**3.847**	**42.2**	**111.4**	**49.3**	**48.6**	**87.9**
MAX	3.209	0.500	4.750	1.075	4.753	46.7	125.9	91.7	54.0	94.2
MIN	2.995	0.460	3.075	0.125	3.141	34.9	91.0	34.3	39.1	80.5
SD	0.072	0.013	0.600	0.260	0.492	3.7	11.4	16.7	5.1	4.7
SE	0.095	0.041	0.274	0.180	0.248	0.7	1.2	1.4	0.8	0.8

hBCGfs – height of the BCG at finished first salto
ttofs – time from take off from the table to finished first salto
Vxfs – BCG velocity in x axis at finished first salto
Vyfs – BCG velocity in y axis at finished first salto
Vxyzfs – BCG velocity in xyz axis at finished first salto
sfs – shoulder angle at finished first salto
efs – elbow angle at finished first salto
hfs – hip angle at finished first salto
kfs – knee angle at finished first salto
ttfs – angle between trunk and x axis at finished first salto

Height of the gymnast BCG at finished first salto is 3.098 m.

The time from take off from the table to finished first salto is 0.480 second.

Velocity (in x axis) of gymnasts BCG at the moment of finished first salto is 3.979 m/s, velocity (in y axis) is 0.438 m/s, velocity (in xyz) is 3.847 m/s.

Shoulder angle at the moment of finished first salto is 42.2 degree, elbow angle is 111.4 degree, hip angle is 49.3 degree, knee angle is 48.6 degree, angle between trunk and x axis is 87.9 degree.

Table 11. *Finished the second salto*

	hBCGss [m]	ttoss [s]	Vxss [m/s]	Vyss [m/s]	Vxyzss [m/s]	sss [deg.]	ess [deg.]	hss [deg.]	kss [deg.]	ttss [deg.]
X	**2.294**	**0.807**	**3.717**	**3.675**	**5.244**	**43.4**	**101.9**	**40.1**	**51.6**	**90.8**
MAX	2.528	0.860	4.575	4.375	6.031	52.1	117.1	50.7	59.4	97.2
MIN	2.069	0.760	3.375	3.250	4.953	36.3	80.6	30.6	38.4	81.7
SD	0.162	0.032	0.410	0.342	0.385	4.7	10.9	5.7	6.9	5.3
SE	0.142	0.063	0.226	0.207	0.219	0.8	1.2	0.8	0.9	0.8

hBCGss – high of the BCG at finished second salto
ttoss – time from take off from the table to finished second salto
Vxss – BCG velocity in x axis at finished second salto
Vyss – BCG velocity in y axis at finished second salto
Vxyzss – BCG velocity in xyz axis at finished second salto
sss – shoulder angle at finished second salto
ess – elbow angle at finished second salto
hss – hip angle at finished second salto
kss – knee angle at finished second salto
ttss – angle between trunk and x axis at finished second salto

High of the gymnast BCG at finished second salto is 2.294 m.

The time from take off from the table to finished second salto is 0.807 second.

Velocity (in x axis) of gymnasts BCG at the moment of finished second salto is 3.717 m/s, velocity (in y axis) is 3.675 m/s, velocity (in xyz) is 5.244 m/s.

Shoulder angle at the moment of finished second salto is 43.4 degree, elbow angle is 101.9 degree, hip angle is 40.1 degree, knee angle is 51.6 degree, angle between trunk and x axis is 90.8 degree.

Table 12. *Average velocity of rotation*

	Vfs [degrees/s]	Vss [degrees/s]	Vl [degrees /s]
X	**800.5**	**1104.5**	**693.2**
MAX	822.9	1200.0	820.9
MIN	728.0	1000.0	605.0
SD	29.5	64.1	86.0
SE	1.9	2.8	3.3

Vfs – from take off from table to finished first salto
Vss – from finished first salto to finished second salto
Vl – from finished second salto to first contact at landing

From the take off from the table to finished first salto is angular velocity 800.5 degree/second, from the finished first salto to finished second salto is angular velocity 1104.5 degree/second, and from finished second salto to first contact at landing is angular velocity 693.2 degree/second.

During the final phase (in table 12, variable Vl) the gymnast stretch his legs in hip and knee joints and with this he increases the moment of inertia. This is the reason for lower angular velocity.

Table 13. *Comparison of angular velocity between different saltos*

VAULT	AVERAGE ANGULAR VELOCITY [degree/second]	Author
VAULT – Handspring double salto forward tucked	843	Takei, 2007
FLOOR – Double salto forward tucked	838	Štuhec, 2001
RINGS – Triple salto backward tucked	1000	Držaj, 2001
FLOOR – Double salto backward tucked	665	Ferkolj, 2000; Čuk and Ferkolj, 2000
FLOOR – Triple salto backward tucked	853	Ferkolj, 2000; Čuk and Ferkolj, 2000

Landing (the first contact on the mat)

Table 14. *Landing – the first contact on the mat*

	hBCGl [m	Vxl [m/s]	Vyl [m/s]	Vxyzl [m/s]	sl [deg.]	el [deg.]	hl [deg.]	kl [deg.]	ttl [deg.]	atBCGl [deg.]
X	**1.045**	**3.588**	**5.783**	**6.816**	**59.8**	**98.3**	**137.7**	**133.0**	**108.3**	**52.3**
MAX	1.210	4.200	6.609	7.230	82.8	120.9	165.0	152.4	130.8	74.6
MIN	0.921	2.675	5.300	6.257	38.5	71.3	98.5	94.1	72.9	35.3
SD	0.104	0.455	0.432	0.352	15.4	17.2	22.2	19.6	19.5	12.7
SE	0.114	0.239	0.232	0.210	1.4	1.5	1.7	1.6	1.6	1.3

hBCGl – height of the BCG at finished second salto
Vxl – BCG velocity in x axis at finished second salto
Vyl – BCG velocity in y axis at finished second salto
Vxyzl – BCG velocity in xyz axis at finished second salto
sl – shoulder angle at finished second salto
el – elbow angle at finished second salto
hl – hip angle at finished second salto
kl – knee angle at finished second salto
ttl – angle between trunk and x axis at finished second salto
atBCGl – angle between floor and BCG at first contact on the floor

The height of the gymnast's BCG at the moment of the first contact on the mat is 1.045 m.

Velocity (in x axis) of gymnasts BCG at the moment of the first contact on the floor is 3.588 m/s, velocity (in y axis) is 5.783 m/s, velocity (in xyz) is 6.816 m/s.

Shoulder angle at the moment of the first contact on the floor is 59.8 degree, elbow angle is 98.3 degree, hip angle is 137.7 degree, knee angle is 133.0 degree, angle between trunk and x axis is 108.3 degree, angle between feet fingers and BCG is 52.3 degree.

CONCLUSIONS

The handspring double salto tuck is one of the top elements of the vault and has become a basic element within vaulting routines, on which other movements are based. Vaults with piked body positions and turns have also been performed. Coaches should therefore be familiar with the biomechanical breakdown of these movements. Coaches that are coaching elite gymnasts should emphasise the following points:

- fast approach sprint,
- correct feet position on springboard (few gymnasts use the optimal position of feet on springboard),

- maximum active extension in handstand at the point of take off from the apparatus,
- very fast tucking after take off from apparatus,
- as the angular velocity of rotation is very high it is essential for gymnasts to gain appropriate motor control (a good sense of height and body position) to prepare for landing.

This new apparatus allows less skilled gymnasts to perform the vault (improved arm position on apparatus), however the landing phase of the vault may still prove to be difficult for these gymnasts and caution must be taken when less skilled gymnasts use the vaulting apparatus.

For the development of new vaulting routines or to perform more difficult vaulting routines, gymnasts should increase approach sprint speed, increase take off speed from the springboard, and implement a faster bend during their vaulting routines.

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THE EVOLUTION OF FLIGHT ELEMENTS IN COMPETITIVE UNEVEN BARS ROUTINES

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Abstract

The purpose of this study was to evaluate and characterize external load trends related to flight elements in elite level uneven bars routines, based on analyses from 83 uneven bars routines from the world championships and the Olympic Games finals between 1989 and 2004. An observation category was constructed and validated, comprising eleven variables: number, difficulty, direct combinations of 2 and 3 flight elements, execution with straight or closed body configuration, preparatory elements, direction outwards or inwards to the low bar, and execution on the 1st or 2nd phase of the routine. Results showed a significant decrease in the number of preparatory elements, and the number of flight elements outwards from low bar and inwards to low bar significantly changed. With regards to the other observed variables we found no significant differences. Elite gymnasts usually perform 1 or 2 flight elements during uneven bars routines.. The difficulty of flight elements ranged from 1 to 2 D value flight elements in all cycles and gymnasts performed using predominantly closed body configurations. Based on the results it can be concluded that the number, direct combinations, and difficulty of the flight elements contradict what has been reported in the gymnastics literature, where a large increase of variables of external load in uneven bars routines was predicted.

Keywords: *artistic gymnastics, uneven bars, flight element, trends.*

INTRODUCTION

Literature in Artistic Gymnastics (AG) has frequently addressed evolution trends of difficulty or complexity of elements and routines performed by elite level gymnasts (Arkaev and Suchilin, 2004; Caine, DiFiori, and Maffulli, 2006; Irwin, Hanton, and Kerwin, 2005; Jemni, Friemel, and Delamarche, 2002; Sands, Caine, and Borms, 2003), as well as the increase in acrobatic elements that AG has experienced in recent years (Daly, Bass, and Finch, 2001; Hofmann, 1999; Smolevsky and Gaverdovsky, 1996). In the specific case of Uneven Bars (UB), considerations about evolution trends of number, difficulty, and special connections with flight elements in competition routines have been investigated (Arkaev and Suchilin, 2004; Smolevsky and Gaverdovsky, 1996; Touricheva, 1986).

However, few studies have used objective measures of AG routines to come to their conclusions. Some of the

International Federation of Gymnastics (FIG) analyses have been published after each world championship and Olympic Games, addressing important aspects of routine evolution. Based on the analysis of total participants in world championships and Olympic Games (Table 1), it is possible to observe that gymnasts performed more flight elements per routine in the last Olympics compared with previous ones (FIG, 1994, 1997b, 1999, 2000, 2001, 2003, 2004). However, these analyses lack the measurement of global load in competition routines.

Table 1. *Evolution of flight elements from "C" executed by total participants in some world championships and Olympic Games (FIG, 1994, 1997b, 1999, 2000, 2001, 2003, 2004).*

		Nº of flight elements from "C" executed						
		0	1	2	3	4	5	6
Year	N	Nº of gymnasts (percentage of total participants)						
1994	58	3 (5.2%)	13 (22.4%)	32 (55.2%)	7 (12.0%)	3 (5.2%)	-	-
1996	94	-	28 (29.8%)	42 (44.7%)	21 (22.3%)	3 (3.2%)	-	-
1997	133	9 (6.7%)	44 (33.1%)	63 (47.4%)	16 (12.0%)	1 (0.8%)	-	-
1999	225	25 (11.1%)	66 (29.3%)	94 (41.8%)	34 (15.1%)	6 (2.7%)	-	-
2000	84	1 (1.2%)	13 (15.5%)	45 (53.6%)	21 (25.0%)	3 (3.5%)	1 (1.2%)	-
2001	151	12 (7.9%)	22 (14.6%)	45 (29.8%)	43 (28.5%)	25 (16.5%)	3 (2.0%)	1 (0.7%)
2003	197	8 (4.1%)	19 (9.6%)	41 (20.8%)	88 (44.7%)	35 (17.8%)	5 (2.5%)	1 (0.5%)
2004	85	1 (1.2%)	1 (1.2%)	13 (15.3%)	29 (34.1%)	33 (38.8%)	6 (7.1%)	2 (2.4%)

The origin and evolution of different gymnastics elements are directly related to factors including body positions or postures, and the number of rotations (Arkaev and Suchilin, 2004; Liang and Tian, 2003). The gymnastics Code of Points (CP) states that the difficulty value of elements increases according to the number of rotations and/or body configurations during each execution. According to Arkaev and Suchilin (2004) the structural complexity of movements can also be increased through the execution of complex elements without prior acceleration, i.e. without preparatory elements.

World class gymnasts provide the best reference point for AG development status. In order to identify how AG has progressed competition routines from recent tournaments must be compared with routines from past years.

The purpose of this study therefore, was to evaluate and characterize external load trends in elite level uneven bars routines, specifically related to flight element parameters, based on the analyses extracted from world championships and Olympic Games finalists in four Olympic cycles between 1989 and 2004.

METHODS

The study sample comprised a group of world elite gymnasts in Women's Artistic Gymnastics (WAG). Uneven bars routines from world championships and Olympic Games finals between 1989 and 2004 were analyzed. From a total of 96 finalists, 13 failed during their competition routine, these were excluded since they might have changed their routine for that reason, leaving 83 routines for analyses. Participants were measured during 12 competitions including 4 Olympic cycles, 2 world championships, and 1 Olympic Games (Table 2).

Table 2. *World championships and Olympic Games observed.*

	Cycle	World Championships		Olympic Games
1º	1989 - 1992	1989 (Stuttgart)	1991 (Indianapolis)	1992 (Barcelona)
2º	1993 - 1996	1993 (Birmingham)	1995 (Sabae)	1996 (Atlanta)
3º	1997 - 2000	1997 (Lausanne)	1999 (Tianjin)	2000 (Sydney)
4º	2001 - 2004	2001 (Ghent)	2003 (Anaheim)	2004 (Athens)

Through observational methodology, an observation category was constructed and validated, comprising eleven variables considered as indicators of external load during flight elements in uneven bars.

The flight elements observed are understood as those performed on the same bar in accordance with the CP (FIG, 2006), including the backwards giant circle with hop 1/1 turn (360º) in handstand phase, which was removed from this category after 1996.

To record the complexity and difficulty associated with the execution of flight elements, five variables were considered:

1 – Nº of flight elements;
2 – Total difficulty of flight elements performed;
3 – Nº of direct connections of 2 flight elements;
4 - Nº of direct connections of 3 flight elements;
5 – Nº of preparatory elements.

The execution of a simple giant swings (forward and backward) immediately before the flight element was regarded as a preparatory element and to classify the element's difficulty the values assigned by the CP of 2006 (FIG, 2006) were used.

For the observation of body positions in flight elements execution, four positions were considered, two regarding the position related to the low bar (facing inwards or outwards) and two concerning the body shape (closed or straight):

6 – Nº of flight elements facing inwards to low bar;

7 - Nº of flight elements facing outwards from low bar;

8 - Nº of flight elements with closed (straddle or piked) body configuration;

9 - Nº of flight elements with straight body configuration.

Finally, in order to observe the distribution of the flight elements by half routines the following variables were observed:

10 – Nº of flight elements executed on the 1º part of the routine;

11 - Nº of flight elements executed on the 2º part of the routine.

Instrument validation was based on the expert judgement of WAG coaches, judges, and academics or researchers. Two individuals from each field were selected.

To assess the internal validity, a first observation of 20 routines (5 from each studied cycle randomly selected from 3 different time periods) was performed. In the first two evaluations (A and B) the leading researcher performed the observations with a month interval. A third evaluation (C) was performed by a team of 4 experts (international judges of AG) previously trained.

The intra and inter-observer agreement was calculated using Spearman correlation coefficient. To assess the intra-observer agreement data from the first 2 observations (A-B) were compared (a total of 20 routines), and the inter-observer agreement was assessed by comparing data from the first two observations with the third observation separately (A-C and B-C).

From the 99 correlations analyzed (9 comparisons x 11 variables) we found that for 10 studied variables, the correlation coefficient was equal to 1.00 (p=0.000) for all comparisons made (inter and intra-observer), i.e. a perfect correlation showing full agreement between observations. For the remaining variable (Nº of flight elements with straight body configuration) 6 correlation values were slightly less than 1.00 but showed high correlations ($0.921 \leq r_s \leq 0.987$). These are positive results, showing good correlations for both inter and intra-observer agreement.

Descriptive statistics were calculated (Mean, standard deviation, median and range), and Kruskal Wallis (k-w) test was used to compare the values found over the four cycles studied with a significance level of 5% ($p \leq 0.05$). Wilcoxon test was used to analyze the significance of the differences observed between similar variables. Correlations between variables were analyzed using Spearman correlation coefficient, with a significance level of 5%. Only results with $r_s \geq 0.40$ were considered, which represent a moderate or high level of linear association.

RESULTS

Table 3 shows that the mean number of flight elements decreased slightly between the first and last cycles, from 1.85 to 1.63. No significant changes were observed in the other variables, except the number of preparatory elements (p = 0.044) and the positions related to the low bar (p = 0.019 and p = 0.001). Preparatory elements decreased to zero on last cycle, and the number of flight elements executed facing inwards to low bar increased from 0.45 in first cycle to 1.13 in last, while the flight elements performed facing outwards to low bar decreased from 1.40 to 0.50 over the same period.

Table 3. *Descriptive and Kruskal Wallis (k-w) test values to the analyzed variables, during the four studied cycles (* $p \leq 0.05$).*

Indicator	Statistics	Cycle			
		1989-1992	1993-1996	1997-2000	2001-2004
Nº of flight elements	Mean ± sd	1.85 ± 0.67	1.83 ± 0.78	1.79 ± 0.66	1.63 ± 0.72
	Median / Range	2.00 / 2	2.00 / 2	2.00 / 2	1.50 / 2
	k-w	$X^2 = 1.199$		$p = 0.753$	
Nº of direct combinations of 2 flight elements	Mean ± sd	0.15 ± 0.37	0.26 ± 0.62	0.08 ± 0.28	0.19 ± 0.40
	Median / Range	0.00 / 1	0.00 / 2	0.00 / 1	0.00 / 1
	k-w	$X^2 = 1.213$		$p = 0.750$	
Nº of direct combinations of 3 flight elements	Mean ± sd	0.00 ± 0.00	0.09 ± 0.29	0.00 ± 0.00	0.00 ± 0.00
	Median / Range	0.00 / 0	0.00 / 1	0.00 / 0	0.00 / 0
	k-w	$X^2 = 5.282$		$p = 0.152$	
Nº of preparatory elements	Mean ± sd	0.15 ± 0.37	0.30 ± 0.47	0.08 ± 0.28	0.00 ± 0.00
	Median / Range	0.00 / 1	0.00 / 1	0.00 / 1	0.00 / 0
	k-w	$X^2 = 8.085$		p = **0.044** *	
Nº of flight elements on the 1º part of routine	Mean ± sd	1.20 ± 0.41	1.17 ± 0.49	1.13 ± 0.45	0.94 ± 0.44
	Median / Range	1.00 / 1	1.00 / 2	1.00 / 2	1.00 / 2
	k-w	$X^2 = 3.404$		$p = 0.333$	
Nº of flight elements on the 2º part of routine	Mean ± sd	0.65 ± 0.49	0.65 ± 0.49	0.67 ± 0.48	0.69 ± 0.87
	Median / Range	1.00 / 1	1.00 / 1	1.00 / 1	0.50 / 3
	k-w	$X^2 = 0.307$		$p = 0.959$	
Difficulty coefficient of flight elements	Mean ± sd	0.76 ± 0.31	0.76 ± 0.32	0.73 ± 0.27	0.68 ± 0.31
	Median / Range	0.80 / 1	0.80 / 0.80	0.80 / 0.90	0.65 / 0.80
	k-w	$X^2 = 0.572$		$p = 0.903$	
Nº of flight elements outwards from low bar	Mean ± sd	1.40 ± 0.82	1.17 ± 1.11	0.88 ± 0.74	0.50 ± 0.82
	Median / Range	1.50 / 3	1.00 / 3	1.00 / 2	0.00 / 2
	k-w	$X^2 = 9.947$		p = **0.019** *	
Nº of flight elements inwards to low bar	Mean ± sd	0.45 ± 0.51	0.61 ± 0.58	0.92 ± 0.50	1.13 ± 0.50
	Median / Range	0.00 / 1	1.00 / 2	1.00 / 2	1.00 / 2
	k-w	$X^2 = 15.702$		p = **0.001** *	

Continues on next page

Nº of flight elements with straight body	Mean ± sd	0.20 ± 0.62	0.35 ± 0.78	0.25 ± 0.53	0.37 ± 0.72
	Median / Range	0.00 / 2	0.00 / 3	0.00 / 2	0.00 / 2
	k-w	X^2 = 1.313		p = 0.726	
Nº of flight elements with closed body	Mean ± sd	1.55 ± 0.69	1.48 ± 0.67	1.54 ± 0.51	1.19 ± 0.54
	Median / Range	2.00 / 3	1.00 / 3	2.00 / 1	1.00 / 2
	k-w	X^2 = 4.232		p = 0.238	

Although there were no significant differences found in relation to body configuration, the mean values of the flight elements executed with closed body shape were consistently higher than those performed with stretched body position.

The number of direct combinations of 2 flight elements were always low, ranging from 0.08 to 0.26 and only during the third cycle were values found that were different from zero (0.09) for combinations of 3 elements, which were performed twice by the same gymnast in two different competitions.

Table 4. *Spearman correlation coefficients (r_s) between variables related to flight elements ($r_s \geq$ 0.40 and $p \leq 0.05$).*

		Nº of direct combinations of 2 flight elements	Nº of flight elements on the 1º part	Nº of flight elements on the 2º part
Nº of flight elements outwards from low bar	r_s	0.548		
	p	0.000		
Nº of flight elements with straight body	r_s	0.698	0.511	
	p	0.000	0.000	
Nº of flight elements with closed body	r_s			0.608
	p			0.000
Nº of flight elements on the 1º part of routine	r_s	0.603		0.010
	p	0.000		0.926

Table 5. *Wilcoxon test results for the same-sense variables (* p ≤ 0.05).*

Indicator	Statistics	Cycle 1989-1992	1993-1996	1997-2000	2001-2004
Nº of direct combinations of flight elements (2 and 3)	Z	-1.732	-2.000	-1.414	-1.732
	p	0.083	0.046*	0.157	0.083
Nº of flight elements on each part of routine (1º and 2º part)	Z	-3.051	-3.207	-2.840	-1.136
	p	0.002*	0.001*	0.005*	0.256
Body position related to low bar during flight elements (inwards and outwards)	Z	-2.886	-1.707	-0.179	-1.904
	p	0.004*	0.088	0.858	0.057
Body configuration during flight elements (closed and straight)	Z	-3.318	-3.279	-4.031	-2.415
	p	0.001*	0.001*	0.000	0.016*

DISCUSSION

Firstly, the results show that in the four analyzed cycles there was no significant change in the number of flight elements performed by elite gymnasts in their competition routines.

The comparison between the values obtained by FIG (1994; 1997b; 1999; 2000; 2001; 2003; 2004), related to all participants in competitions included in the last three cycles studied, with our results from finalists in many of the same competitions, show a very different behavior in this kind of elements.

The observed finalists didn’t perform more than three flight elements and the gymnasts that executed that amount were in the minority compared with the ones who performed one or two flight elements in their routines (between 12.50% and 21.74%).

Regarding the last analyzed cycle (2001-2004) and based on the reports from FIG Technical Committee (FIG, 2001; 2003; 2004), which analyzes all participants, we found important differences between all gymnasts and finalists, namely : 8.50% from total vs. 50.00% from finalists performed only one flight element, 22.00% vs. 37.50% executed 2, 35.80% vs. 12.50% performed 3 times this kind of element, and surprisingly, 24.40% of all gymnasts vs. 0.00% of finalists showed four flight elements in their routines, and 3.90% of all gymnasts performed it five times.

This antagonistic behavior between finalists and all the gymnasts suggests that while many coaches believe in the benefits of a large number of flight elements, those whose gymnasts reach the finals and win medals don’t risk so much or simply do not master so many different elements, contrary to the ideas and trends proposed by several authors (Arkaev and Suchilin, 2004; Smolevsky and Gaverdovsky, 1996; Touricheva, 1986). In fact there are gymnasts who follow the trend of increased flight elements but don’t achieve as good a result. However, the Olympic champions in uneven bars in the four cycles observed performed only one or two flight elements in their routines.

We believe the situation described above is a consequence of inconsistencies promoted by the CP, the same that also created a controversy in the High Bar (HB) finals in the Olympic Games in Athens in 2004.

On the one hand, to promote spectacle in gymnastics and to recognize the difficulty of such elements, CP encourages its performance by assigning the coefficient of difficulty "D" or higher to the majority, requiring the execution at least once and awarding bonus points to the direct connections of flight elements or between these elements with other equally complexed elements. Also, the incentives described above do not seem to overcome the disadvantages from their inclusion, even in the absence of large faults, because associated to the execution of more flight elements in routines, gymnasts are directly penalized for small faults in the elements themselves and consequently the routines are often interrupted, thus less dynamic, due to the need to execute one or two connection elements to return to the starting position. However, due to the changes on CP after 2004, future research is needed to confirm these results, specifically the analysis of finalist's performances from the last Olympic cycle (2005-2008).

The observed evolution of flight elements performed facing inwards to low bar is in accordance with findings from Kerwin, Irwin and Exell (2007a), revealing that the Tkachev flight element performed in this direction enables gymnasts to develop more angular momentum and to release the bar with greater vertical velocity. Authors also state that changing the direction presented to female gymnasts gives the opportunity to perform piked Tkachevs and may lead to the performance of straight Tkachevs in the future.

With regards to the distribution of the flight elements by half routines, it is not possible to conclude that the intention of gymnasts to perform such elements in periods of increased energy availability, except the correlations observed showing a positive association between the number of flight elements with straight body configuration with the number of these elements performed in the first part of routine, and the ones executed with closed body configuration in the second part.

One of the variables where significant differences were found was in the number of preparatory elements for flight. It is particularly interesting to note that no preparatory elements were recorded in the fourth cycle.

According to Witten and Witten (1991) and Arampatzis and Bruggemann (1999), the execution of flight elements, in both HB and UB, requires preparation through elements capable to generate the necessary mechanical energy for the desired amplitude. Authors also state that the exercise leading up to the flight elements is most often the giant swing and the reality reflected by the results presented in this paper shows that female gymnasts have not been using giant swings to prepare their flight elements.

Arampatzis and Bruggemann (2001) studied the mechanical energy processes during the giant swing before “Tkachev” on UB and HB and observed more similarity between the “Tkachev” giant in UB with the giant executed by men on HB, when they perform “Tkachev-Tkachev”, therefore without any preparation. Authors found energy loss in some UB giant phases and suggest that future research should study the way to gain the energy required for increased amplitude in this kind of element.

If the current technique used in giant swing prior to a flight element doesn't give enough energy, we understand the results, i.e. the non execution of unnecessary elements preceding flight elements. We can also interpret the absence of any exercise to prepare flight elements as an increase in the complexity of the observed routines if we consider one of the directions pointed by Arkaev and Suchilin (2004) for the development of structural complexity of movements, the execution of complex elements without prior acceleration.

The reduced presentation of direct combinations of 2 and 3 flight elements seems to contradict the UB tendencies of execution of series with three and more flight elements presented by some authors (Arkaev and Suchilin, 2004; Smolevsky and Gaverdovsky, 1996).

The ideas of some authors mentioned above are based on the trend of general approach of techniques used by female gymnasts on UB relative to the male gymnasts on HB (Arkaev and Suchilin, 2004; Cimnaghi and Marzolla, 1988; FIG, 1994, 1997b; Sands et al., 2003; Schembri, 1983; Smolevsky and Gaverdovsky, 1996; Witten and Witten, 1991), which seems not to happen concerning flight elements, probably due to the lower amplitude presented by female gymnasts on UB compared with men on HB (Smolevsky and Gaverdovsky, 1996).

Kerwin, Irwin and Exell (2007b) affirm that apparatus construction appears to be very important in accounting for the differences between the straddle Tkachev performed by male and female gymnasts. Concerning the structure of UB, the space restrictions imposed by the width of the bars and the greater rail circumference have been presented as additional limitations by several authors (Prassas, Kwon, and Sands, 2006; Sands, 2000; Sands et al., 2003).

Krug, Knoll and Wagner (1997) justified the differences found between men and women in the techniques used in the giant swing before difficult flight elements, by the differences in the apparatus structure, based on results from studies concerning the forces applied to the apparatus during such giants, which show values related to the forces absorbed by HB with magnitude of 6 to 7 times body weight compared with lower values (4 to 5 times body weight) absorbed by UB.

Krug et al. (1997) also state that women present lower effectiveness in the utilization of elastic properties of apparatus when compared with men, probably due to differences in body weight. According Arampatzis and Bruggemann (1999), the increase of energy due to the relationship between the athlete's body and the elastic capacity of the bar was only detected in the use of “power” or “scooped” technique of backward giant swing, which is used less by female gymnasts on UB (Hiley and Yeadon, 2005).

Other studies and arguments contribute to manifest the difference between the elements performed by men on HB and the same elements performed by women on UB. One example is the preferential use of the "traditional" technique by female gymnasts to execute backward giant swing (Hiley and Yeadon, 2005), producing less angular momentum to release the bar (Arampatzis and Bruggemann, 1999), so with less energy. Smolevsky and Gaverdovsky (1996) confirm consistently lower speeds and flight amplitudes of the elements performed by women compared with men.

These differences suggest a lower ability of women to create enough energy to execute flight elements with the highest and most desirable amplitude, demonstrating an inability to execute it with the least loss of points possible, and combine it in combinations.

The closed body configuration preferred by gymnasts also suggests the referred lower amplitude, which makes the execution of preparatory elements unnecessary, namely to achieve the necessary energy to execute elements with stretched body.

Through the several observed correlations it is possible to perceive that in the rare presentations of a direct combination of 2 flight elements, gymnasts performed it typically facing outwards to low bar position and that its execution is also associated with the unusual execution of flight elements with straight body shape.

The coefficient of difficulty of flight elements also revealed no significant development and the elite gymnasts have kept the level of difficulty of the flight elements of their routines, which correspond to elements of value "D".

Through the development program "Age Group" (FIG, 1997a), FIG recommends both learning and execution of flight elements with value "E", as well as the direct combination of 2, 3 or more flight elements. As shown, the reality of the most qualified performances on UB contradicts this approach, namely the reality of the world's best gymnasts suggests that it is not profitable to increase the routine's difficulty by adding more valuable flight elements or direct connections between these kinds of movements.

CONCLUSION

The majority of variables of the flight elements performed by elite gymnasts didn't change, neither in volume nor in difficulty, keeping the reference of one or two elements of value "D" per routine. However, with the introduction of new rules from the CP 2006 and 2009, it is necessary to confirm these results through observation of the last Olympic cycle (2005-2008) and later. Aspects related to the apparatus structure, to the morphology of women, and to the CP seem to condition the presentation of more flight elements, broader and interconnected.

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Slovenski izvlečki / Slovene Abstracts

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ALI LATERALNOST NAPOVEDUJE SMER OBRAČANJA V GIMNASTIKI?

Čeprav so obrati ključni del pri mnogih gimnastičnih prvinah, je malo znanega o povezanosti med smerjo obračanja z različnimi zahtevami delovanja in ostalimi dejavniki, kot je na primer ugotavljanje lateralnosti (uporabe desne/leve strani). Z raziskavo smo ugotavljali povezanost smeri obrata z lateralnostjo pri različnih gimnastičnih prvinah. Na vzorcu N = 44 telovadcev smo ugotovili: telovadci, ki se v stoji na nogah obračajo v levo večkrat izvedejo premet vstran z obratom nazaj v desno $\chi^2 = 13.09$, $p < .01$, in pri saltu nazaj z obratom v levo$\chi^2 = 17.79$, $p<.01$. Telovadci, ki so stalni ali občasni levičarji so se bolj pogosto obračali v levo pri stoji na nogah $F(1, 42) = 10.71$, $p < .01$, in tisti, ki so se bolj pogosto obračali na desno $F(1, 42) = 6.07$, $p = .02$, so se pri premetu vstran z obratom nazaj bolj pogosto obračali v desno. Ugotovili smo, da je smiselno pri učenju gibanja poskušati z obrati v različnih smereh, zato, da telovadec lahko izkoristi svoje zmožnosti glede na lateralnost.

Ključne besede: izbor smeri obrata, premet vstran z obratom nazaj, salto nazaj z obratom, skok z obratom, stoja na rokah z obratom.

Trevor Dowdell

ZNAČILNOSTI USPEŠNEGA UPRAVLJANJA GIMNASTIČNE VADBE

Raziskava je ugotavljala značilnosti uspešnega upravljanja gimnastične vadbe. Z uporabo različnih tehnik analize obravnavanega področja smo sestavili seznam osnovnih značilnosti uspešnega upravljanja gimnastične vadbe. Najvišje v hierarhiji značilnosti je načrtovanje vadbe, sledi uspešno poučevanje, poznavanje posebnosti gimnastike, primerno postavljanje ciljev in poudarjanje odličnosti pri izvajanju vadbe. Ostali pomembni dejavniki so še medosebno sporazumevanje, vodstvene sposobnosti, sposobnost zagotavljanja varnosti, sposobnost vizualizacije izvedenih prvin, napovedovanje želenih učinkov vadbe in nadzorovanje vadečih.

Ključne besede: gimnastika, uspešno upravljanje vadbe, dejavniki vadbe.

Bojan Leskošek, Ivan Čuk, István Karácsony, Jernej Pajek, Maja Bučar

ZANESLJIVOST IN VELJAVNOST SOJENJA V MOŠKI ŠPORTNI GIMNASTIKI NA UNIVERZIADI 2009

Zagotavljanje zanesljivosti in veljavnosti v športni gimnastiki je težko. Čeprav so pri FIG spremenili Pravilnik za ocenjevanje, je malo dokazov o vplivu sprememb pravil na povečanje kvalitete sojenja. Po zadnji veliki spremembi pravil leta 2008, je bila univerziada 2009 v Beogradu drugo največje tekmovanje do takrat. Končna ocena v gimnastiki je sestavljena iz ocene vsebine sestave in ocene izvedbe sestave. Oceno izvedbe sestave določijo štirje (v predtekmovanju in finalu mnogoboju) ali šest sodnikov (v finalih na posameznih orodjih). Za ocene sodnikov izvedbe so bile izračunane mere zanesljivosti in veljavnosti (medvrstni korelacijski koeficient, Cronbachova alfa, Kendalllow koeficient skladnosti, theta koeficient, razlike v aritmetičnih sredinah) s pomočjo statističnega programa SPSS Statistics 17.0. Rezultati kažejo na visoko zanesljivost ocenjavanja. Ugotovljeno je bilo tudi sistematično slabo sojenje posameznih sodnikov in sojenj na posameznem orodju. Vrednosti statističnih parametrov se izboljšujejo s številom ocenjenih sestav. Ne glede na dobro zanesljivost in veljavnost sojenja, moramo poudariti, da se kvaliteta sojenja razlikuje med orodji, vrstami tekmovanja in sodniki.

Ključne besede: moška športna gimnastika, sojenje, zanesljivost, veljavnost, univerziada.

Matjaž Ferkolj

KINEMATIČNE ZNAČILNOSTI PREMET DVOJNEGA SALTA NAPREJ SKRČENO NA MIZI ZA PRESKOK

Na svetovnem prvenstvu leta 2001 v Ghentu je FIG zamenjala tradicionalnega konja za preskok z novim orodjem – mizo za preskok. Nova miza je širša in nekoliko bolj elastična. To je povzročilo povečanje števila telovadcev, ki izvajajo premet dvojni salto naprej skrčeno. Cilj je bil ugotoviti kinematične značilnosti proučevanega preskoka v posameznih delih (poti, časovne značilnosti, hitrosti, kote, kotne hitrosti), ki vplivajo na kvaliteto izvedbe preskoka. Vzorec merjencev je predstavljalo devet telovadcev, ki so v predtekmovanju na svetovnem prvenstvu v Debrecnu leta 2002 izvajali omenjeni preskok. Statistične analize so bile izvedene na vzorcu 98 spremenljivk s pomočjo statističnega programa SPSS 15.0. Premet dvojni salto naprej skrčeno postaja osnovni preskok, iz katerega razvijajo nove preskoke (sklonjeno, z obrati), zato je poznavanje kinematičnih značilnosti pomembno za telovadce, trenerje in sodnike.

Ključne besede: moška športna gimnastika, preskok, miza, biomehanika, premet dvojni salto naprej skrčeno.

José Ferreirinha, Joana Carvalho, Cristina Côrte-Real in António Silva

RAZVOJ PRVIN LETA V SESTAVAH NA DVOVIŠINSKI BRADLJI

Namen članka je bil oceniti in opisati značilnosti zunanjih obremenitev povezanih s prvinami leta pri vrhunskih telovadkah na dvovišinski bradlji. V ta namen je bilo analiziranih 83 sestav, ki so bile izvedene na svetovnih prvenstvih in olimpijskih igrah od leta 1989 do leta 2004. Ocenjevane so bile spremenljivke: število prvin leta, težavnost, povezanost z dvemi ali tremi prvinami leta, izvedba s stegnjenim ali sklonjenim telesom, vrsto predprvin, smer izvedbe (k ali od nižje lestvine) in izvedba v prvem ali drugem delu sestave. Rezultati kažejo na značilno zmanjševanje predprvin in tudi značilno spremenjeno število letov od nižje lestvine in na nižjo lestvino. Pri ostalih spremenljivkah ni bilo opaziti značilnih sprememb. Vrhunske telovadke običajno izvajajo 1-2 prvini leta D težavnosti v celotnem analiziranem obdobju in običajno s sklonjenim telesom. Na osnovi analize lahko zaključimo, da se število, neposrednih povezav letov in težavnost letov ni povečala, kar je napovedovala gimnastična literatura.

Ključne besede: ženska športna gimnastika, dvovišinska bradlja, prvine leta, smer razvoja

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