Science of Gymnastics Journal

vol. 12, num. 2, year 2020

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

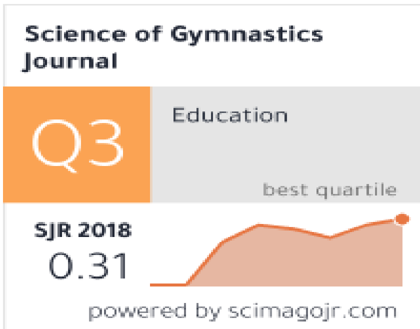
Science of Gymnastics Journal (ScGYM®)

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

Science of Gymnastics Journal is indexed in
Web of Science (ESCI data base, since 2015), EBSCOhost SPORTDiscus, SCOPUS, COBISS (IZUM), SIRC (Canada), ERIHPLUS, OPEN. J-GATE, GET CITED, ELECTRONIC JOURNALS INDEX, SCIRUS, NEW JOUR, GOOGLE SCHOLAR, PRO QUEST and INDEX COPERNICUS. ScGYM® (ISSN 1855-7171) is an international online journal published three times a year (February, June, October).

Front page design: Sandi Radovan, Slovenia.

Editorial Office Address
Science of Gymnastics Journal
Faculty of Sport, Department of Gymnastics
Gortanova 22, SI-1000 Ljubljana, Slovenia
Telephone: +386 (0)1 520 7765
Fax: +386 (0)1 520 7750
E-mail: scgym@fsp.uni-lj.si
Home page: http://www.scienceofgymnastics.com



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

CONTENTS

EDITORIAL

Dear friends,

Our expectations to celebrate the highest achievements in gymnastics at the Olympic Games in Tokyo have been postponed for a year. I hope we will be able to enjoy the Games next year. Who would have thought that one small micro size organism can stop the whole world! Some countries cancelled all sport activities, some still do let them run. Our human race is being tested. Let's hope our families, friends and everyone else will come through this crisis without any serious problems.

On the other hand, we still attend to our day-to-day activities that make our days happier. Prof. Anton Gajdoš, our collaborator on history topics and friend, has just celebrated his 80th birthday. Advanced age from some people's perspective, but Anton is still full of energy. In this issue we learn a bit more about his history diaries. We wish him many happy and healthy years to come!

For this issue our authors researched many different topics. I'm very pleased that we probably have the first research paper on the definition of aesthetic movement. In art it is believed that beauty is in the eye of the beholder. Pia Vinken and Thomas Heinen from Germany tried to define what aesthetic movement in gymnastics is supposed to be (content, no errors). Ludwig Friderich Jahn would be proud of them.

For the first time we present articles from the Democratic People's Republic of Korea and Indonesia. One article is about modelling the Jurchenko vault and another is about aerobic fitness in relation to diet.

The remaining five articles were contributed by authors from Germany (judging trampolining, motor control), Portugal (morphologic characteristics), Mexico (psychology), United Kingdom and Australia (acrobatics). All together, there are eight very interesting articles in this issue.

Anton Gajdoš provides a short historical note on Professor Vladimir Ivanovič Silin of Russia.

Just to remind you, if you quote the Journal, its abbreviation on the Web of Knowledge is SCI GYMN J.

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

Ivan Čuk
Editor-in-Chief

PERCEIVED AESTHETIC FEATURES DIFFERENTIATING BETWEEN COMPLEX ARTISTIC DANCE SKILLS OF VARYING STYLE

Pia M. Vinken[1], Thomas Heinen[2]

[1] Institute of Sport Science, Georg-August-University Göttingen, Germany
[2] Faculty of Sport Science, Leipzig University, Germany

Original article

Abstract
Research on (empirical) aesthetics investigates properties and features of objects, the resulting response-mechanisms to such objects in the observer, and the interplay between factors of the object and the observer in a given context. This study focuses on object-related factors, such as biological motion. The question is addressed of whether there are perceived aesthetic features differentiating between complex artistic skills ranked most and least aesthetic by experienced observers. Therefore, 18 participants with dance experience were asked to evaluate the perceived aesthetics of stick-figure video sequences of three different complex motor skills, namely dance jumps, poses, and turns. As a result, three specific aesthetic features are pointed out as aesthetic fundamentals in the perception and evaluation of aesthetic sports and performing arts: 1) an outwards direction away from the dancers longitudinal axis and body center, 2) a focus on external rotation of the limbs (turn-out), and 3) a (diagonal) spread of body movements creating the impression of elongating the dancer's body. In particular, aesthetic features that demand the performer's ability and challenge physical laws seem to be robust parameters when aiming to create aesthetic motion stimuli. Concluding, a skill-specificity for aesthetic features, as well as the need to differentiate between the interaction of different aesthetic features, is pointed out – aspects which seem especially apparent in biological motion stimuli.

Keywords: *artistic sports, performing arts, stick-figure video sequences, two-alternative forced choice task, motion perception.*

INTRODUCTION

One central aim of artistic sports as well as of performing arts is to create and perform biological motion in such a way that it evokes an aesthetically pleasing impression in the observer (Arkaev & Suchilin, 2009; Christensen & Calvo-Merino, 2013). It is thought that an aesthetically pleasing impression results from the interplay between the perceived motion (the *object*), the perceiving spectators (the *observers*), and the (socio-cultural) environment in which the performed motion is observed (the *context*; Jacobsen, 2006; Pearce, Zaidel, Vartanian, et al., 2016). Because aspects such as the observer and the context are regulated in artistic sports, the focus of this study is the object in terms of the perceived (biological) motion. In artistic sports, the mastery of complex skills is judged accoring to their difficulty and execution, whereas their ratio to the final score differs between disciplines and is written in the Codes of Points (Čuk, Fink, & Leskošek, 2012; FIG, 2016). In performing arts, the mastery of complex skills is most often not judged explicitly, and there are rather implicit movement catalogs from which artists chose their skills (Burrows, 2010; Laban, 2011). However, in artistic sports as well as in performing arts, the impression which is created by mastering movements skillfully seems to be related to interdisciplinary motion aesthetics (Brielmann & Pelli, 2018). The central question yet arises, whether there are perceived aesthetic features differentiating between complex artistic skills ranked most and least aesthetic by experienced observers?

Current research on (empirical) aesthetics aims to investigate properties and features of aesthetic objects, the resulting response-mechanisms to such objects in the observer, and the interplay between factors of the object and the observer in a given context (Brielmann & Pelli, 2018; Chatterjee & Vartanian, 2014; Jacobsen, 2006; Leder & Nadal, 2014; Pearce, Zaidel, Vartanian, et al., 2016). Thereby, aesthetic features for non-biological and biological stimuli reveal varying attention in research on empirical aesthetics and follow different aims, measurements, and hypotheses.

When observing *non-biological objects* such as paintings or graphic patterns, stimulus-driven aesthetic features discussed in the literature are complexity, curvature, figure-ground contrast, the goodness of form, ideal habitat, symmetry, and the golden ratio (Brielmann & Pelli, 2018; Reber, Schwarz, & Winkielman, 2004; Tinio & Leder, 2009). Symmetric, average, and curved objects generally seem to be perceived as more aesthetic when compared to asymmetric and angular ones (Brielmann & Pelli, 2018). Furthermore, a high figure-ground contrast, the goodness of form (few forms arranged vertically), as well as symmetry, are discussed to affect processing fluency of objects positively and thus increasing their perceived aesthetics (Reber et al., 2004). However, there are still contradicting results, especially concerning the golden ratio, the complexity of, and the familiarization with the stimulus (Brielmann & Pelli, 2018; Tinio & Leder, 2009). For example, Tinio and Leder (2009) found that symmetry and complexity are reliable determinants when participants should indicate their perceived aesthetics of black and white patterns. Complex and symmetric patterns received the highest aesthetic rankings followed by simple and symmetric, complex and non-symmetric, and simple and non-symmetric patterns. However, if participants were familiarized with complex stimuli, they indicated higher aesthetic ratings to simple stimuli and vice versa (Tinio & Leder, 2009). It can be concluded that aesthetic features, like symmetry, familiarity, and object-specific aspects (e. g., the goodness of form) which support a stimulus' processing fluency, should be utilized when aiming to create aesthetic objects.

In this study, the focus is on object-driven factors of perceived biological motion aesthetics. It is acknowledged that perception and evaluation of motion aesthetics occur in the observer and thus can hardly be interpreted separately. The following aspects of the relationship between the object and the observer should be outlined: the observer's visual, sensory-motor, and conceptual expertise concerning the aesthetics of the perceived motion. Orgs and colleagues (2018) describe dance as social art form and communication between performer and spectator. The performer transmits information via the movement to the observer. However, if the transmitted information is understood, depends on both the performer's ability to transmit the information via his/her bodily movements, as well as the observer's own visual, sensory-motor, and conceptual expertise about such movements.

Furthermore, the authors argue, that movements with low motor familiarity in the observer might be less aesthetically pleasing than movements for which the observer has the corresponding motor familiarity (Orgs, Calvo-Merino & Cross, 2018). An aspect that can be described as follows: Watching biological motion engages motor resonance in the observer and seems to be an embodied process (Christensen & Calvo-Merino, 2013; Cross, 2015). In light of the findings on processing fluency, outlined above, familiar motion stimuli can be processed more fluently in the observer, thus increasing perceived motion aesthetics (Orgs et al., 2018; Reber et al., 2004).

Nevertheless, observers equally enjoy such motion stimuli that exhibit a high level of skill, ability, and virtuosity of the performer and naïve dance observers aesthetically prefer movements they declare as not being reproducible for themselves. Consequently, motor familiarity alone cannot explain motion aesthetics because everybody can enjoy watching dance either because of motor familiarity or because of the spectacularity of the movement (Cross, 2015; Orgs et al., 2018). Furthermore, observers most enjoy such motion stimuli for which they possess physical, visual, and auditory experiences. Motion stimuli for which observers possess only auditory experience or no experience at all were enjoyed less (Kirsch, Dawson & Cross, 2015). It can be concluded that the observer's expertise, motor familiarity, and processes of an embodiment are related to observer's perceived motion aesthetics and should be controlled when aiming to focus on stimulus-driven features of motion aesthetics.

The same is true for contextual factors like, for example, ornamentation, (background) color, and (bodily) appearance of the performer (Calvo-Merino, Jola, Glaser & Haggard, 2008; Christensen & Calvo-Merino, 2013; Christensen, Nadal, Cela-Conde & Gomila, 2014). Consequently, in this study, original motion stimuli are transferred into stick-figure video sequences aiming to remove bias on personal and context information and to reduce original dance movements to their kinematic motion characteristics (cf., Findlay & Ste-Marie, 2004). By doing so, it is argued that aesthetic features of the object, namely aesthetically pleasing biological motion, can be adequately studied.

For *biological motion*, in general, and dance motion, in particular, aesthetic features discussed in current research are amplitude, balance time, complexity, direction, effort, horizontal and vertical orientation, smoothness, speed, symmetry, and synchronization (Christensen & Calvo-Merino, 2013; Daprati, Iosa, & Haggard, 2009; Orgs et al., 2018; Torrents, Castañer, Jofre, Morey, & Reverter, 2013). Those motion specific aesthetic features partly complement the features outlined for non-motion specific stimuli. There are several approaches to study and measure features of motion aesthetics. First, kinematic measures focusing on the physical properties of biological motion are implemented (Daprati et al., 2009; Torrents et al., 2013). Second, neuroscientific measures aiming to capture aspects of brain activity when watching aesthetic stimuli (Calvo-Merino et al., 2008; Cross, 2015; Kirsch et al., 2015). Third, affective and behavioral measures are used to indicate the observer's perception, evaluation, and experience to aesthetic stimuli. Affect, for example, is measured by indicating positive and negative valence to the stimuli presented (Christensen et al., 2014). Behavioral measures, for example, address concepts such as beauty, liking, and interest indicated via Likert-scales, semantic differentials, or forced-choice tasks (Calvo-Merino et al., 2008; Christensen et al., 2014; Cross, 2015; Daprati et al., 2009).

In general, findings on aesthetic features of biological motion stimuli indicate that smooth and predictable movements are aesthetically preferred when compared to complex, jerky, and asymmetrical movements (Orgs et al., 2018). An aspect, which may refer to the processing fluency of the stimuli (cf., Reber et al., 2004). Furthermore, naïve dance observers prefer more vertical limb displacements compared to less vertical ones (Daprati et al., 2009). Additionally, fast turning speeds, large balance time, and large general amplitude of movement are related to higher perceived motion aesthetics compared to slow turning speeds, small balance time, and low amplitudes (Torrents et al., 2013).

Additionally, features that characterize the ability of the performer can be summarized. Such features are especially prominent in aesthetic sports and performing arts where the ability of the performer is expressed via skillful bodily movements, which are being embodied in both, the performer and the observer (Calvo-Merino et al., 2008; Christensen & Calvo-Merino, 2013; Cross, 2015; Kirsch et al., 2015). Contrary to non-biological stimuli, in aesthetic sports and performing arts, the object cannot be observed detached from the performing body. Therefore, aesthetic features which may be fundamental for non-biological stimuli may be *different* when it comes to biological stimuli and their perceived (motion) aesthetics. Different, first, concerning their general appearance and occurrence. And second, presumably also different concerning their impression while being performed and observed. It can be concluded that smooth movements which can be processed easily, focus on vertical orientation, and underline the performer's ability, should be utilized when aiming to create aesthetic motion stimuli.

The impression of aesthetic features in biological motion is often hard to capture by simply measuring parameters such as physical displacement of the limbs. Therefore, qualitative measures of biological motion are recommended (Thomas, Nelson, & Silverman, 2015). Calvo-Merino and colleagues (2008), for example, looked for physical descriptors within such dance movements that target "aesthetic" brain areas in naïve dance observers undergone functional magnetic resonance imaging (fMRI) measures while watching ballet and capoeira sequences. The authors argue that physical parameters such as horizontal and vertical displacement – actions that are especially necessary during jumping – may target aesthetically-relevant brain areas (e. g., occipital cortices and right premotor cortex; Calvo-Merino et al., 2008). However, it remains open which features within variations of such jumps are related to a jump's perceived aesthetics.

Other, rather qualitative aesthetic features discussed in dance are the flexibility of the performer, extensively stretched feet, and external rotations (*turn-out*) of the hip, knee, and ankle joint (Christensen & Calvo-Merino, 2013). Authors argue that such features challenge the range of motion of the human body and create the impression of elongating the performer's body and range of motion in space. Besides, such features may be related to fertility and courtship behavior.

Christensen and colleagues (2014) combined quantitative and qualitative measures of motion aesthetics in classical ballet stimuli. Quantitative (e.g., number of pirouettes) and qualitative parameters (e. g., movement dynamics as well as Laban score; Laban, 2011) were assessed. Parameters such as movement path, movement quantity, and Laban score predicted aesthetic ratings of inexperienced dance observers. Expressed in terms of motion aesthetics, those parameters appear in soft, expansive, and horizontal movements executed in an indulging, flexible, and gently fluent way (Christensen et al., 2014). As a result, combinations of quantitative and qualitative measures seem to capture the holistic manner of perceived biological motion aesthetics, by combining physical parameters and their induced impression in the observer via the performer's ability.

Taken together, context and the observer's expertise should be controlled when aiming to focus on stimulus-driven features of perceived motion aesthetics. Furthermore, in particular, in this study, a qualitative approach capturing the holistic manner of biological motion aesthetics should be emphasized, aiming to find prototypical aesthetic features within biological motion stimuli (Castañer, Torrents, Morey, & Jofre, 2014; Mack, Hennig, & Heinen, 2018). Previous research indicates that smooth movements that can be processed easily, focus on vertical orientation, and underline the performer's ability, are promising parameters of perceived motion aesthetics. It is therefore assumed that such parameters represent interdisciplinary aesthetic features, which differentiate between complex artistic skills, namely dance jumps, poses, and turns of varying style.

METHODS

Participants (*N* = 18) with dance experience in classical, modern, and/or jazz dance were recruited to take part in this study. Participants (16 females, 2 males) were 29 ± 11 years old, and they reported to have an average of 16 ± 12 years of dancing experience with 6 ± 5 training hours per week. Their task was to evaluate the perceived motion aesthetics of stick-figure video sequences of three different artistic skills, namely variations of dance jumps, poses, and turns.

Additionally, *N* = 9 experienced female dancers (mean age: 29 ± 3 years) were recruited as an additional group in order to generate video stimuli (stimuli group). They were asked to perform variations of dance jumps, poses, and turns. Dancers reported having substantial experience in different dance styles, such as classical dance, modern dance, or jazz dance (Chi, 2006). Their average dancing experience was 21 ± 8 years with 4 ± 1 hours per week of regular practice.

All participants voluntarily joined this study and gave informed consent about participation. The study was conducted according to the guidelines of the local University's ethics committee.

Each dancer of the stimuli group separately arrived at the gymnasium and was informed about the general purpose of the study, as well as the process of video stimuli generation. She gave her informed consent to voluntary participate in this study and completed a short questionnaire about her dance experience. She was allowed an individual warm-up and practice phase. Video stimuli generation for the three artistic skills, namely dance jumps, poses, and turns, occurred randomly for each dancer. First, the dancer was instructed about the motion prerequisites of the dance skill performed initially (cf., Tab. 1). Then, she individually practiced the skill and its variations while being allowed to ask questions about movement variations, prerequisites, and the process of video stimuli generation. Afterward, the dancer was asked to perform at least four variations of the first dance skill. When finishing this, she was asked whether she was satisfied with her performance or wanted to do another variation. Finally, when at least four variations of the first dance skill were successfully performed and captured, the aforementioned process was repeated for the two remaining dance skills. When the dancer performed at least four variations of each of the three dance skills, she was debriefed.

Dance skill variations were performed in a capture area of 5 x 5 meters while being videotaped utilizing six video cameras operating at 60 Hz (640 x 480 pixels). In total, 47 jumps, 43 poses, and 45 turns were recorded. The 135 recorded video sequences were subjected to a silhouette-based computer-based algorithm to extract movement kinematics from the video sequences *(iPi Motion Capture* ™, iPi Soft, Russia). The video footage of all six cameras was used to calculate a 3D volume model of a human body consisting of head, trunk, two upper and lower arms, two hands, two thighs and shanks, two feet, as well as the appropriate joints, namely, neck, shoulders, elbows and wrists, spine, hips, knees, and ankles.

From the extracted movement kinematics, stick-figure video sequences were generated. This had the advantage of reducing the original video footage to its kinematic motion information, and to control for potential contextual and bodily biases (Findlay & Ste-Marie 2004). From the captured dance skills, stick-figure video sequences of 28 jumps, 30 poses, and 19 turns could be generated with excellent movement quality. Within the performed dance skills, there were equal variations between dancers of, for example, a *pirouette en dehors* occurring in classical ballet with the left foot in a *sur le coup de pied* position. From those equal variations, one stick-figure video sequence was randomly selected to achieve a sufficient variety of stimuli dance skills. In general, ten video sequences of each dance skill were selected for stimuli presentation and evaluation, thus representing a sufficient variety of different dance jumps, dance poses, and dance turns. At the end of the aforementioned steps, there were thirty stick-figure video sequences of dance skill variations, namely ten jumps, ten poses, and ten turns.

Artistic dance skills were evaluated using a two-alternative forced-choice task (2AFC; Palmer, Schloss, & Sammartino, 2013), whereas jumps, poses, and turns were evaluated separately and in randomized order. For each 2AFC task, two stick-figure video sequences labeled "A" and "B", were presented next to each other. Thereby, A was presented on the left side of the screen and shown first, while B was presented on the right side of the screen and presented second. Both video sequences were presented in the original speed on a 2.5 x 1.8-meter projection screen. After the presentation, participants had to indicate which of the two stick-figure video sequences, A (left) or B (right), they perceived as more aesthetic. They were asked to indicate their decision for A or B on a questionnaire sheet by ticking either A or B for the corresponding forced-choice task. This procedure was repeated until each, for example, jump sequence was compared to each of the other jump sequences resulting in 45 comparisons for the dance jump's 2AFC task. When the forced-choice task of the first dance skill, was completed, the same course of action was repeated for the two remaining artistic dance skills. In sum, this procedure resulted in 3 x 45 = 135 forced choices for each participant resulting in a total number of 2.430 choices for all participants.

Each participant was invited separately to a laboratory room at the local university. He/she was informed about the general purpose of the study, signed an informed consent form, and completed a short questionnaire about his/her dance experience. Before data collection, the experimenter introduced the evaluation procedure, and the participant was shown exemplary stick-figure video sequences for calibration purposes. The two-alternative forced-choice task (2AFC) was done for each of the three dance skills separately, while jumps, poses, and turns were presented in random order. After the evaluation of the first dance skill, participants were allowed to take a short break. Then, the same procedure was repeated for the remaining two dance skills. There was no time pressure, but the participant was instructed to indicate his/her evaluation spontaneously. After data collection, he/she was debriefed.

Each participant's decision was scored as 1 when the participant perceived this sequence as more aesthetic, while the compared sequence received a score of 0 in this forced choice. This was done for each comparison of each participant. Afterward, the participant's scores of each stick-figure video sequence were summed up. This procedure provided a ranking order of stick-figure video sequences ranging from most aesthetic (rank 1) to least aesthetic (rank 10), and was done separately for the three dance skills, namely dance jump, pose, and turn. Participants' summed rankings of the video sequences evaluated most and least aesthetic were compared using Wilcoxon signed-rank test to ensure their statistical distinctness. In order to explore aesthetic features differentiating between complex artistic skills of varying style, a qualitative description of video sequences was conducted (Thomas et al., 2015): First, the perceived content in the video sequences evaluated most and least aesthetic was described. Second, differences and similarities within the two sequences were contrasted, aggregated, and ordered concerning kinematic (Watkins, 2014) and contextual (Castañer et al., 2014; Laban, 2011; Mack et al., 2018) parameters.

Table 1
List of prerequisites, instructions, and variations for the three artistic skills, namely dance jump, pose, and turn.

	Prerequisites	Instructions	Variations
Jump	Stand upright with feet hip-width apart and arms on the side of the body - jump from the left leg with a 45° turn to land on the right leg - come back to the upright stance with feet hip-width apart and arms positioned on the side of the body	Show variations of this jump by individually varying - movement of legs, arms, trunk, and whole body - accentuation and complexity	- jump height - jump width - involvement of arms - involvement of legs - involvement of trunk and head - accentuation of different movement phases (preparation phase, jump phase, landing and resolution phase)
Pose	Stand upright with feet hip-width apart and arms on the side of the body - use the left leg as standing leg and exhibit a one-legged pose - come back to the upright stance with feet hip-width apart and arms positioned on the side of the body	Show variations of this pose by individually varying - movement of legs, arms, trunk, and whole body - accentuation and complexity	- involvement of arms - involvement of legs - involvement of trunk and head - accentuation of different movement phases (standing phase, moving phase, (off-) balance phase, resolution phase)
Turn	Stand upright with feet hip-width apart and arms on the side of the body - do a 450° turn to the left with your right leg as standing leg - come back to the upright stance with feet hip-width apart and arms positioned on the side of the body	Show variations of this turn by individually varying - movement of legs, arms, trunk, and whole body - accentuation and complexity	- involvement of arms - involvement of legs - involvement of trunk and head - accentuation of different movement phases (preparation phase, turning phase, resolution phase)

RESULTS

Figure 1 shows picture sequences of the three dance skills evaluated most (rank 1) and least (rank 10) aesthetic. For dance jumps, the skill variation evaluated most aesthetic received a score of 122, while the skill variation evaluated least aesthetic received a score of 16 (Z = -3.72, p < .05). For dance poses, the skill variation evaluated most aesthetic received a score of 123, and the skill variation evaluated least aesthetic received a score of 39 (Z = -3.36, p < .05). For dance turns, the skill variation evaluated most aesthetic received a score of 124, whereas the skill variation evaluated least aesthetic received a score of 27 ($Z = -3.55$, $p < .05$).

The dance jump evaluated most aesthetic starts from an upright stance and begins with a preparation phase in which the left leg is flexed to approximately 90° (one-legged *grand plié*) while the right leg and both arms are directed to the front lower-left corner for a preparation movement. From there, both arms are raised above the head to a *third position* while both legs are bend, rotated external (turned out), and abducted one after the other. At the highest point of the jump, both arms are above the head in a *third position*, and both legs reach their maximum height, external rotation, and simultaneous flexion. The landing phase is characterized by bending the right leg, while both arms and the left leg are lowered, heading towards the front lower-right corner. From this position, the dancer erects into the upright stance.

The dance jump evaluated least aesthetic starts from an upright stance and begins with a preparation phase in which the left leg is bent a little while the right leg is abducted heading to the future landing spot. Thereby, the left arm is lifted to shoulder height with a flexed elbow joint and the right arm is lifted to navel height and almost straightened. At the highest point of the jump, both legs are abducted to the lower-right side (right leg) and lower-left side (left leg) and show a little flexion in the knee joint. The right leg is rotated externally (turned out), and the left leg is rotated internally (turned in). The right arm is lifted to navel height and nearly straighten while the left arm is lifted to shoulder height with flexion of approximately 90° in the elbow joint. The landing phase is characterized by bending the right landing leg while the left leg is bent and positioned next to the right one. Both arms are moved towards the trunk while swinging first to the right and then to the left. This comes along with a swing of the trunk until the movement is slowed down fully. From this position, the dancer erects into the upright stance.

The dance pose evaluated most aesthetic starts from an upright stance. Weight is shifted to the left leg as the standing leg while the right leg is moved to the back lower-left corner. Thereby, the left leg is flexed to approximately 90° (one-legged *grand plié*) while rotated external (turned out). Both arms are raised into an elongation of the trunk, which is aligned with the elongated right leg. When the standing leg reaches its greatest flexion, the right leg is elongated to the back lower-left corner in line with head, trunk, as well as both arms, which point to the front upper-right corner. From this position, the left leg starts to straighten while the right leg, as well as both arms, are moved back to the ending position, namely the upright stance.

The dance pose evaluated least aesthetic starts from the upright stance. Weight is shifted to the left leg as the standing leg. Following, the right leg is lifted to approximately knee height to the front while the left arm is moved to a *preparatory position*. The right arm is held next to the body and rotated laterally. Then, the right leg is rotated externally, then internally, and then again externally at the hip and knee joint, while being bent in the knee and hip joint and moved from the front to the side (comparable to the *rond de jambe en l'air en dehors* in classical ballet). Simultaneously, the left arm is moved from the *preparatory*, over the *first*, to the *third position*, and then lowered back next to the body. The right arm is rotated internally, then externally, and finally moved back next to the body in the shoulder and elbow joint. This occurs simultaneously to the external and internal rotation at the hip and knee joint while moving the right leg. Finally, the right leg, as well as both arms, are moved back to the ending position, namely the upright stance.

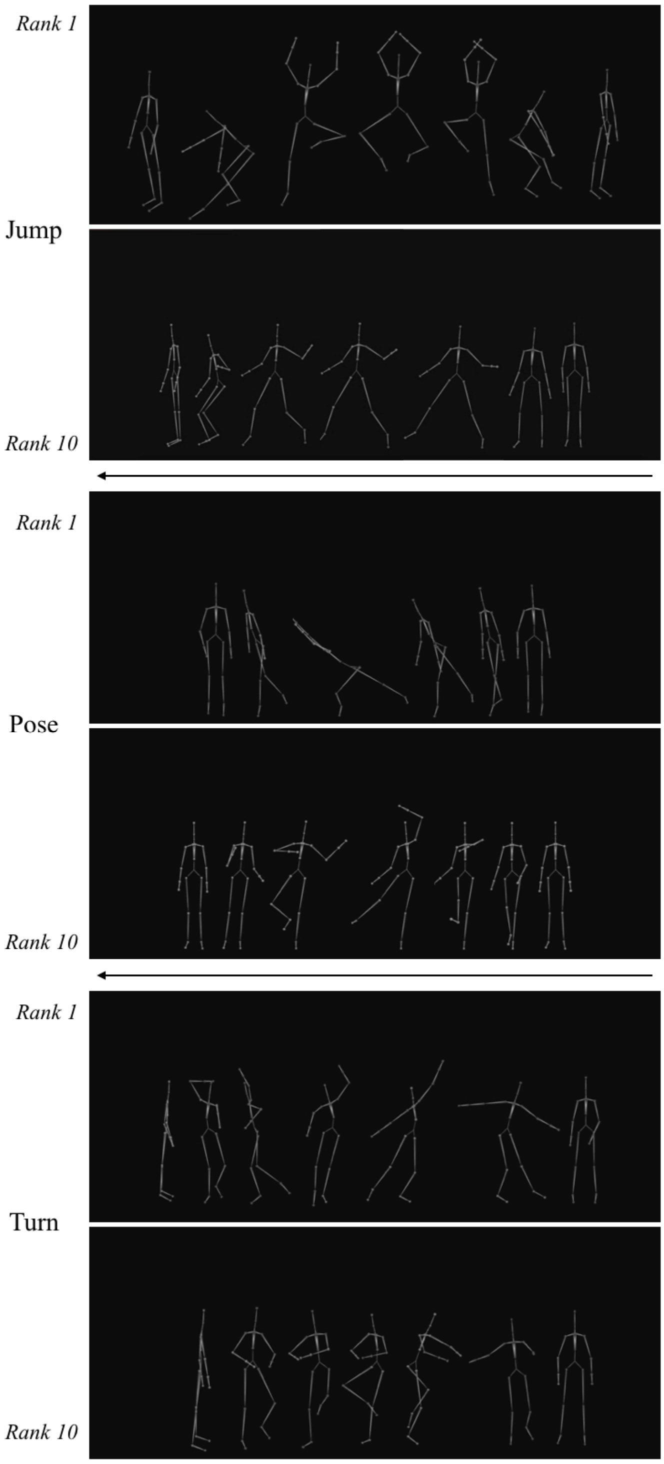


Figure 1. Picture sequences of the jump, pose, and turn stick-figure video sequences ranked most (rank 1) and least (rank 10) aesthetic. Arrows indicate the movement direction.

The dance turn evaluated most aesthetic starts from the upright stance by shifting weight to the right leg while the left leg is moved to the lower left side. Thereby, the elongated right arm is abducted and raised to the upper-right side while the elongated left arm is raised to the lower-left side. During the first 270° of the turn, both arms are held in this position, while the left leg is abducted, pointing to the lower-left side. During the last 180° of the turn, the left leg is adducted from the lower left side next to the standing leg. This leg is straightened in such a way that both legs are finally positioned parallel to each other. Simultaneously, both arms are rotated internally, then externally, then again internally, and back next to the body in both shoulder and elbow joints. Thereby, both arms are moved next to the body – the right arm from the upper-right side and the left arm from the lower-left side. Finally, when the turn is executed, the dancer finishes in an upright stance.

The dance turn evaluated least aesthetic starts from the upright stance and begins with a preparatory phase in which the dancer moves from the upright stance into her preparatory position. Here, weight is shifted to the slightly flexed right leg, while the left leg points to the lower-left side, and the arms are lifted, abducted, and elongated to shoulder height and parallel to the floor. From this position, the left leg is moved to the lower-back side, while the left arm is moved at shoulder height to the front. Then, the right leg is first flexed and then straightened to lift the left leg, which is flexed at the hip and knee joint, positioning the left foot next to the right knee. Thereby, both slightly flexed arms are moved into a *first position* with hands at navel height, while head and trunk are slightly curved forward. This position is hold until the turn is fulfilled and resolved into the ending position, namely the upright stance.

When contrasting the main movement phases of the different dance skills evaluated most and least aesthetic, the following aspects become apparent: jump height of the most aesthetic jump is larger compared to the least aesthetic jump, whereas jump width is comparable. Furthermore, the most aesthetic jump shows an elevation of both arms above shoulder height and both legs to approximately hip height. Compared to the least aesthetic jump, this elevation is much more prominent and may underline the impression of achieved jump height, additionally.

The most aesthetic dance pose is characterized by one single accentuation. In contrast, the least aesthetic pose shows several accentuations. The single, and thus emphasized accentuation of the most aesthetic pose is characterized by a diagonal spread implementing the elongation of the non-supporting leg and parallel arms, thus creating an impression of elongating the dancer's body. Furthermore, the flexion in the supporting leg, in combination with the shift along the corresponding *diametrale* (cf., Laban, 2011), creates an off-balance that needs to be compensated by the dancer's ability and flexibility. In contrast, the least aesthetic pose is characterized by flexed arms and a flexed non-supporting leg. Furthermore, the limbs are moved while the supporting leg functions as a stable base, thus creating the impression of balance, which does not need to be compensated due to the accentuations of the arms and the non-supporting leg.

The most aesthetic dance turn creates the impression of being directed *outwards*, which is achieved first, by spreading the arms diagonal to the upper-right (right arm) and lower-left (left arm) corners, away from the dancer's longitudinal axis and body center. Second, this diagonal spread is underlined by the abduction of the elongated non-supporting left leg to the lower-left corner, away from the dancer's longitudinal axis and body center, too. In contrast, the least aesthetic dance turn creates the impression of being directed *inwards*. This is achieved first, by simultaneously and parallel moving both arms to a *first position*. Second, the non-supporting leg is lifted to a *passé position* towards the dancer's longitudinal axis and body center. Furthermore, the dancer's trunk in the most aesthetic turn is upright, thus underlining the impression of being directed outwards. In contrast, the curved trunk of the dancer in the least aesthetic turn emphasizes the impression of being directed inwards.

DISCUSSION

This study aimed to address the question of whether there are perceived aesthetic features differentiating between complex artistic skills ranked most and least aesthetic by experienced observers. From the results the following three aspects could be derived: 1.) Dance skills that implement body positions directed outwards and away from the dancer's longitudinal axis and body center are perceived as more aesthetic. 2.) An external rotation (*turn-out*), especially in the hip, knee, and ankle joint, is related to higher aesthetic rankings. 3.) Diagonal body positions with extended limbs, which create the impression of elongating the dancer's body and spread, receive higher aesthetic rankings compared to body positions, which implement several diagonal accentuations of flexed limbs.

The results of this study are in line with previous findings on aesthetic features of biological motion aesthetics (Calvo-Merino et al., 2008; Christensen & Calvo-Merino, 2013; Christensen et al., 2014). It is thus argued that outwards direction, external rotation (*turn-out*), and spread seem to be aesthetic fundamentals in the perception and evaluation of aesthetic sports and performing arts. However, and from a mechanical point of view, the aforementioned body positions are somewhat contrary to the economy of the skill's physical motion. For instance, spreading the arms outwards when performing a turn increases the dancer's moment of inertia, thus reducing angular velocity (cf., Watkins, 2014). A similar aspect is apparent in the jump and the pose. During the jump, both legs are elevated and flexed at the hip and knee joints. This produces a counter-movement, which is directed against the initial vertical direction of the movement. During the pose, the *diametral* spread of the whole body shifts the dancer's center of mass away from the initial area of support of the left standing foot (cf., Watkins, 2014). Both mentioned aspects demand a dancer's ability and may impress the observer, thus affecting his/her evaluation of perceived motion aesthetics.

Furthermore, the qualitative description of artistic dance skills ranked most aesthetic is compatible with the results of previous research by Christensen et al. (2014). Especially such aesthetic features which demand the performer's ability and challenge physical laws seem to be robust parameters when aiming to create aesthetic motion stimuli. Additionally, the results of this study underline a skill-specificity for aesthetic features and their interaction that results in a pleasing impression in the observer. While symmetry, outwards direction, external rotation (*turn-out*), and spread are apparent in the most aesthetic jump, symmetry is not apparent in the most aesthetic pose. Still, outwards direction, external rotation (*turn-out*), and spread are. Interestingly, symmetry is apparent in the least aesthetic dance turn, which is directed inwards and lacks external rotation (*turn-out*), as well as spread.

However, findings on the aesthetic feature symmetry discussed as an *aesthetic fundamental* (Brielmann & Pelli, 2018; Jacobsen, 2006; Tinio & Leder, 2009) in non-biological motion stimuli could not be confirmed. It seems as if symmetric body positions and their perceived motion aesthetics are skill-specific. While the dance jump ranked most aesthetic shows a clear top-down and left-right symmetry, such symmetry is neither apparent in the dance pose, nor the dance turn ranked most aesthetic. Interestingly, the dance turn ranked least aesthetic shows symmetry in the arm positioning. This finding may indicate a skill-specificity of aesthetic features and thus seems partly controversial to the aesthetic perception and evaluation of, for example, paintings and graphic patterns (Jacobsen, 2006; Tinio & Leder, 2009).

Similarly, object-driven factors affecting processing fluency of biological motion stimuli seem skill-specific, too. The dance pose and turn ranked most aesthetic focus on one accentuation, whereas the dance pose and turn ranked least aesthetic show several accentuations. An aspect that may affect processing fluency in such a way, that single accentuations in a given time can be processed more fluently, thus affecting aesthetic motion perception (cf., Orgs et al., 2018; Reber et al., 2004). However, when comparing the dance jumps ranked most and least aesthetic, it is argued that the dance jump ranked least aesthetic should be processable more fluently compared to the dance jump ranked most aesthetic. In the least aesthetic jump, accentuation, implementation of limbs, and dancer's displacement are less apparent and should result in more fluent processing. However, observers seem to prefer object-driven factors that challenge their processing fluency when evaluating motion aesthetics of dance jumps. It is thus stated that the perception and evaluation of perceived biological motion aesthetics partly follow different routes compared to the perception and evaluation of non-biological (motion) aesthetics. Aspects of embodied perception and cognition may explain such differences (Christensen & Calvo-Merino, 2013; Cross, 2015). However, investigating such aspects was not the primary aim of this study but could be addressed in subsequent research.

It is acknowledged that there are several limitations of this study, and the following two aspects should be highlighted: First, dance skills and movement variations of this study were generated concerning the ability and variability of the dancers of the stimuli group. Future studies may shed light on whether manipulation of, for example, the amount of outwards direction, external rotation (*turn-out*), or spread causes changes in the evaluation of perceived motion aesthetics in the observer. Second, behavioral measures were implemented by asking experienced observers to indicate perceived aesthetics in a forced-choice task. How observers with different visual, sensory-motor, and contextual experience to the presented stimuli evaluate motion aesthetics should be investigated further. The same is true for combining or contrasting behavioral measures with, for example, affective measures or modifiable motion stimuli. One could argue that behavior and affect are targeted to a stronger degree in experimental settings when participants could manipulate physical and body-related parameters in an analog fashion by themselves (cf., Troje, 2002).

Concerning practical implications, the following is inferred: when aiming to create and perform aesthetically pleasing complex whole-body movements in aesthetic sports or performing art, three aesthetic features should be implemented when experienced observers are addressed. First, body movements which are directed outwards away from the performer's longitudinal axis and body center. Second, body movements that implement an external rotation of the limbs (*turn-out*), for example, of the hip, knee, and ankle joints. Third, body movements which create the impression of elongating the performer's body by focusing on a (diagonal) spread, for example, by creating long lines between extended feet, legs, trunk, arms, and hands. Knowledge about those aesthetic features may support coaches, choreographers, and performers aiming to create aesthetic motion stimuli. Additionally, the results of this study underline the importance of highlighting such aesthetic features in the Code of Points as it is already done, for example, in women's artistic floor gymnastics (cf., artistry and expressiveness as well as artistic harmony and feminine grace; FIG, 2016). By doing so, potential biases (cf., Findlay & Ste-Marie, 2004) can be resolved in such a way that highlighting and honoring fundamental aesthetic features may have the potential to reduce allegedly subjective aesthetic judgments. Finally, the need to further investigate similarities and differences between biological and non-biological (motion) stimuli and their processing behavior within the observer is acknowledged. The results of this study, including previous research, indicate that aesthetic features are skill-specific and different between biological and non-biological stimuli.

CONCLUSION

In this study, it is argued that the perception and evaluation of motion aesthetics is a complex phenomenon depending on the interplay between the object which is perceived from the observer(s) in a given context. Consequently, this interplay of factors affecting perceived motion aesthetics should be investigated and interpreted holistically. Three specific object-driven aesthetic features can be highlighted that distinguish between motion stimuli ranked most and least aesthetic: 1) an outwards direction of the movement, 2) an external rotation (*turn-out*) of the limbs, and 3) a (diagonal) spread. Although factors of the observer and the context were controlled in this study, it is argued that the object-driven aesthetic features pointed out here are transferable to observers with different sensory-motor and contextual experiences as well as to different contexts. Future studies may shed light on the different amounts of object-, observer-, and context-dependent parameters of perceived motion aesthetics, thus aiming to understand the processes of creating, choreographing, and performing pleasing motion aesthetics holistically.

REFERENCES

Arkaev, L., & Suchilin, N. (2009). *Gymnastics: how to create champions*. Aachen: Meyer & Meyer.

Brielmann, A. A., & Pelli, D. G. (2018). Aesthetics. *Current Biology, 28*(16), 859-863. https://doi.org/10.1016/j.cub.2018.06.004

Burrows, J. (2010). *A choreographer's handbook*. Taylor & Francis.

Calvo-Merino, B., Jola, C., Glaser, D. E., & Haggard, P. (2008). Towards a sensorimotor aesthetics of performing art. *Consciousness and Cognition, 17*, 911-922. https://doi.org/10.1016/j.concog.2007.11.003

Castañer, M., Torrents, C., Morey, G., & Jofre, T. (2014). Appraising choreographic creativity, aesthetics, and the complexity of motor responses in dance. In O. Camerino, M. Castañer, & M. T. Anguera (Eds.), *Mixed methods in the movement sciences* (pp. 146-175). London: Routledge. https://doi.org/10.4324/9780203132326

Chatterjee, A., & Vartanian, O. (2014). Neuroaesthetics. *Trends in Cognitive Sciences, 18*(7), 370–375. https://doi.org/10.1016/j.tics.2014.03.003

Chi, M. T. H. (2006). Two approaches to the study of experts' characteristics. In K. A. Ericsson, N. Charness, P. Feltovich, & R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 21-30). Cambridge University Press. https://doi.org/10.1017/CBO9780511816796.002

Christensen, J. F., & Calvo-Merino, B. (2013). Dance as a subject for empirical aesthetics. *Psychology of Aesthetics, Creativity, and the Arts, 7*(1), 76-88. https://doi.org/10.1037/a0031827

Christensen, J. F., Nadal, M., Cela-Conde, C. M., & Gomila, A. (2014). A norming study and library of 203 dance movements. *Perception, 43*, 178-206. https://doi.org/10.1068/p7581

Cross, E. (2015). Beautiful embodiment: the shaping of aesthetic preference by personal experience. In J. P. Huston, M. Nadal, F. Mora, L. F. Agnati, C. Jose Cela Conde (Eds.), *Art, aesthetics, and the brain* (pp. 189-208). Oxford University Press.

Čuk, I., Fink, H., & Leskošek, B. (2012). Modeling the final score in artistic gymnastics by different weights of difficulty and execution. *Science of Gymnastics Journal, 4*(1), 73-82.

Daprati, E., Iosa, M., & Haggard, P. (2009). A dance to the music of time: aesthetically-relevant changes in body posture in performing art. *PLoS ONE, 4*(3), 1-11. https://doi.org/10.1371/journal.pone.0005023

FIG (2016). 2017 – 2020 *Code of points – women's artistic gymnastics*. Fédération Internationale de Gymnastique. http://www.fig-gymnastics.com/publicdir/rules/files/en_WAG%20CoP%202017-2020.pdf

Findlay, L. C., & Ste-Marie, D. M. (2004). A reputation bias in figure skating judging. *Journal of Sport and Exercise Psychology, 26*, 154-166. https://doi.org/10.1123/jsep.26.1.154

Jacobsen, T. (2006). Bridging the arts and sciences. A framework for the psychology of aesthetics. *Leonardo, 39*(2), 155-162. https://doi.org/10.1162/leon.2006.39.2.155

Kirsch, L. P., Dawson, K., & Cross, E. S. (2015). Dance experience sculpts aesthetic perception and related brain circuits. *Annals of the New York Academy of Sciences, 1337*, 130-139. https://doi.org/10.1111/nyas.12634

Laban, R. (2011). *The mastery of movement*. Dance Books Ltd.

Leder, H., & Nadal, M. (2014). Ten years of a model of aesthetic appreciation and aesthetic judgments: the aesthetic episode - Developments and challenges in empirical aesthetics. *British Journal of Psychology, 105*, 443-464. https://doi.org/10.1111/bjop.12084

Mack, M., Hennig, L., & Heinen, T. (2018). Movement prototypes in the performance of the handspring on vault. *Science of Gymnastics Journal, 10*(2), 245-257.

Orgs, G., Calvo-Merino, B., & Cross, E. (2018). Knowing dance or knowing how to dance? Sources of expertise in aesthetic appreciation of human movement. In B. Bläsing, M. Puttke, & T. Schack (Eds.). *The neurocognition of dance* (pp. 238-256). London: Routledge. https://doi.org/10.4324/9781315726410

Palmer, S. E., Schloss, K. B., & Sammartino, J. (2013). Visual aesthetics and human preference. *Annual Review of Psychology, 64*, 77-107. https://doi.org/10.1146/annurev-psych-120710-100504

Pearce, M. T., Zaidel, D. W., Vartanian, O., Skov, M., Leder, H., Chatterjee, A., & Nadal, M. (2016). Neuroaesthetics: the cognitive neuroscience of aesthetic experience. *Perspectives on Psychological Science, 11*(2), 265-279. https://doi.org/10.1177/1745691615621274

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing fluency and aesthetic pleasure: is beauty in the perceiver's processing experience? *Personality and Social Psychology Review, 8*(4), 364-382. https://doi.org/10.1207/s15327957pspr0804_3

Thomas, J. R., Nelson, J. K., & Silverman, S. J. (2015). *Research methods in physical activity*. Champaign, IL: Human Kinetics.

Tinio, P. P. L., & Leder, H. (2009). Just how stable are stable aesthetic features? Symmetry, complexity, and the jaws of massive familiarization. *Acta Psychologica, 130*, 241-250. https://doi.org/10.1016/j.actpsy.2009.01.001

Torrents, C., Castañer, M., Jofre, T., Morey, G., & Reverter, F. (2013). Kinematic parameters that influence the aesthetic perception of beauty in contemporary dance. *Perception, 42*, 447-458. https://doi.org/10.1068/p7117

Troje, N. F. (2002). Decomposing biological motion: a framework for analysis and synthesis of human gait patterns. *Journal of Vision, 2*, 371-387. https://doi.org/10.1167/2.5.2

Watkins, J. (2014). *Fundamental biomechanics of sport and exercise.* London: Routledge.

Corresponding author:

Pia M. Vinken
Institute of Sport Science,
Georg-August-University Göttingen,
Sprangerweg 2, 37075 Göttingen,
Germany
Email: pia.vinken@sport.uni-goettingen.de

HOW DOES AUDITORY INFORMATION INFLUENCE OBSERVERS' PERCEPTION DURING THE EVALUATION OF COMPLEX SKILLS?

Frederike Veit
Faculty of Sport Science, Leipzig University, Germany

Original article

Abstract
Perceiving and gathering information from the environment are essential abilities of humans, especially in sports. An individual's perception of aspects such as the surrounding conditions or the movements of other athletes can be decisive for a successful performance. The question that arises is whether an individual's level of expertise affects his or her ability to use task-specific information. Furthermore, it should be determined whether the type of information that is gathered differs across people with different sport-specific experiences. The aim of the study was to investigate the role of auditory information in the observation and evaluation of complex skills in gymnastics. Participants with different amounts of experience were asked to estimate the duration of flight phases in straight-back somersaults on the floor under manipulated auditory conditions. The results of the current study show that participants with no specific experience in gymnastics performed worse than participants with visual or motor experiences. Additionally, the current gymnasts outperformed the other participants. One could speculate that current gymnasts benefit from their motor experiences, which lead to improved perceptual sensitivity and a better ability to identify differences between two cues. In conclusion, it could be enriching to take the auditory information into account in motor learning tasks.

Keywords: *common-coding, paired comparison, perceptual sensitivity, acrobatic series on floor, expert-novice paradigm.*

INTRODUCTION

Perceiving and gathering information from the environment are essential abilities of humans, especially in sports. An individual's perception of aspects such as the surrounding conditions or the movements of other athletes can be decisive for a successful performance. More specifically, the ability to use domain- and task-specific information may be a crucial advantage for athletes in generating an effective motor action (Mann, Williams, Ward, & Janelle, 2007). Not only the performance of athletes but also the performance of judges and coaches depend on their perceptual abilities. Recent studies have noted that the performance of judges and coaches relate to aspects such as their gaze behavior (Pizzera, Möller, & Plessner, 2018), their own motor experiences (Pizzera, 2012), and years of practical experience (Pizzera & Raab, 2012). The question that arises is whether an individual's level of expertise affects his or her ability to use task-specific information. Furthermore, it should be determined whether the type of information that is gathered differs across people with different sport-specific experiences. Therefore, the aim of the study was to investigate the role of visual and auditory information in the observation and evaluation of complex skills in gymnastics. More specifically, the aim was to extend the knowledge on the extent to which people with different degrees of expertise rely on various sources of information.

According to the common coding theory, perceived information from the visual and auditory system activates the same representation that is utilized when executing a perceived action (Prinz, 1997). Hommel (2019) supplemented this general assumption with a conjecture about the degree of influence of the task-relevant dimension (e.g., technical characteristics). He describes that "codes of feature on a dimension that is (assumed to be) relevant for the presently relevant task will have a stronger impact on representing an event then codes of features related to currently irrelevant dimensions […]" (Hommel, 2019, p. 2141). Observing and evaluating skills in sports are of great importance.

In technical sports such as gymnastics, visual information is also the subject of the evaluation for judges. Therefore, the final ranking of the athletes depends on the perceptual analysis of judges (Ste-Marie, 1999). Relatedly, some studies have investigated the role of visual information in and which factors determine the judging performance and the quality of judgments (Heinen, Vinken, & Velentzas, 2012; Pizzera, Möller, & Plessner, 2018).

Heinen, Vinken, and Velentzas (2012) examined, for instance, the role of visual and motor experiences in judging performances. They asked gymnastic judges (only visual experiences) and laypeople (only motor experiences) to rate handsprings performed on vault. The results indicate that both visual and motor experiences can influence judging performance. Regarding visual experiences, Pizzera, Möller, and Plessner (2018) investigated, whether gaze behavior affects judging performance. Furthermore, they contextualized the gaze behavior with additional motor experiences. In total, they asked 35 judges to judge 21 gymnasts on vault via video performances. The participants differed in their expertise. The authors compared the performance and gaze behaviors of the judges with a high-level of expertise and a lower level of expertise (as measured by license levels) and the performance and gaze behaviors of judges, who can perform the skill on the vault and those who do not have the ability. Contrary to the results in previous studies, the results showed that specific motor experiences do not influence judging performance. Furthermore Pizzera, Möller and Plessner (2018) identified the certification level as an influencing factor.

Concerning the influence of different factors on perceptual judgments and judgment performance, in addition to the abovementioned factors (i.e., motor experiences, license level, years of judging experiences), Plessner and Schallies (2005) proposed that different factors related to the viewing position influence the evaluation of gymnastics skills. They asked 80 participants (40 male judges, and 40 students (26 female and 14 male) as layout people) to judge the cross on rings from three different viewpoints. They examined whether the viewing position of judges and laypeople, as the perceptual factor, influences the judging performance. The results showed that the judges performed much better than did the laypeople. Additionally, the judges were significantly more influenced by the viewing position than were the laypeople.

Additionally, in gymnastics, the auditory information from the natural movement seems to be an essential source of information (Veit & Heinen, 2019). Here different groups (i.e., current gymnasts, former gymnasts, judges/coaches, and laypeople) were asked to observe and evaluate a complex gymnastic skill in visual, audio-visual, and auditory conditions. The main focus of the study was on the judgment of the duration of the flight phase of a straight-back somersault. The results showed that current gymnasts have a significantly higher score in the audio-visual and auditory condition than in the visual condition. Experienced athletes can use movement sounds to evaluate and to improve the quality of their performance (Agostini, Righi, Galmonte, & Brino, 2004; Stauffer, Haldemann, Troche, & Rammsayer, 2012). Judges/coaches, in contrast, outperformed the current and former gymnasts and laypeople in the visual condition.

There exists the assumption that different sensory information affects perception. Kennel, Streese, Pizzera et al. (2015) investigated the influence of natural movement sounds on motor control. More specifically, they conducted a study with 20 participants, who performed a hurdling task in three auditory conditions (normal movement sounds, manipulated movement sounds, and delayed movement sounds). The movement sounds were presented as feedback during the task through headphones. The results suggested that movement sounds, as a result of contacting the floor during running, have an impact on motor control.

Heinen, Koschnick, Schmidt-Maaß, and Vinken (2014) examined the role of auditory and visual information in skill performance, particularly during a synchronization task on trampolines. The experimental task of two gymnasts was to perform synchronized leaps. The study aimed to investigate the role of auditory and visual information in the synchronization of trampolining. To synchronize their performances, gymnasts must perceive and identify relevant information. Twenty female gymnasts had to perform straight leaps in three conditions (1. full visual and auditory information available, 2. limited auditory information available, 3. limited visual information available). Results showed that neither the visual information alone nor auditory information alone can explain the synchronization process. Nonetheless, it seems that visual information plays a dominant role, which is supported by auditory information.

The studies described above illustrate that perception is driven by different sensory information. The state-of-the-art shows that the main focus is on visual aspects. However, an increasing number of recent studies have been conducted on other sources of information, such as auditory cues, which also provide important information for action perception and movement execution. In the context of motor learning, the role of auditory information seems to play an important role. Baudry, Leroy, Thouvarecq, and Chollet showed in 2006 that auditory information during the learning process could be helpful for gymnasts. One could speculate that focusing on the auditory information (e.g., rhythm) makes it easier to develop a representation of the movement. In the track and field, previous studies have highlighted the significance of auditory information and feedback for motor learning, action perception and agent identification (hammer throwers, Agostini, Righi, Galmonte, & Bruno, 2004; hurdling, Kennel, Streese, Pizzera et al., 2015).

It is common ground that different sensory information affects perception. In recent studies, primarily the visual information has been examined. Moreover, the research focus has moved to the auditory sources in different contexts and sports (complex movements) and various domains (e.g., anticipation, agent identification, motor learning). However, it remains unknown how the auditory information is used by people with different sport-specific experiences in gymnastics.

It was hypothesized that the quality of observation and evaluation in gymnastics depends on the expertise of the participants (Heinen, Vinken, & Velentzas, 2012). Overall, it was expected that gymnastics experts (judges/coaches as visual experts and current gymnasts as motor experts) outperform laypeople. It was expected that the manipulated auditory sounds do not influence judges/coaches (visual experts) and that they make decisions primarily based on the visual information rather than the auditory information, even when the auditory information indicates conflicting information caused by the manipulation of the audio file. In contrast, it was expected that the current gymnasts make decisions based on auditory information, even when the visual information indicates conflicting information (Veit & Heinen, 2019).

METHODS

In total, N = 36 participants took participated in this study (age range 19-36; M_{age} ± SD = 28 ± 4 years). The recommended number of participants was derived from a power analysis (Cohen's f = 0.25, type-I-error probability = 5%, type-II-error probability = 20%). The participants were assigned to one of three groups based on their motor and visual experience and expertise in gymnastics: group 1 - neither motor nor visual expertise with the experimental task (n_1 = 12 laypeople), group 2 - extensive visual experience with the motor task (n_2 = 12 judges/coaches), and group 3 - extensive motor expertise with the motor task at the time of the study (n_3 = 12 current gymnasts).

The laypeople were defined as people having no or only minor experiences with watching or performing gymnastics. The judges and coaches had substantial experience (at least seven years) in observing, coaching and judging gymnastics skills in general and with the experimental task used in this study in particular. The current gymnasts (motor experts) were able to perform the acrobatic series (see below) on the floor at the present time and had at least ten years of gymnastics experience in general, particularly in performing a round-off, followed by a back handspring and a straight-back somersault on the floor.

None of the participants reported having any hearing disorders or corrected-to-normal vision. They were furthermore informed about the procedure and aim of the study and gave their written consent before the beginning of the study. The study was conducted in line with the ethical guidelines of the local ethics committee.

The experimental task of the study was to observe an acrobatic series on the floor. The series comprised three gymnastics elements, namely a round-off, followed by a back handspring, and a straight-back somersault (George, 2010). The series was performed on a standard gymnastics spring floor, and these elements constitute a common acrobatic series in floor exercises (Arkaev & Suchilin, 2004). While the round-off followed by a back handspring function as preparatory elements (i.e., the generation of angular momentum towards the take-off of the somersault), the straight-back somersault is usually characterized by maximization of flight duration and an optimization of angular momentum (Prassas, Kwon, & Sands, 2006). During the flight phase, gymnasts perform a rotation of 360 degrees in a straight body posture about the somersault axis before landing on the ground.

Prior to data acquisition, ten female expert gymnasts were asked to perform the acrobatic series six times. Their performances were videotaped with a Full-HD digital video camera recording data at 240 Hz. The camera was placed orthogonal to the execution direction at a distance of approximately 15 meters. From the recorded video sequences, six were selected for further stimulus generation. The selection was made based on there being little background noise and clear natural thumping sounds when the individuals made contact with the floor. The thumping sound was the result of the gymnasts contacting with the floor when performing the acrobatic series.

The recorded video sequences were digitized frame by frame using the movement analysis system Simi Motion® version 9 (Simi Reality Motion Systems GmbH, Munich, Germany). Coordinates of 14 body landmarks corresponding to the joints of a ten-segment model of the human body were digitized for each frame of the video sequences (Enoka, 2008). For each digitized video sequence, a stick-figure video sequence was generated, consisting of a black stick-figure in front of a gray background and a straight horizontal line that represented the floor (see Figure 1 as an example). This was done to mask the personal characteristics of the gymnasts, making it easier for the participants to focus on the movement information instead of the surface characteristics, such as the leotard color and background objects. In addition, the stick-figures were scaled to the same size. The audio information from the original video file was added to the stick-figure video sequences.

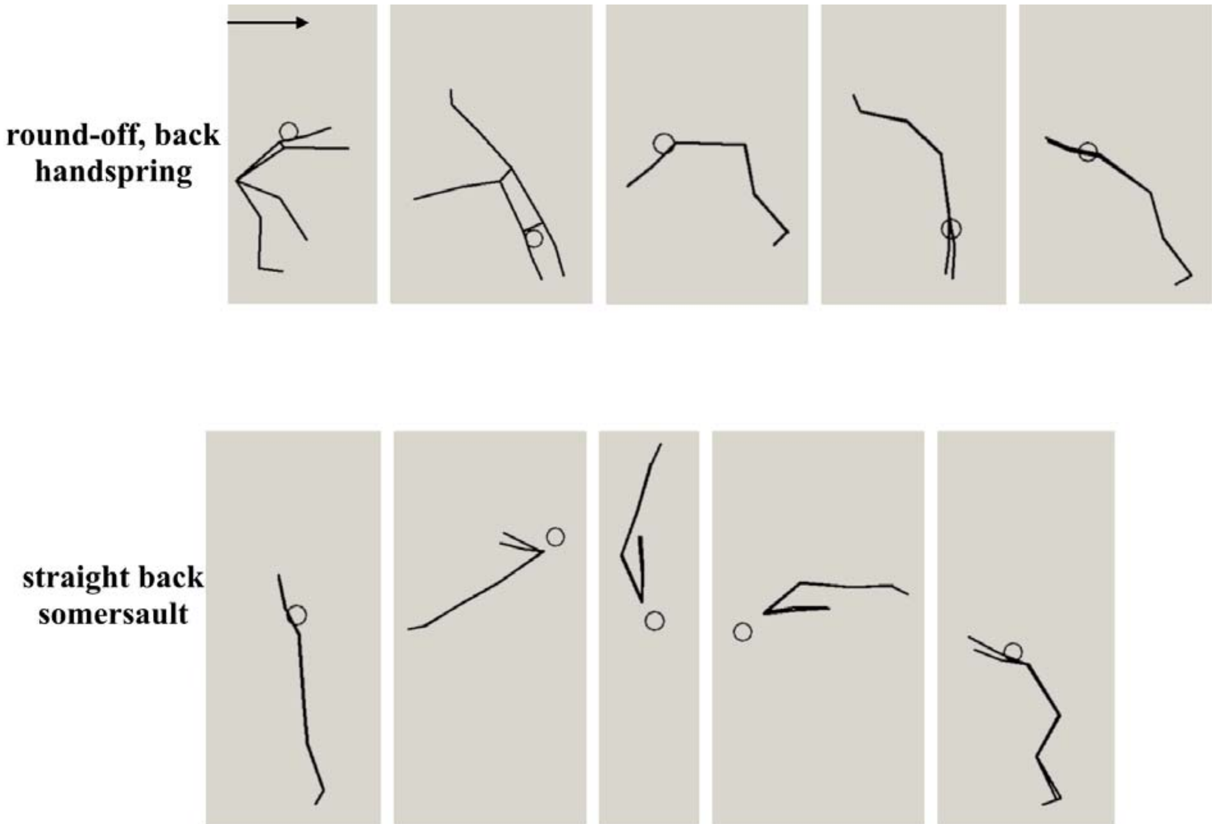


Figure 1. Stick-figure sequence of the motor task (round-off, back handspring and straight-back somersault).

From each original stick-figure video sequence, two additional and modified versions were created using the software iMovie (version 10.1.14, © 2001-2019 Apple Inc.). The natural movement sound from the take-off of a straight-back somersault on the floor was manipulated (+23%, -23% loudness) to generate the different conditions. In one version, the loudness of the original audio information was increased by 23%, while in the second version, the loudness was decreased by 23%. Twenty-three percent was chosen because it was the percent of change that was not noticeable according to previous pilot-studies and expert evaluations. At the end of the aforementioned process, every stick-figure sequence was available in three different versions (original, +23% loudness, -23% loudness).

For example, in the unchanged version, one of the longest somersaults had a flight duration of 0.77 seconds and a short-term loudness during the take-off of -29.6 LUFS (loudness unit), while one of the shortest somersaults had a flight duration of 0.62 seconds and a short-term loudness during the take-off of -34.7 LUFS.

The participants' task was to observe stick-figure video sequences of the acrobatic series (described above). The stick-figure sequences were presented in pairs on a 27-inch computer screen with one sequence in the upper part of the computer screen and the other sequence in the lower part of the screen (see Effenberg, 2005, and Kennel et al., 2015 for a similar approach). Auditory information for the stick-figure sequences was played via a Sony MDR-XB950AP headphones (Sony Corporation, Tokyo, Japan) that the participant wore while completing the task. The experimental task was to correctly identify the straight-back somersault video with the longer flight phase. Thus, after watching the two stick-figure videos, the participants had to select one of the three response options: 1. The upper stick-figure sequence comprised a straight somersault with the longer flight phase than did the bottom one, 2.) the bottom stick-figure sequence comprised the straight somersault with the longer flight phase, or 3.) the upper and lower stick-figure sequence comprised a straight somersault with the same flight duration. The second video-clip was presented two seconds after the first clip, and the next pair of stick-figure sequences were presented after three seconds. In total, the test lasted approximately 25 minutes.

In the current study, five conditions were realized: 1) baseline (auditory information and the video file were unchanged), 2) the loudness of the audio file of the video clip with the longer flight duration was increased by 23% (longer + 23%), 2a) the loudness of the audio file of the video-clip with the shorter flight duration was increased by 23% (shorter + 23%), 3) the loudness of the audio file of the video clip with the longer flight duration decreased by 23% (longer -23%), and 3a) the loudness of the audio file of the video-clip with the shorter flight duration was decreased by 23% (shorter -23%). For the baseline pairs, the longer, the louder-assumption clearly applied. Thus, the video clip with the longer flight duration in the layout somersault always correspondend to the clip with the louder auditory information. However, in conditions 3 and 2a in particular, the aforementioned manipulation of auditory information resulted in conflicting information (i.e., a longer flight phase/lower loudness or shorter flight phase/higher loudness compared to another stick-figure video sequence).

To prevent the position in which the video-clip is presented from affecting the results, every item was presented in the upper part of the computer screen as well as in the lower part. Additionally, the order of the conditions and the order of the trials were randomized. In total, 75 trials were presented to each participant. The center of interest was the participants' choice. For every participant, the ratio of correct decisions was calculated. The ratio of correct decisions per condition was calculated as the sum up of the correct answers from each trial divided by the number of trials per condition. For each condition, every participant was able to make a maximum of 15 correct decisions per condition and a minimum of 0. The participants' answers were recorded by an online questionnaire that they completed on a tablet (see below).

In order to collect the data, an online questionnaire was created. It consisted of a general section comprising demographic questions and a specific section comprising questions related to the participants' specific experiences in gymnastics. In addition to the participant's age and sex, his or her current activity in gymnastics was addressed by the questions. The information about the current activity was addressed in four sections within the specific section of the questionnaire. The current gymnasts had to answer four more questions about their experiences in gymnastics (years that they have been actively practicing, weekly training hours/frequency/amount of training, participation, and level of competitions attended). Coaches and judges had to give information about the amount of coaching or judging they have performed in hours, the level of competitions attended, and whether the floor sequence is an integral part of their training or competitions. At the end of the questionnaire, every participant answered the question on whether they ever performed the sequence on the floor. The third part of the questionnaire was presented to the participants during the experimental task so that the participants' answers for each experimental trial could be recorded.

The study was conducted in three phases and lasted approximately 35 minutes. In the first phase, the participants arrived at the laboratory and were informed about the procedure, the task, and the general purpose of the study. Afterwards, the participants used a tablet to completed the first two parts of the questionnaire, comprising general sociodemographic questions as well as specific questions about his/her experiences in gymnastics as a gymnast, as a coach, or as a judge. After the questionnaire, the participants were shown several exemplary stick-figure sequences so that they were familiarized with the task. After familiarization, the gymnasts had the opportunity to ask some questions.

In the second phase, data acquisition was conducted. After watching a trial, each participant had to choose one of three response options: 1.) the upper video clip showed the longer flight phase, 2.) the lower video clip showed the longer flight phase or 3.) the upper and lower video clips flight phases of the same duration. In total, he/she had to make 78 decisions. At the beginning of the data collection, three additional pairs were shown for the familiarization (see above), and these pairs were not included in the analysis. The subsequent 75 decisions were used for further data analysis. After 40 trials, the participants were given a short break to prevent a loss of concentration.

In the third phase, the effect of manipulation check was verified by asking the participant whether he/she noticed anything abnormal during the data collection. No data had to be excluded because there were no positive response to the manipulation check (meaning none of the participants noticed the sound was manipulated). Finally, he/she received a reward for participating in the study.

The significance level was set at 5% for all results. Before the main hypotheses were tested, whether the data met the assumptions for analysis of variance were determined. The results of the Kolmogorov-Smirnov test and the Mauchly test indicated that the data could be considered normally distributed and that the assumption of sphericity was not violated.

RESULTS

It was hypothesized that the quality of observation and evaluation in gymnastics depends on the expertise of the participants. Overall, the gymnastics experts (judges/coaches as visual experts and current gymnasts as motor experts) were expected to outperform the laypeople. Given the aforementioned hypothesis, it was expected that the manipulated auditory sounds would not influence the decisions of the judges/coaches. They should base their decisions primarily on visual information, even when auditory and visual information is conflicting (e.g., the auditory information is manipulated).

However, the current gymnasts should base their decisions first and foremost on auditory information, even when the visual and auditory information are conflicting. Additionally, it was hypothesized that increasing the loudness of the videos can increase the number of correct decisions.

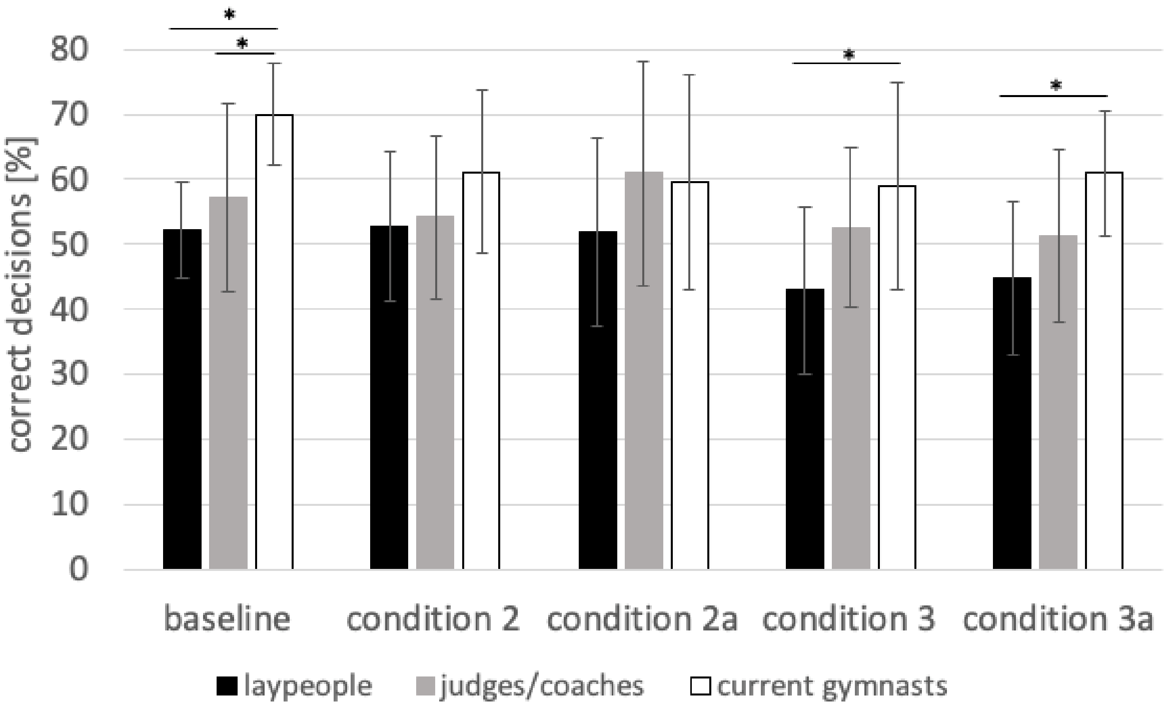


Figure 2. Means and standard errors of the participants' relative number of correct decisions in the experimental conditions.

To test the hypotheses, an analysis of variance (ANOVA) with repeated measures was performed. The decision ratio was included as the dependent variable. The ANOVA results show a significant main effect of condition, $F(4, 132) = 3.143$, $p = .017$, Cohen's $f = 0.31$, as well as a significant main effect of group, $F(1, 3) = 9.375$, $p < .001$, Cohen's $f = 0.75$. There was no significant interaction effect, $F(8, 132) = .874$, $p = .540$. The results suggest different decision ratios across the conditions and between the groups. The post hoc tests demonstrate that the participants made more correct decisions in the baseline condition than in the other conditions. Additionally, the participant's ratio of correct decisions was significantly lower, when the auditory information was manipulated by decreasing the loudness (condition 3 and 3a; $p = .025$; $p = .007$). Interestingly, a close examination of the decision ratios of the groups within the conditions shows that the current gymnasts did not make fewer correct decisions regardless of whether the loudness was increased or decreased. Between groups the ratio of correct decisions of the laypeople was significantly lower than that the current gymnasts. Additionally, there was no significant effect between the judges/coaches and current gymnasts ($p = .075$). A study with a larger sample size should be conducted to determine whether this effect is significant at the significance level of 5%.

DISCUSSION

The aim of the current study was to investigate the role of visual and especially auditory information in the observation and evaluation of complex skills in gymnastics. The participants had to evaluate the duration of the flight phase of somersaults as the last element in an acrobatic series on the floor. The participants differed in their expertise in gymnastics (laypeople with no experience in gymnastics, coaches/judges as visual experts, current gymnasts as motor experts). The natural movement sound from the take-off of a straight-back somersault on the floor was manipulated (+23%, -23% loudness), to generate different testing conditions.

The results show that participants without any specific experiences in gymnastics performed worse than did the participants with visual or motor experiences, which is in line with the results of previous studies (Pizzera & Raab, 2012). In total, the ratio of correct decisions in the evaluation of the duration of straight-back somersaults was the highest in the current gymnasts (motor experts), but only the difference between the laypeople and current gymnasts was significant. Regarding whether there is a weighting of motor or visual expertise in the evaluation of complex skills, a conclusion cannot be made from these results. The ratios of correct decisions illustrate that specific experiences are essential, but neither the visual experts nor the motor experts had a significantly different number of correct decisions. If there was be a significant difference in the decision ratios between the current gymnasts and the judges/coaches, one would be able to identify a weighting of motor or visual expertise.

Following the common-coding idea of Prinz (1997), perception and action possess shared representations. One could speculate that current gymnasts benefit from their motor experiences, which lead to improved perceptual sensitivity and a better ability to identify differences between two cues. When taking into account the above calculated statistical trend, the current gymnasts did outperform the visual experts. Regarding the conditions, it is noteworthy that the quality of observation and evaluation of the duration of straight-back somersault were relatively consistent.

To determine whether there is a weighting of visual or auditory information, the auditory information was manipulated. There were no significant differences between the groups within conditions 2 and 2a (increased loudness). One could speculate that the auditory information strengthens the differences between two flight phases, which makes it easier for participants to identify discrepancies independent of their experience level, leading to more correct decisions. More specifically, auditory information supports visual information (Eysenck & Keane, 2010). It is noteworthy that current gymnasts significantly outperformed the laypeople (and significant tendency to the judges/coaches) within condition 3 and condition 3a (decreased loudness). This result might, in part, be explained by the auditory information ceasing to support the visual information, making it more challenging to identify the differences between two cues; thus, the participants had to rely on their experiences. According to the common-coding theory (Prinz, 1997), the common codes of motor experiences and perceptual experiences may be useful for the observation and evaluation of the duration of straight-back somersaults. It seems that the motor experiences of the current gymnasts are supportive for the observation and evaluation of the duration of straight back somersaults. Additionally, conditions 3 and 2a included trials with conflicting information, so perceptual sensitivity was challenged when the participants evaluated the flight durations. However, there may be a task-specific effect because the current gymnasts were able to perform the acrobatic series at the time of the investigation.

It is acknowledged that this study has several limitations, and two aspects should be highlighted. First, gymnasts, judges and coaches usually do not have to judge or evaluate stick figures, which were used as experimental stimuli in this study. However, stick figures were used to control the surface characteristics, which is nearly impossible when actual video sequences are used. Nevertheless, one could speculate that the unusual stimuli may have influenced the decision ratios. Nevertheless, none of the participants reported being disturbed by the video format used in the current study.

Second, judges (especially in female gymnastics) usually do not hear the natural movement sound as precisely as it was presented to them in the study. However, this was done to evaluate the role of auditory information when they observed gymnastics skills. Nevertheless, additional studies on the different components of the auditory information that correspond to the gymnastics apparatuses (i.e., amplitude, frequency) should be conducted.

CONCLUSION

According to the current results, one could conclude that current gymnasts weigh visual and auditory information differently than do judges/coaches. Therefore, it may be enriching to complement visual/verbal feedback with auditory feedback (Kennel, Streese, & Pizzera et al., 2015). Therefore, sensitization for gymnasts (the use of auditory information) and coaches (for different learning types) may be beneficial.

Additionally, judges of women's gymnastics routines on the floor do not typically hear natural movement sounds (depending on the competition area, level, etc.). Furthermore, it would be interesting to determine whether a "perfect fit" of music and acrobatic or gymnastic series on the floor influences the perception and, consequently, the evaluation of complex skills in gymnastics. A potential task may be to ask judges to evaluate different series on the floor (acrobatic series and gymnastic jumps and leaps) that are additionally manipulated. There exists the possibility that increased or coordinated music during the takeoff or reactive leap of a somersault by a kick drum, for example, influences judges' perception of flight phases or movement amplitudes.

ACKNOWLEDGEMENTS

The author thanks the judges, coaches, gymnasts and laypeople for participating in the study.

REFERENCES

Abdi, H., & Williams, L. J. (2010). Tukey's Honestly Significant Differences (HSD) Test. In N. Salkind (Ed.), *Encyclopedia of Research Design* (pp. 1-5). Thousand Oaks, CA: Sage.

Agostini T., Righi, G., Galmonte, A., & Brino, P. (2004). The relevance of auditory information in optimizing hammer throwers performance. In B. Pascolo (Ed.), *Biomechanics and sports* (pp. 67-74). Vienna, Austria: Springer.

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

Baudry, L., Leroy, D., Thouvarecq, R., & Chollet, D. (2006). Auditory concurrent feedback benefits on the circle performed in gymnastics. *Journal of Sport Sciences, 24*(2), 149-156.

Effenberg, A. O. (2005). Movement sonification : Effects on perception and action. *IEEE Multimedia*, *12*(2), 53–59.

Enoka, R.M. (2008). *Neuromechanics of Human Movement* (4th ed.). Champaign, IL: Human Kinetics.

Eysenck, M. W., & Keane, M. T. (2010). *Cognitive psychology. A student's handbook* (6th ed.). Psychology Press, Hove, East Sussex, UK.

George, G.S. (2010). *Championship gymnastics: biomechanical techniques for shaping winners*. Designs for Wellness Press, Carlsbad, CA.

Heinen, T., Vinken, P. M., & Velentzas, K. (2012). Judging performance in gymnastics: A matter of motor or visual Experience? *Science of Gymnastics Journal, 4*(1), 63–72.

Heinen, T., Koschnick, J., Schmidt-Maaß, D., & Vinken P. M. (2014). Gymnasts utilize visual and auditory information for behavioural synchronization in trampolining. *Biology of Sport, 31*, 223-226.

Hommel, B., (2019). Theory of event coding (TEC) V2.0: Representing and controlling perception and action. *Attention, Perception, & Psychophysics 81*(7), 2139-2154.

Kennel, C., Streese, L., Pizzera, A., Justen, C., Hohmann, T., & Raab, M. (2015). Auditory reafferences: the influence of real-time feedback on movement control. *Movement Science and Sport Psychology, 6*(69), 1-6.

Mann, D. T. Y., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport and Exercise Psychology*, *29*(4), 457-478.

Pizzera, A. (2012). Gymnastic judges benefit from their own motor experience as gymnasts. *Research Quarterly for Exercise and Sport, 83*(4), 603-607.

Pizzera, A., & Raab, M. (2012). Perceptual judgments of sports officials are influenced by their motor and visual experience. *Journal of Applied Sport Psychology*, *24*(1), 59–72.

Pizzera, A., Möller, C., & Plessner, H. (2018). Gaze behavior of gymnastic judges: where do experienced judges and gymnasts look while judging? *Research Quarterly for Exercise and Sport, 89*(1), 112-119.

Prassas, S., Kwon, Y.-H., Sands, W. A. (2006). Biomechanical research in artistic gymnastics: a review. *Sports Biomechanics, 5*(2), 261-291.

Prinz, W. (1997). Perception and action planning. *European Journal of Cognitive Psychology*, *9*(2), 129–154.

Simi Motion ® (Version 9) [Computer software]. Munich, Germany: Simi Reality Motion Systems GmbH.

Stauffer, C. C., Haldemann, J., Troche, S. J., & Rammsayer, T. H. (2012). Auditory and visual temporal sensitivity: evidence for a hierarchical structure of modality-specific and modality-independent levels of temporal information processing. *Psychological Research*, *76*(1), 20-31.

Ste-Marie, D. M. (1999). Expert-novice differences in gymnastic judging: An information-processing perspective. *Applied Cognitive Psychology 13*, 269-281.

Veit, F., & Heinen, T. (2019). The role of visual and auditory information in the observation and evaluation of complex skills in gymnastics. *Journal of Physical Fitness, Medicine & Treatment in Sports*, *6*(2), 1-7.

Corresponding author:

Frederike Veit
Leipzig University
Faculty of Sport Science
Jahnallee 59, 04109 Leipzig,
Germany
e-mail: frederike.veit@uni-leipzig.de
phone number: +49 (0) 341 97-31709

PHYSIOLOGICAL AND ANXIETY RESPONSES TO SOCIALLY PRESCRIBED PERFECTIONISM FOR GYMNASTIC COMPETITION: CASE STUDY

Antonio Pineda-Espejel, Marina Trejo, Lucía Terán, Lourdes Cutti, Edgar Galarraga

Facultad de Deportes, Universidad Autónoma de Baja California, México

Case study

Abstract

The purpose of this study was to analyze the psychophysiological responses (anxiety, cortisol, heart rate, skin conductance) to acute psychological stress during a visualization of competition, under the influence of pressure for perfection exerted by parents, and pressure for perfection exercised by the coach. Artistic gymnasts (3 men and 3 women) with an age range of 13 to 15 years participated, who were present in four sessions for data collection that included salivary cortisol, heart rate and skin conductance. The first session was the baseline, where we apply a booklet of questionnaires that inquire about competitive anxiety and pressure for perfection. The remaining three sessions included guided viewing; session two to create mental images and live the gymnastic competition; the third highlights the pressure for perfection created by the coach (PPE); and the fourth highlights the pressure for perfection created by parents (PPP). The results showed that the visualization of competitive situation causes stress and anxiety, although the increase in salivary cortisol was within the normal daytime level. The physiological changes were greater in those gymnasts who perceived high PPE and PPP. However, for some gymnasts the situation was considered threatening (decrease in skin conductance, and small increases in heart rate), and for others was challenging (increase in skin conductance and heart rate). In conclusion, the pressure for perfection integrates a link for the different physiological responses in competition.

Keywords: *stress, interpretation, perfectionism, parents, coach.*

INTRODUCTION

Artistic gymnastics is a sport where you start at an early age, taking part in competitions of different demands in a vulnerable period such as adolescence, where gymnasts are exposed to high levels of physical and psychological stress during numerous hours of training, and number of competitions.

The competition is a situation of social evaluation of the actions, where the result is unpredictable, sometimes the situation is unstable, and the pressure to obtain a good result is present. The competition itself is a source of psychophysical activation and, eventually, stress (Núñez & García, 2017). Stress is suffered by athletes in precompetitive situations and during the competition (Jones & Hardy, 1990), which can lead to lack of concentration, tremor, restlessness, or sweating, symptoms that affect athletic performance.

Stress is a psychosocial process that involves the perception of abilities to self-regulate personal factors, and the perception and interpretations of contextual factors. The stress response depends on how events are interpreted (Salvador, 2005). The interpretation can be like a threatening situation, which involves the assessment of the potential for damage or loss; or as a challenging situation, when it considers that the event is controllable, that it depends on its effort, and is evaluated as opportunities to grow (Lazarus, 1999; Salvador, 2005). So that, stress can also be positive, preparing the body to maintain greater attention span. (Ferreira, Valdés & González, 2002). The interpretation as a threatening situation is associated with increased cortisol, small increases in cardiac activity, stable peripheral vascular resistance, and emotions perceived as harmful (Jones, Meijen, McCarthy & Sheffield, 2009; Salvador, 2005; Seery, 2011). An answer to the threatening situation is anxiety, defined as an emotional state of nervous tension and intense fear, characterized by somatic symptoms such as tremor, restlessness, sweating, hyperventilation, palpitations, whose cognitive symptoms are psychic restlessness, hypervigilance, loss of concentration and distortions Cognitive (Saz, 2000).

On the other hand, salivary cortisol is a steroid hormone produced in the hypothalamic-pituitary-adrenal axis (HPA) that is secreted in saliva, especially when people are stressed (Aguilar et al., 2014). Then, cortisol is one of the indicators of physical and psychological stress (Boudarene, Legros & Timsit-Berthier, 2002), both in children and adolescents (Aguilar et al., 2014). The cortisol elevation derives from the stimulation of the HPA axis, indicating experiences of stress and / or physical exertion (Salvador & Acosta 2009). The competitive situation provides the potential for these conditions (Cerin, Szabo, Hunt & Williams, 2000). For example, Kim, Chung, Park & Shin (2009) obtained significant differences in the cortisol concentration between the baseline (one day before the competition) and the precompetitive moment (30 minutes before the competition) in golfers.

Filaire, Alix, Ferrand & Verger (2009) suggested a possible relationship between cortisol concentration, state anxiety, and sports physical performance, since this hormone influences decision making, attention, or memory, by inhibition in the process of information (Lautenbach & Laborde, 2016). While Robazza et al. (2018) confirmed that the increase in cortisol levels is related to high cognitive anxiety (visual attention, mental attention, memory).

On the other hand, situational demands choose whether it is a threatening or challenging interpretation (Lazarus, 1999), so that in sports stressors can be physiological and psychosocial, since sport competition involves the comparison of efforts between the best and worst athletes, while being subject to classification and social evaluation. This social evaluation, and the uncertainty of the result in competition can generate anxiety, so that competitive anxiety is also influenced by factors of a social nature.

Based on multidimensional theories of perfectionism (Frost, Marten, Lahart & Rosenblate, 1990; Hewitt & Flett, 1991), the competition provides a situation with high levels of socially prescribed perfectionism, which includes high goals in which the person has little control, that is, to pursue goals imposed by others (Hewitt & Flett, 1991); Therefore, it is related to negative consequences (Stoeber & Childs, 2010), considering it as a facet of perfectionism that is not very adaptive (Stumpf & Parker, 2000).

According to Frost, Marten, Lahart and Rosenblate (1990), Dunn, Dunn and Syrotiuk (2002) and Stoeber, Otto and Stoll (2006), those who can impose those goals unlikely to achieve on the sport, are parents and coach, suggesting the facets of pressure for perfection on the part of the parents, and pressure for perfection on the part of the coach. For these authors, the facet of pressure for perfection, represents the perception of the athlete that their parents or coach set high goals, even impossible to achieve (expectations), and that are very critical, or exert a lot of pressure to achieve those goals or obtain a certain level of performance (criticism).

Parents and coaches can be a source of stress and anxiety (Brustad, Babkes & Smith, 2001). Outside the sports field, research indicates that socially prescribed perfectionism is related to anxiety (Hewitt & Flett, 2002); but also with happiness (Stornelli, Flett & Hewitt, 2009). In the sports field Ivanović, Milosavljević and Ivanović (2015) with youth athletes, they found that little adaptive perfectionism is related to somatic and cognitive anxiety, and negatively with self-confidence, indicating that perfectionism is an important variable that explains anxiety in sport and athletic achievement in adolescence. Dunn, Gotwals, Causgrove and Lizmore (2019), in their study carried out 24 hours before starting an important competition, found that a slightly adaptive profile of perfectionism (high efforts and high concerns) is related to concern (cognitive anxiety indicator) in young soccer players.

On the contrary, Donachie, Hill and Hall (2018), in their study carried out between 45 minutes and 120 hours before a competition with teenage soccer players, showed that socially prescribed perfectionism is not related to anxiety. Likewise, the perception of pressure for perfection by coaches and parents is related to the fear of uncertainty, and fear of evaluation and failure (indicators of cognitive anxiety) in young soccer players, although to a greater extent the pressure for the perfection of the coach (Dunn et al., 2019).

Although certain sports require athletes to achieve perfect executions, the tendency to be cognitively concerned with improvement, often undermines performance and fosters a sense of dissatisfaction with one's performance (Flett & Hewitt 2005). Miller, Chen and Cole (2009) point out that it is necessary to analyze the relationships between social context and stress. Since it is necessary to identify factors that explain the differences between athletes in their competitive emotions (Donachie et al., 2018), because psychophysiological stress factors are related to performance during the competition (Mckay, Selig, Carlson & Morris, 1997).

To date there are few studies that analyze biopsychological states of stress, and their alterations in situations under pressure due to perfection in competition, and studies that analyze the effect of pressure for perfection by parents are scarcer. Therefore, it is necessary to identify how social factors affect the competitive stress response. To do this, we rely on the biopsychosocial model of challenge and threat (Blascovich, 2008) that integrates the biological (endocrine and autonomous influences on the cardiovascular system), psychological variables (affective and cognitive influences on the evaluation process), and the social aspect (i.e. environment).

In this sense, we measure biopsychosocial states, through objective (physiological) and subjective (psychological) indices, with the purpose of analyzing psychophysiological responses (anxiety, cortisol, heart rate, skin conductance) to acute psychological stress during visualization of competition, under the influence of pressure for perfection exerted by parents, and pressure for perfection exerted by the coach.

It is hypothesized that the visualization of competitive situation will cause physiological changes (cortisol, heart rate, skin conductance), and psychological changes (anxiety), and that the physiological changes will be more evident under high pressure perception for the perfection of the coach, and high perception of pressure for the perfection of the parents.

METHODS

The sample consisted of seven youth artistic gymnasts (3 men and 4 women), with an age range of 13 to 15 years (M = 14.2 years; SD = 1.09). They were participants of the gymnastics team of the Autonomous University of Baja California, with several years of training (M = 7.20 years; SD = 2.38), and a large amount of daily practice (M = 4 hours; SD = 1.5). Since one of the participants, registered with the number 1, only attended the first session, was excluded from the study, leaving an effective sample of six gymnasts.

The gymnasts completed a sociodemographic questionnaire that compiles information related to the participant (age, sex), sports training (age at the start of training, days of weekly training, hours of daily training), and clinical history. In the case of women, a section of gyneco-obstetrics antecedents (age of menarche, menstrual cycle, and alterations thereof) was included.

The "trainer pressure" subscale of the Multidimensional Inventory of Perfectionism in Sport, Spanish version (MIPS; Pineda-Espejel, Arrayales, Castro, Morquecho, Trejo, Fernández, 2018) was used to measure the pressure for perfection by the coach (PPE). It consists of six items, which are answered on a six-point Likert scale, ranging from never (1), to always (6).

The subscale "parental pressure" of the Multidimensional Sport Perfectionism Scale-2, Spanish version (S-MPS-2; Pineda-Espejel, Morquecho-Sánchez & Gadea-Cavazos, 2018) was used to measure the pressure for perfection by parents (PPP). It consists of nine items that are answered with a 5-point Likert scale, ranging from totally disagree (1), to totally agree (5).

To measure competitive anxiety, the Competitive State Anxiety Inventory-2 Reviewed, Spanish version was used (CSAI-2R; Pineda-Espejel, López-Walle & Tomás, 2014), which consists of 17 reagents distributed in three factors: somatic anxiety with 7 reagents, cognitive anxiety with 5 reagents, and self-confidence with 5 reagents. They respond with a four-point Likert scale, ranging from nothing (1), to much (4).

For the recording of the physiological variables a digital stress thermometer was used, stress Market, Inc., which measures the skin conductance (SCL); it was placed on the middle finger of the left hand. To measure the heart rate (TD), a Zondan bar oximeter model FAIRY A5 was used, placed on the left index finger. For the collection of saliva, sterile transparent propylene tubes with a cap were used, with a capacity of 2 ml SalivaBio Saliva Collection Aid and Cryovials, Salimetrics.

The approval of the institutional ethics committee was obtained before carrying out the study. First, a presentation was made with the gymnastics and technical teams, so that they would know the general objectives pursued by the study. According to the declaration of Helsinki, the informed consent of parental involvement was obtained. All gymnasts participated voluntarily, and were treated according to the ethical guidelines for human research given by the American Psychological Association (APA).

Then, the dates for the administration of the tests were specified. At first, a semi-structured interview was carried out to collect personal and health data. The instruments that measure pressure for perfection were applied, and from that information, two subsequent visualization sessions (sessions 3 and 4) were carried out.

With the intention of obtaining information on the different variables of the same group of gymnasts, and for subsequent analysis of the changes produced, four sessions of psychophysiological records were performed, taking salivary cortisol measurements, heart rate (TD), and the conductance level of the skin (SCL). In all cases salivary cortisol was collected at the same time of day (16 hours), to eliminate the circadian variation of cortisol. In the case of women, all measurements were programmed in days within the luteal phase, to decrease the noise of SCL associated with the menstrual cycle.

The first session was held on a normal training day, and before starting it in a rest situation. This was considered as baseline.

The second session used guided visualization or mental imagery, applying the technique individually in a reposet chair. The participants were asked to close your eyes to allow to enter a state of comfort and readiness for the visualization technique (Rodríguez & Galán, 2007). They were also asked to concentrate on breathing and the sensation produced by each inhalation and exhalation, as a preamble of generating the optimal state to create the mental images of the place he chose to live the competition (Rodríguez & San Juan, 2005), and thus begin to transform the scenario, and facilitate creating a mental screen as similar to the last one competitive moment, with images of places, things, feelings, sensory experiences and physiological responses that the gymnast experience; this in order to develop direct mental images and the most natural and spontaneous sensory responses possible, as allowed by their mind (Amasiatu, 2013). They were invited, through your creativity, to generate the stage through as clear and real mental images as possible, they was requested to place their self at the time of transfer to the place of competition, observe their arrival and travel to the place (Moreno, Ávila & Damas, 2001), personal belongings, the people who accompany them, the team and the coach; how, through the door, there are several elements and stimuli that attract their attention, how its impact when they notice them, and what sensation it produces until they reach the area that corresponds to they to prepare to be called to compete in the apparatus that represents the most challenge to execute. The athlete was asked to observe what it is like to enter the routine, develop and finish it, as well as waiting for grades.

The duration of the visualization was an approximate time of 35 to 40 min per individual session. At the end of each session, the gymnast is asked to return his attention to breathing, the natural movements of his body, and to feel the chair, his posture and the voice of the guide, until he is aware of the space to slowly open his eyes (De La Cuadra, 2013). TD and SCL were measured once the stimulus started. While salivary cortisol was taken after visualization. Only in this session, each participant answered the CSAI-2R after collecting the saliva.

The third session followed the same procedure mentioned above. Here the purpose is to pay attention to the presence of the coach and what this implies in the gymnast's dynamics; in the participation of its guided visualization, the pressure for perfection on the part of the coach during the arrival, the start of the competition, in the execution, and at the end of the routine is highlighted. The above, according to the individual responses given in the MIPS.

The fourth session performs the same procedure outlined above, we asked to focus attention within their imagination guided to the parents figure; how they perceive the pressure for the perfection of their parents before, during and at the end of the visualization of competition. The above, according to the individual responses given in the S-MPS-2.

The measurement of HPA activation, which measures stress, can be performed non-invasively through the collection of cortisol in saliva using the ELISA method (Mandel, Ozdener & Utemohlen, 2011). The salivary sample of steroid hormones may reflect the amount of free hormones in circulation, which are more desirable than the total circulating levels (Lewis, 2006). This route makes it possible to obtain parental authorization and cooperation of the child without difficulty. Likewise, the saliva sample provides a valid and reliable indicator of cortisol not bound to the plasma (Cadore et al., 2008).

In order to collect saliva samples, the criteria established by the Salimetrics Saliva Collection and Handling Advice (Salimetrics, 2015) were taken into account. Before taking saliva samples, the subjects were asked not to consume food 60 minutes before the sample was collected and not to brush or brush their teeth 3 hours before the sample was to be collected. The passive expectoration technique was used, which consisted of the subjects having to rinse their mouths with water for 10 seconds and then evacuate the contents, the participants were asked to wait for 10 minutes without speaking, this so that the water they used did not dilute the saliva, the subjects were subsequently told to remain relaxed and sit with their head tilted forward trying to collect as much saliva as possible from the sublingual area of the mouth, this for two minutes without doing any kind of stimulation and performing the minimum possible orofacial movement. At the end of the 2 minutes, the collection tube was provided to the subjects, and they were asked to deposit the saliva into the tube. 0.5 to 1 milliliter of saliva were collected from each subject. Once the sample was collected, it was frozen at 80º C.

The data collection was carried out in the exercise physiology laboratory of the Faculty of Sports, which was found at a temperature of 25°C, with noises as fans. Coaches and parents were not present in the data collection.

RESULTS

Table 1 presents the internal consistency of the instruments (Cronbach's alpha), the means and typical deviations obtained in the measured variables, as well as the correlation between them. The reliability for all the variables measured by the instruments was adequate. From the nominal midpoint of the response scale of the instruments, it is noted that the sample reflected moderate PPP, PPE, moderate high cognitive anxiety and self-confidence, as well as high somatic anxiety. Likewise, PPP correlated significantly with somatic anxiety, and PPE did so with cognitive anxiety.

From the scores of the physiological variables in the different phases of the study (baseline, competition, influence of PPP, and influence of PPE), the values in each variable were analyzed individually. Figure 1 shows salivary cortisol levels in each phase. For these ages, the normal daytime range is <0.25 µg/dL (Salimetrics, 2015). Therefore, only two subjects showed physiological stress response, one before the PPE, and another subject before the PPP.

Figure 2 shows the behavior of the SCL for each subject at different times of taking. Values near or above 90º F indicate absence of anxiety, and values near or below 75.8º F indicate a state of anxiety. Thus, participants 2, 3 and 4 expressed anxiety in the competition, and participants 3 and 4 did so during the PPE and PPP.

Figure 3 shows the change of TD at the different times of shooting. In this case, the increase in TD with respect to the baseline measurement, indicates the challenging perception of the stress situation, while small increases suggest a threatening perception.

Additionally, the minimum appreciable change was analyzed, by Cohen's d, of salivary cortisol, TD and SCL levels, between the competitive situation and the competitive situation emphasizing the pressure for perfection by the coach (Cohen's d = -1.22; r = -0.52), and between the competitive situation and the competitive situation emphasizing the pressure for perfection by the parents (Cohen's d = -1.3; r = -0.54). These results revealed extremely large appreciable changes (> .90; Hopkins, Marshall, Batterham & Hanin, 2009). In contrast, the appreciable changes for TD were moderate (d <.30), and small (d <.10) for SCL between the two comparisons.

To help understand these results, Figure 4 shows the individual levels of pressure perception for perfection by the coach and parents, where participants 2, 4 and 6 clearly present high PPE, and participants 4, 6 and 7 high PPP.

Table 1
Reliability, descriptive statistics, and Pearson's correlation matrix of the study variables.

	Range	*M*	*DT*	1	2	3	4	5
1 PPP	1-5	2.90	0.76	(.83)				
2 PPE	1-6	3.54	1.27	.65	(.91)			
3 Somatic anxiety	1-4	3.02	0.29	.90*	.74	(.90)		
4 Cognitive anxiety	1-4	2.76	0.45	.80	.91*	.81	(.87)	
5 Self-confidence	1-4	2.84	0.49	-.21	-.31	-.50	-.65	(.74)

Note. *$p < 0.05$; PPE: perception of pressure for perfection by the coach; PPP: perception of pressure for perfection by parents; reliability in brackets.

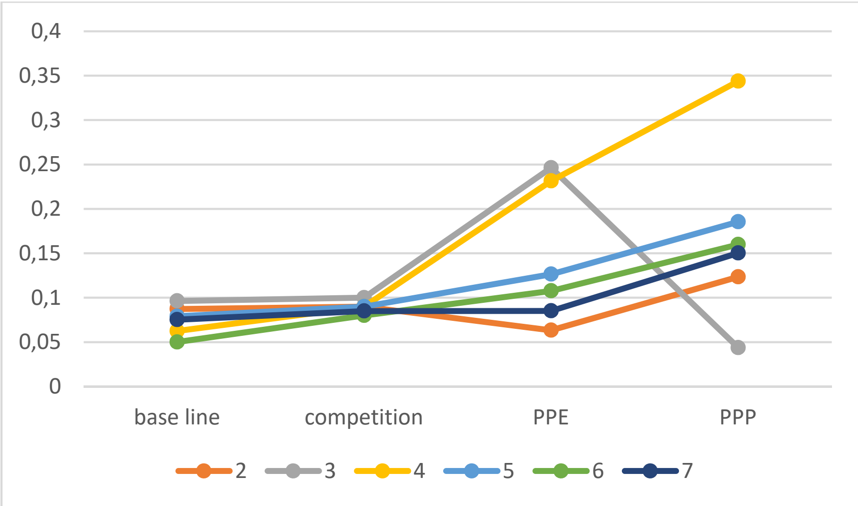


Figure 1. Salivary cortisol concentration in the four different measurement sessions.

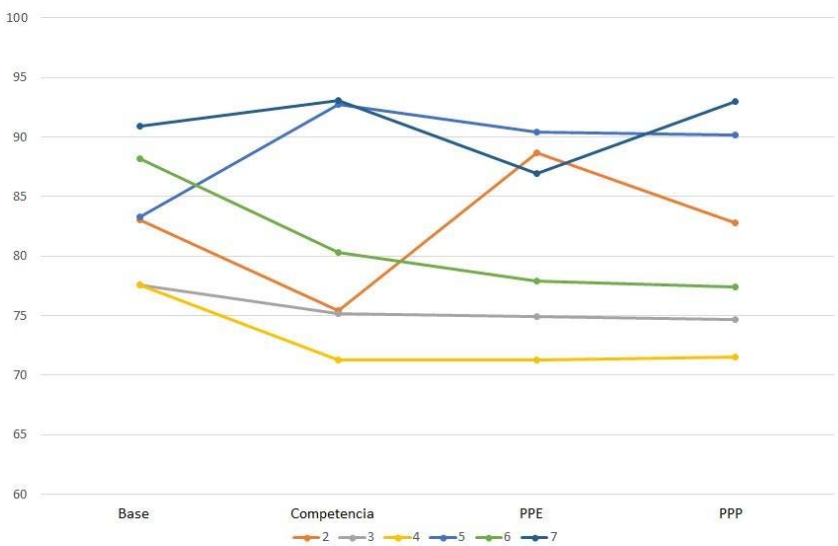


Figure 2. Skin conductance level (SCL) in the four different measurement sessions.

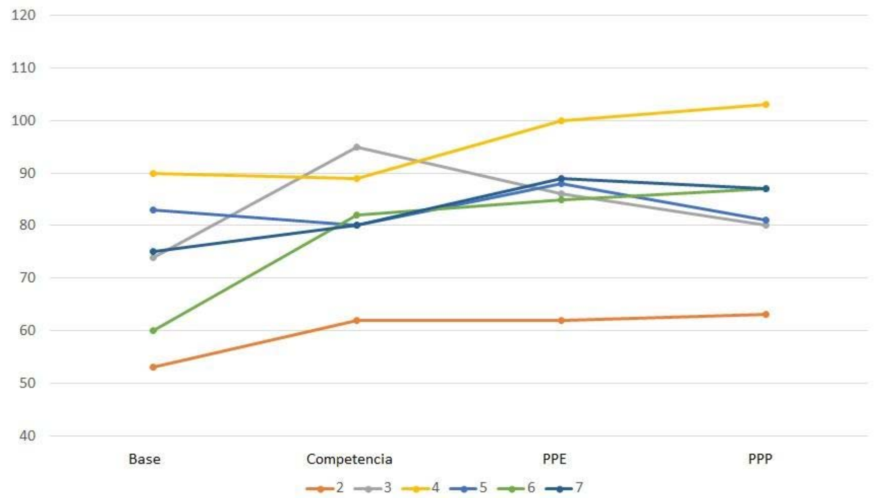


Figure 3. Heart rate (TD) in the four different measurement sessions.

Figure 4. Levels of pressure for perfection perceived by the athlete

DISCUSSION

This case study was carried out in adolescent gymnasts, with the aim of analyzing the psychophysiological responses (anxiety, cortisol, heart rate, skin conductance), before acute psychological stress during a visualization of competition, under the influence of pressure by the perfection exerted by parents, and pressure for perfection exerted by the coach.

The results reflect that, during a visualization of gymnastic competition, anxiety (somatic and cognitive) is present, since the average anxiety score in the sample was above the nominal average value of the test response scale of pencil and paper. On the other hand, salivary cortisol levels increased compared to the baseline, although this increase was not above normal daytime range values. This, more than stress, suggests effort, since it involves little increase in cortisol (Lundberg & Frankenhaeuser, 1980). However, this result should be taken with caution, since Passelergue, Robert and Lac (1995) and

Crewther, Heke and Keogh (2011), showed that salivary cortisol increases are lower in a simulated competition, compared to a real competition.

In this sense, if gymnasts experience anxiety, then they are more likely to be distracted, and to perceive that energy as unpleasant (Vast, Young & Thomas, 2010), which is associated with sports performance (González, Garcés de los Fayos & Ortega, 2014). However, when analyzing the results individually, on par with physiological indicators such as salivary cortisol, TD and SCL, supported by Salvador (2005), Jones et al. (2009) and Seery (2011), it can be inferred that for some gymnasts (subjects 3 and 5) the competition was interpreted as challenging, as it is accompanied by increased heart rate. In this case, emotions help performance, being a functional stress, which appears as an element that facilitates action (Monasterio et al., 2016). While for other gymnasts (subjects 4 and 6) it is interpreted as threatening (decrease in SCL, and tendency to maintain stable TD), suggesting that they perceive that the demands of the competition exceed their resources, or put the status at risk social (Taylor, Papay, Webb & Reeve, 2016).

The fact that the stressful situation can be considered as a challenge rather than a threat may be due to self-confidence (Nicholls & Polman, 2007), as this helps to perceive anxiety symptoms as facilitators (Guillén & Sánchez 2009; Neil, Wilson, Mellalieu, Hanton & Taylor, 2012). Thus, high conviction that the required behavior can be executed successfully and produce a result can reduce psychological stress, evidenced in subjects 3 and 5, whose self-confidence score was above the midpoint of the scale of response.

On the other hand, in those gymnasts who perceive that their coach imposes high perfect unrealistic expectations performance standards on them, which criticize them when they fail, or press them to achieve a certain level of performance, the concentration of salivary cortisol increases in comparison to the competition situation where the influence of the coach was not considered, since the minimum appreciable change was large. This was observed in subjects 2, 3, 4 and 6, which suggests a stressful situation. However, subjects 3, 4 and 6 reflected decrease in SCL and stable TD, alluding to a threatening interpretation; while subject 2 considered it challenging (increase in SCL, although TD remains stable instead of increasing). The minimum appreciable change shows that PPE increases the concentration of salivary cortisol in competition.

For those who perceive that their parents impose perfect performance standards on them, which criticize them when they fail to achieve them or press them to achieve a certain level of performance (subjects 4, 6 and 7), the competition is stressful (increased salivary cortisol), but only some (subjects 4 and 6) interpret it as threatening, since the SCL was lowered and the TD was stable. While for subject 7, this stressful situation was challenging, since the SCL increased and the TD was stable. The minimal appreciable change shows that PPP increases the concentration of salivary cortisol in competition.

The reason that some gymnasts interpret the situation as threatening or challenging can also be attributed to skill levels, since high ability causes the subject to evaluate the situation as challenging rather than threatening; while with poor skills the situation is evaluated in terms of threat, so in future studies this variable should be analyzed.

These results confirm that social evaluation is one of the main stressors, however, in all cases stress is not interpreted as threatening, according to Lazarus (1999) in that situational demands choose whether it is a threatening response or challenging. The above can be associated with the study of Flett and Hewitt (2016), where feelings of anxiety an hour before the competition were more common in the most successful gymnasts, but they at the same time, are able to transform their anxiety into positive energy, instead of being worried with dreams of personal perfection.

At the correlational level, the pressure for perfection on the part of parents is related to somatic responses of competitive anxiety, such as palpitations, restlessness, or sweating. In sum, the pressure for perfection by the coach hinders visual and mental attention, the memory of the athlete, and favors the formation of catastrophic thoughts, as Dunn et al. (2019). This excessive cognitive anxiety can act as a form of cognitive interference and prevent focusing on the task (Dunn & Causgrove Dunn, 2001), affecting athletic performance. This result is consistent with approximations of previous studies (Dunn et al., 2019; Ivanovic et al., 2015), and is contrary to what was found by Donachie et al. (2018). One of the reasons for this disagreement may be due to the different methodology used; they analyzed precompetitive anxiety over a very wide range of time in anticipation of the competition, while competitive anxiety was analyzed in this study.

Although at the correlational level it is supported that the pressure for perfection is a little adaptive facet of perfectionism (Stumpf & Parker, 2000), because it is related to negative consequences (Stoeber & Childs, 2010) as competitive anxiety, when the data is analyzed individually and are accompanied by physiological variables, the results show that only in some gymnasts the pressure for perfection is not very adaptive (threatening response), while in others it can be adaptive (challenging response). Then socially prescribed perfectionism can also be associated with adaptive responses, as shown in the educational context by Stornelli et al. (2009).

Competitive stress in artistic gymnastics can be accompanied by high pressure for perfection, because the social comparison inherent in sports competition, and the nature of the sport itself, since, in female artistic gymnastics, each routine is evaluated With reference to what is expected of a perfect presentation, then gymnasts must show a perfect technique (FIG, 2017). In male artistic gymnastics, the regulation states that each element is defined by a perfect final position or by a perfect realization; the elements are executed with perfection (FIG, 2017). Under these rules, it is natural for coaches and parents to demand perfect executions, and be very critical of the quality of gymnastic execution.

It should be noted that the sample was treated in general, because Georgopoulos et al. (2011) in gymnasts, they did not find differences in salivary cortisol, with respect to age, body mass, and normorrheic and amenorrheic gymnasts, nor did they obtain significant effects of age, gender or sexual maturation on the activity of the HPA axis.

Limitations are recognized in this study, such as not including personality traits, since competitive stress responses also depend on previous experience, or propensity for specific behaviors (trait anxiety), since athletes with high trait anxiety are more prone to interpret the situation as threatening and exhibit more anxiety symptoms (Cerin & Barnett, 2011; Wolf, Eys & Kleinert, 2014). Another limitation was not having measured the interpretation of anxiety (Jones, 1995), which is also related to performance (Neil, Wilson, Mellalieu, Hanton, & Taylor, 2012), since the cognitive interpretation of competition demand seems be more important for the hormonal response, than the result itself (Jones, 1995). Therefore it is suggested to include these constructs in future studies; as well as controlling antecedents such as skill level, requirement or importance of competition, or competitive level, since these variables condition the level of stress (Ruiz-Juan, Zarauz & Flores-Allende, 2016) or its interpretation (Tsopani, Dallas & Skordilis, 2011).

Another limitation refers to the lack of values of TD ranges for excitation and relaxation in these age groups and athletes.

On the other hand, he inquired about his sports experience, but not about his competitive experience, a variable that can give more information about familiarity and adaptation to these competitive events. The results may be affected by the lack of familiarity for the participants in the visualization technique. In addition, these results should be taken with caution given the small sample size, since the athletes were teenagers, of an individual sport and of a particular performance, therefore it cannot be assumed that similar results occur in athletes of different ages, performance, of other sports or competitive levels.

This study has theoretical and practical contributions. From the theoretical point of view we study artistic gymnastics from an integrative perspective, analyzing the connection between psychological responses (anxiety), and biological variables related to stress, as well as its change through different social agents of pressure for perfection in a visualization of a competition The present results extend knowledge according to the effects of the social environment on biological responses, and their key role on the stress response. It supports that the stress response depends on how events are interpreted (Salvador, 2005), and that parents and coaches play an important role in organizing negative and positive psychosocial experiences in sport (Horn and Weiss, 1991).

This study helps to understand competitive physiological and psychological behavior, and suggests future research in directions that can clarify these ideas. Finally, it is an important study, since to date it had not been published on psychophysiological responses in competition in gymnasts under pressure for the perfection exerted by coach and parents. It is important to consider the practical implications for gymnasts and those who work in the field of sports psychology. This study strengthens the need for the use of more adaptive behaviors, which will impact on better practice and sports competition for those gymnasts who perceive the pressure for perfection as threatening.

We propose that sports psychologists and coaches can explore strategies to help athletes compete or reduce pressure for the perfection of parents and coaches through psychological interventions, since when feelings of excessive pressure by coaches or parents to Get high performance standards are present, gymnasts are vulnerable to experiencing stress, and sometimes consider it as threatening by interfering with sports performance. These results suggest that individualizing psychophysiological training strategies can be implemented to help athletes prepare for the competition or obtain some performance, as Hill (2016) pointed out, because psychophysiological stress factors are related to competition performance (Mckay et al., 1997).

CONCLUSION

This study confirms the hypothesis raised, and indicates that psychophysiological responses to competition in artistic gymnastics are affected by pressure levels by the perfection of parents and coach. This study provides evidence that when male and female gymnasts compete in similar circumstances, their response to competitive stress is different from the pressure for perfection, suggesting that for some gymnasts it is challenging, and for others threatening, so the pressure for perfection integrates a link for the different physiological responses in competition.

REFERENCES

Aguilar, M.J., Sánchez, A.M., Mur, N., García, I., López, R., Ortegón, A., & Cortes, E. (2014). Cortisol salival como indicador de estrés fisiológico en niños y adultos: revisión sistemática [Salivary cortisol as an indicator of physiological stress in children and adults; a systematic review]. *Nutrición Hospitalaria*, *29*(5), 960-968.

Amasiatu, D.N. (2013). Mental imagery reharsal as a psychological technique to enhancing sports performance. *Educational Research International, 1*(2), 69-77.

Blascovich, J. (2008). Challenge and threat. In A.J. Elliot (Ed.), *Handbook of approach and avoidance motivation* (pp. 431-445). New York: Psychology Press.

Boudarene, M., Legros, J.J., & Timsit-Berthier, M. (2002). Study of the stress response: Role of anxiety, cortisol and DHEAs. *Encephale. 28,* 139-146.

Brustad, R.J., Babkes, M.L., & Smith, A.L. (2001). Youth in sport: psychological considerations. In: R.N. Singer, H.A. Hausenblas & C.M. Janelle (Eds.) *Handbook of Sport Psychology* (pp. 604-635). 2nd Ed. New York: Wiley.

Cadore, E., Lhullier, F., Brentano, M., Silva, E., Ambrosini, M., Spinelli, R., …, & Kruel, L. (2008). Correlations between serum and salivary hormonal concentrations in response to resistance exercise. *Journal of Sports Sciences, 26*, 1067–1072.

Cerin, E., & Barnett, A. (2011). Predictors of pre- and post-competition affective states in male martial artists: A multilevel interactional approach. *Scandinavian Journal of Medicine & Science in Sports, 21,* 137–150.

Cerin, E., Szabo, A., Hunt, N., & Williams, C. (2000). Temporal patterning of competitive emotions: A critical review. *Journal of Sports Sciences, 18*, 605–626.

Crewther, B.T., Heke, T., & Keogh, J.W. (2011). The effects of training volume and competition on the salivary cortisol concentrations of Olympic weightlifters. *The Journal of Strength & Conditioning Research*, *25*(1), 10-15.

De La Cuadra, D.S. (2013). La puesta en práctica de la visualización como técnica de auto control en la educación primaria. *Revista Arista Digital*, 30-39.

Donachie, T.C., Hill, A. P., & Hall, H.K. (2018). The relationship between multidimensional perfectionism and precompetition emotions of youth footballers. *Psychology of Sport & Exercise, 37*, 33–42.

Dunn, J.G.H., & Causgrove Dunn, J. (2001). Relationships among the sport competition anxiety test, the sport anxiety scale, and the collegiate hockey worry scale. *Journal of Applied Sport Psychology, 13*, 411–429.

Dunn, J.G.H., Dunn, J.C., & Syrotiuk. D.G. (2002). Relationship between multidimensional perfectionism and goal orientation in sport. *Journal of Sport and Exercise Psychology, 24,* 376-395.

Dunn, J.G.H., Gotwals, J.K., Causgrove, J., & Lizmore, M.R. (2019). Perfectionism, pre-competitive worry, and optimism in high-performance youth athletes. *International Journal of Sport and Exercise Psychology.*

Fédération Internationale de Gymnastique (2017). *Code of points 2017–2020 Men´s Artistic Gymnastics.*

Fédération Internationale de Gymnastique (2017). *Code of points 2017–2020 Women´s Artistic Gymnastics.*

Ferreira, M.R., Valdés, H.M., & González, E. (2002). Estrés en jugadores de fútbol: Una comparación Brasil y Cuba. *Cuadernos de Psicología del Deporte, 2*(1), 7-14.

Filaire, E., Alix, D., Ferrand, C., & Verger, M. (2009). Psychophysiological stress in tennis players during the first single match of a tournament. *Psychoneuroendocrinology*, *34*(1), 150-157.

Flett, G.L., & Hewitt, P.L. (2005). The perils of perfectionism in sports and exercise. *Current Directions in Psychological Science, 14*(1), 14-18.

Flett, G.L., & Hewitt, P.L. (2016). Reflections on perfection and the pressure to be perfect in athletes, dancers, and exercisers. In A.P. Hill (Ed.), *The psychology of perfectionism in sport, dance and excercise* (pp. 298-320). Nueva York: Routledgde.

Frost, R. O., Marten, P., Lahart, C., & Rosenblate, R. (1990). The dimensions of perfectionism. *Cognitive Therapy and Research*, *14*(5), 449-468.

Georgopoulos, N. A., Rottstein, L., Tsekouras, A., Theodoropoulou, A., Koukkou, E., Mylonas, P., ... & Vagenakis, A. G. (2011). Abolished circadian rhythm of salivary cortisol in elite artistic gymnasts. *Steroids*, *76*(4), 353-357.

González, J., Garcés de los Fayos, E., & Ortega, E. (2014). Avanzando en el camino de diferenciación psicológica del deportista. Ejemplos de diferencias en sexo y modalidad deportiva [Advancing on the road of psychological differentiation of sportsmen. Examples in differences in sex and sport mode]. *Anuario de Psicología, 44*(1), 31-44.

Guillen, F., & Sánchez, R. (2009). Competitive anxiety in expert female athletes: Sources and intensity of anxiety in national team and First Division Spanish basketball players. *Perceptual & Motor Skills, 109*, 407–419.

Hewitt, P. L., & Flett, G. L. (1991). Dimensions of perfectionism in unipolar depression. *Journal of Abnormal Psychology*, *100*(1), 98-101.

Hewitt, P. L., & Flett, G. L. (2002). Perfectionism and stress processes in psychopathology. In G. L. Flett, & P. L. Hewitt (Eds.), *Perfectionism: Theory, research, and treatment* (pp. 255–284). Washington, DC: American Psychological Association.

Hill, A. P. (2016). *The psychology of perfectionism in sport, dance and exercise*. New York, NY: Routledge.

Hopkins, W.G., Marshall, S.W., Batterham, A.M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3-12.

Horn, T.S., & Weiss, M.R. (1991). A developmental analysis of children's self-ability judgments in the physical domain *Pediatric Exercise Science*, *3*, 310-326.

Ivanović, M., Milosavljević, S., & Ivanović, U. (2015). Perfectionism, anxiety in sport, and sport achievement in adolescence. *Sport Science, 8*, 35-42.

Jones, G. (1995). More than just a game: Research developments and issues in competitive anxiety in sport. *British Journal of Psychology, 86*, 449-478.

Jones, G., & Hardy, L. (1990). Stress in sport: Experiences of some elite performers. In G. Jones & L. Hardy (Eds.), *Stress and performance in sport* (pp. 247-277). Chichester: John Wiley.

Jones, M., Meijen, C., McCarthy, P.J., & Sheffield, D. (2009). A theory of challenge and threat states in athletes. *International Review of Sport and Exercise Psychology, 2*, 161-180.

Kim, K. J., Chung, J. W., Park, S., & Shin, J. T. (2009). Psychophysiological stress response during competition between elite and non-elite Korean junior golfers. *International Journal of Sports Medicine*, *30*(7), 503-508.

Lautenbach, F., & Laborde, S. (2016). The influence of hormonal stress on performance. In M. Raab, B. Lobinger, S. Hoffmann, A. Pizzera y S. Laborde (Eds.), *Performance psychology: Perception, action, cognition, and emotion* (pp. 315-328). London, UK: Elsevier.

Lazarus, R.S. (1999). *Stress and emotion: A new synthesis*. New York: Springer.

Lundberg, U., & Frankenhaeuser, M. (1980). Pituitary-adrenal and sympathetic-adrenalcorrelates of distress and effort. *Journal of Psychosomatic Research, 24,* 125–130.

Mandel, A.L., Ozdener, H., & Utermohlen, V. (2011). Brain-derived neurotrophic factor in human saliva: ELISA optimization and biological correlates. *Journal of Immunoassay and Immunochemistry*, *32*(1), 18-30.

Mckay, J.M., Selig, S.E., Carlson, J.S., & Morris, T. (1997). Psychophysiological stress in elite golfers during practice and competition. *Australian Journal of Science and Medicine in Sport, 29,* 55-61.

Miller, G.E., Chen, E., & Cole, S.W. (2009). Health psychology: Developing biologically plausible models linking the social world and physical health. *Annual Review of Psychology, 60,* 501–524.

Monasterio, E., Mei-Dan, O., Hackney, A.C., Lane, A.R., Zwir, I., Rozsa, S., & Cloninger, C.R. (2016). Stress reactivity and personality in ex-treme sport athletes: The psychobiology of BASE jumpers. *Physiology y Behavior*, *167*, 289-297.

Moreno, F., Ávila, F., & Damas, J. (2001). El papel de la motilidad ocular extrínseca en el deporte. *Revista de Psicomotricidad, 7,* 75-94.

Neil, R., Wilson, K., Mellalieu, S.D., Hanton, S., & Taylor, J. (2012). Competitive anxiety intensity and interpretation: A two-study investigation into their relationship with performance. *International Journal of Sport & Exercise Psychology, 10,* 96–111.

Nicholls, A.R., & Polman, R.C. (2007). Coping in sport: A systematic review. *Journal of Sports Sciences, 25*(1), 11–31.

Núñez, A., & García, A. (2017). Relación entre el rendimiento y la ansiedad en el deporte: una revisión sistemática [Relationship between performance and anxiety in sports: a systematic review]. *Retos, 32*, 172-177.

Passelergue, P., Robert, A., & Lac, G. (1995). Salivary cortisol and testosterone variations during an official and a simulated weight-lifting competition. *International Journal of Sports Medicine*, *16*(05), 298-303.

Pineda Espejel, H.A., López Walle, J. & Tomás, I. (2014). Validación de la versión mexicana del CSAI-2R en sus escalas de intensidad y dirección [Validation of the mexican version of the CSAI-2R with both intensity and direction scales]. *Revista Mexicana de Psicología*, *31*(2), 198-212.

Pineda-Espejel, H.A., Arrayales, E., Castro, S., Morquecho, A., Trejo, M., & Fernández, R. (2018). Versión en español de la subescala presión del entrenador del MIPS: Propiedades psicométricas. *European Journal of Investigation in Health, Psychology and Education*, *8*(2), 119-127.

Pineda-Espejel, H.A., Morquecho-Sánchez, R., & Gadea-Cavazos, E. (2018). Evidencias de validez test-criterio en el uso de la Escala Multidimensional de Perfeccionismo en el Deporte-2 [Evidence of test-criterion validity in the use of the Sport-Multidimensional Perfectionism Scale-2]. *Cuadernos de Psicología del Deporte,18*(3),129-140.

Robazza, C., Izzicupo, P., D'Amico, M.A., Ghinassi, B., Crippa, M.C., Di Cecco, V., ..., & Di Baldassarre, A. (2018) Psychophysiological responses of junior orienteers under competitive pressure. *PLoS ONE 13*(4).

Rodríguez, J., & San Juan, G. (2005). Intervención psicológica mediante rutinas de atención y concentración en un equipo de voleibol para mejorar la efectividad colectiva del saque. *Cuadernos de Psicología del Deporte*, *5*, 219-230.

Rodríguez, M.C., & Galán, S.T. (2007). Programa de entrenamiento en imaginería como función cognitiva y motivadora para mejorar el rendimiento deportivo en jóvenes patinadores de carreras. *Cuadernos de Psicología del Deporte*, *7,* 5-24.

Ruiz-Juan, F., Zarauz, A., & Flores-Allende, G. (2016). Ansiedad precompetitiva en corredores de fondo en ruta en función de sus variables de entrenamiento [Precompetitive anxiety in long-distance runners depending on their training variables]. *Retos, 30*, 110-113.

Salvador, A. (2005). Coping with competitive situations in humans. *Neuroscience & Biobehavioral Reviews, 29*, 195–205.

Salvador, A., & Costa, R. (2009). Coping with competition: Neuroendocrine responses and cognitive variables. *Neuroscience & Biobehavioral Reviews, 33*, 160-170.

Salimetrics, LLC. (2015). *Saliva collection handbook*. Recuperado de https://www.salimetrics.com/assets/documents/Saliva_Collection_Handbook.pdf

Saz, A.I. (2000). *Diccionario de Psicología*. Madrid: Libro Hobby-Club.

Seery, M. D. (2011). Challenge or threat? Cardiovascular indexes of resilience and vulnerability to potential stress in humans. *Neuroscience & Biobehavioral Reviews*, *35*(7), 1603-1610.

Stoeber, J., & Childs, J. H. (2010). The assessment of self-oriented and socially prescribed perfectionism: Subscales make a difference. *Journal of Personality Assessment, 92*(6), 577–585.

Stoeber, J., Otto, K., & Stoll, O. (2006). *Multidimensional Inventory of Perfectionism in Sport (MIPS): English Version*. University of Kent, UK.

Stornelli, D., Flett, G.L., & Hewitt, P.L. (2009). Perfectionism, achievement, and affect in children: A comparison of students from gifted, arts, and regular programs. *Canadian Journal of School Psychology, 24*(4), 267–283.

Stumpf, H., & Parker, W.D. (2000). A hierarchical structural analysis of perfectionism and its relation to other personality characteristics. *Personality and Individual Differences*, *28*(5), 837-852.

Taylor, J., Papay, K., Webb, J., & Reeve, C. (2016). The good, the bad, and the interactive: evaluative concerns perfectionism moderates the effect of personal strivings perfectionism on self-esteem. *Personality and Individual Differences, 95*, 1-5.

Tsopani, D., Dallas, G. & Skordilis, E.K. (2011). Competitive state anxiety and performance in young female rhythmic gymnasts. *Perceptual and Motor Skills, 112*(2), 549-560.

Vast, R.L., Young, R.L., & Thomas, P.R. (2010). Emotions in sport: Perceived effects on attention, concentration, and performance. *Australian Psychologist, 45*(2), 132–140.

Wolf, S.A., Eys, M.A., & Kleinert, J. (2014). Predictors of the precompetitive anxiety response: Relative impact and prospects for anxiety regulation. *International Journal of Sport and Exercise Psychology, 4*, 344-358.

Corresponding author:

Antonio Pineda Espejel
Universidad Autónoma de Baja California, Facultad de Deportes
Esq. Av. Rio Mocorito y Monclova, Col. Ex-ejido Coahuila, Mexicali
Baja California, México.
Email: Antonio.pineda@uabc.edu.mx
Phone: + (686) 564-6263

DYNAMIC MODELLING FOR THE SECOND FLIGHT PHASE OF THE YURCHENKO LAYOUT VAULT BASED ON MSC. ADAMS

Kum-Hyok Hwang[1], Yong-Song Kim[1], Dong-Chol Choi[1], Mun-Il Choi[2]

[1]Faculty of Mechanics, Kim Il Sung University, Pyongyang, Democratic People's Republic of Korea
[2]Korea Sports CollegePyongyang, Democratic People's Republic of Korea

Original article

Abstract
Gymnasts attempt to increase the angles of rotation about transversal and longitudinal axes during the post-flight of vaulting, and these angles are related to different mechanical properties. The present study uses a 3D angle-driven computer simulation model of a gymnast who performs Yurchenko layout vault using ADAMS software. Simulation initial conditions are horizontal and vertical velocities of gymnast's pelvis center and angular velocities about the transversal and longitudinal axes which can be easily measured. The initial linear and angular velocity conditions of the simulation model are each changed in certain increments from measurement data collected from an elite woman gymnast. Increasing initial horizontal velocity results in an increased horizontal flight distance, but has no connection with the duration of flight and angle of twists. The overall angle of twists is concerned with initial vertical velocity and angular velocities about the transversal and longitudinal axes. Also, increasing initial vertical velocity and angular velocity about transverse axis leads to increase in touchdown angle between ground's horizontal axis and gymnast's longitudinal axis.

Keywords: *vault, aerial movement, multibody dynamics, ADAMS.*

INTRODUCTION

Gymnasts get marks which consist of difficulty and performance values of their vaulting in artistic gymnastics. The vault difficulty values are already defined at FIG Code of Points. These difficulty values depend on body configuration and rotation angles about transversal and longitudinal body axes in gymnast's flight performance (Atiković, 2011). The rotations around the transversal and longitudinal body axes are mainly performed in the second flight phase and the gymnasts change body configuration purposely for rotation in this phase.

The second flight of gymnast is related to various mechanical initial conditions at take-off from table and gymnast's body configuration during flight. The elements of successful vaults are vertical velocity at takeoff from the table, angular momentum about the mass center, and moment of inertia about the mass center (Čuk & Karacsony,2004; Prassas, 2002; Takei, 1998).

To simulate human movement, a human body can be divided by several rigid segments which are connected with various joints (Yeadon & King, 2008). Huang (1998) presented a three dimensional human body model to simulate human response within rear-end impact vehicle. This model consisted of 15 rigid bodies which were connected with spherical and revolute joints. King and Yeadon (2015) presented various simulation models of different sports movements with their detailed information. Angle-driven models were simpler to control human body configuration than torque-driven models, so these models were used to simulate complex movements having many degree of freedoms (DOFs). Yurchenko layout vaults include rotations about transversal and longitudinal axes in the second flight phase. Koh (2003a, 2003b) studied optimized performance at table contact phase by using a five segment model of a gymnast in order to obtain maximum flight height and good performance vault. This five segment model was driven by joint angles and angular velocities. Rotations about longitudinal axis can be produced during contact phase at table and during the flight phase by means of asymmetric movements of arm and hip. To simulate this kind of aerial movements, an angle-driven model that comprised four leg segments, four arm segments and three body segments was used (Yeadon 1990, 1993c, 1999).

The study of human movements needs to find joint angles from video data applying inverse kinematics theory. The measured global Cartesian coordinates should be transferred to generalized coordinates including all joint angles by the methods of inverse kinematics. Yeadon and Hiley (2003) collected the global position of the joint centers from two synchronized video data and determined joint angle histories using the Direct Linear Transformation method. Reinbolt (2011) presented an inverse kinematics method to minimize weighted square error between experimental and simulated global positions of markers. Also, Koh and Jennings (2003) used an optimization procedure to solve the inverse dynamics problem for Yurchenko layout vault. This objective function was composed of differences between computed and measured segment angles and between computed and measured center of mass (CM) positions of a gymnast.

MSC. ADAMS is a widely used software based on multibody dynamics, and it can help to simulate kinematics, statics and dynamics problems with its convenient interface. It has the capability to import various types of geometry files such as SolidWorks, IGES and Parasolid files. Once a simulation model is given by users, it builds a dynamic equation of the model automatically, and so users can simulate easily by inputting only simulation duration and interval. Liu and et al (2013) analyzed inverse and forward dynamic problems of bicycle riding human model using LifeMOD and ADAMS software, and presented the effect of bicycle suspension systems to human body.

The purpose of this study is to build a 3D angle-driven simulation model using ADAMS software and simulate the second flight movement of Yurchenko layout vault in various initial conditions. This model has an exclusive user interface to change initial conditions and joint angle trajectories for gymnasts and coaches.

METHODS

A computer simulation model has been built for an elite woman gymnast who performed Yurchenko layout vault using SolidWorks and ADAMS software. This model was driven by joint angle trajectories which were obtained from video data of gymnast's movement. To verify this model, the measured CM positions were compared with computed CM positions presented by simulation under measured initial conditions. Then, the model was repeatedly simulated to find how each of initial conditions influences the angle of twists and somersaults.

A 15 segment simulation model was built comprising head, torso, pelvis, hands, foot and the upper and lower arm and leg segments. During aerial flight phase, twist can be generated by asymmetric arm of hip movement, so the upper and lower arms and hands are each considered as a different segment, and the upper and lower legs and foot are also different segments (Yeadon, 1993c).

Each segment was built from measured geometric properties of the gymnast and combined into a whole body geometric model using SolidWorks software. Then, this whole body model was imported to ADAMS, and inertia properties of the model were calculated automatically by density of segments (Winter, 2005).

The bodies (parts of ADAMS model) should be connected with suitable joints. Generally, the multibody model of human body is considered as tree-type system whose root is the pelvis and each body connects its parent bodies with a joint. Table 1 shows the joints of model and their DOFs. As the pelvis body has 6 DOFs, this model has 36 DOFs.

Table 1
Type of joint used for the model

Position	Adjoining bodies	Type of Joint	DOF
Spine	Pelvis-Torso	Spherical	3
Neck	Torso-Head	Spherical	3
Shoulder(L, R)	Torso-Upper Arm	Spherical	3
Elbow(L, R)	Upper Arm-Lower Arm	Revolute	1
Wrist(L, R)	Lower Arm-Hand	Spherical	3
Pelvis(L, R)	Pelvis-Upper Leg	Spherical	3
Knee(L, R)	Upper leg-Lower leg	Revolute	1
Ankle(L, R)	Lower leg-Feet	Revolute	1

Generally, angles of joints are determined from global positions of markers which are attached to the body (Delbridge, 2015). These markers disturb aerial movement of gymnasts, so they cannot complete their vault to the best of their own physical abilities. Therefore, the movement was recorded using two video cameras (1920×1080 pixels, 400Hz), and global positions of joint points were determined by analyzing video data (Fig 1). As the revolute joint has only one rotational DOF, the angles of elbows and knees can be easily determined. But the spherical joint has three rotational DOFs and the angle coordinates of spherical joints are Cardan angles in ADAMS software. To determine Cardan angles of joints, nonlinear least square method in which Eq. (1) is a minimized objective function was used (Reinbolt, 2011).

$$\min_q \left[\sum_{i=1,\cdots,n} w_i \left\| x_i^{\exp} - x_i(q) \right\|^2 \right] \tag{1}$$

where w_i are weighted coefficients, $x_i^{\exp}$ are measured global coordinates of joint points, q are Cardan angles of spherical joints and calculated global coordinates of joint points $x_i(q)$ are functions of q.

These Cardan angles of joints are considered as nonstationary kinematical constraints using AKISPL function of ADAMS software.

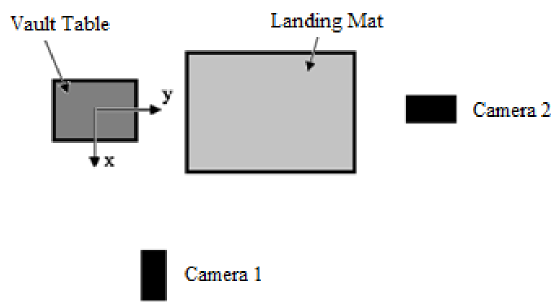


Figure 1. *Locations of Cameras*

Neglecting friction and resistance forces in the air, the external force acting on gymnast is only gravity, so the trajectory of mass center is closely approximated to a parabola. This parabolic movement is related to initial horizontal and vertical velocities (Takei, 1998). And the rotations around the transversal and longitudinal body axes are related to initial angular velocities (Čuk & Karacsony,2004; Prassas, 2002). The CM position of human body governed by CM positions of body segments cannot be directly measured. So, instead of CM velocity of whole human body, the CM velocity of pelvis segment is used as initial linear velocity conditions. And the angular velocities around the transversal and longitudinal body axes at take-off from table are also initial conditions.

For the convenience of users, the customized simulation dialog box was built using the ADAMS Dialog-Box Builder (Fig 2). Users can change initial conditions, trajectories of angle joints and simulation settings in this dialog box. A trajectory of angle joint was defined as a spline curve, so users can change configurations of body in the air by changing it. Also, this dialog box has animation controls and a graph display button to display simulation results such as the total rotation angle of twists, CM position and velocity trajectories of whole body using ADAMS View command language.

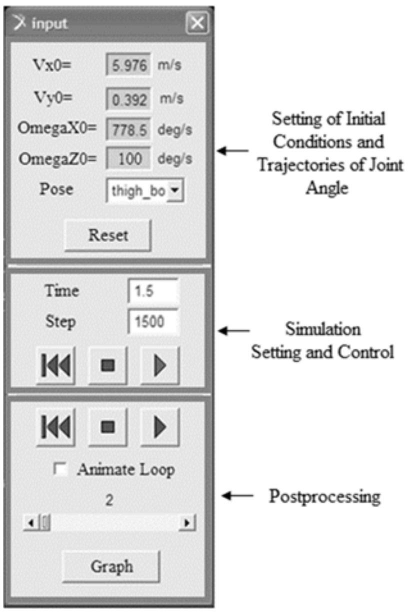


Figure 2. Customized Simulation Dialog Box.

Computer simulation result of the Yurchenko layout vault is shown in Fig. 3. The gymnast performed Yurchenko stretched with 2/1 turns. At the take-off from table, the horizontal velocity of gymnast's pelvis center is 3.0m/s and vertical velocity is 4.3m/s. The angular velocities around longitudinal and transversal axes are respectively 525°/s and 250°/s.

Figure 3. Computer graphics result of the model used in evaluation.

The flight durations of video and simulation are 1.0575s and 1.068s, respectively. The difference of flight duration is 10.5ms and its relative error is about 1%. Fig. 4 shows a comparison between CM position trajectories obtained from simulation result and video. The marker 'o's are CM positions which were calculated from video sequences. It can be seen from Fig. 4 that the simulation result closely matches the video result and its relative error is 8.6%. This error may partly occur in measuring marker positions of body segment to calculate whole body CM position from video sequences, and also partly in inertial parameters of body segments which were determined by their densities.

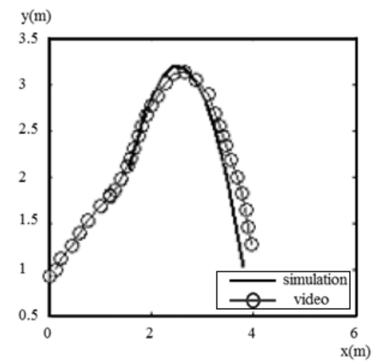


Figure 4. CM trajectories from simulation and video.

X_{max} and height Y_{max}, touchdown twist angle about longitudinal axis of body Φ_T and touchdown somersault angle between horizontal axis of ground and longitudinal axis of body at flight end time θ_{end}. To compare simulation results in various initial conditions, simulations are terminated when the distance from CM position of pelvis to ground is 0.9 meter.

In this simulation model, the orientation angles of the human body can be determined by measuring the CM marker's orientation of the torso segment. Fig. 5 shows the trajectory of the body's somersault, tilt and twist angles when initial velocity conditions are $V_x = 3m/s, V_{y0} = 4.3m/s, \omega_{z0} = 525°/s, \omega_{x0} = 250°/s$

RESULTS

The simulation results are flight duration T_{end}, maximal flight distance

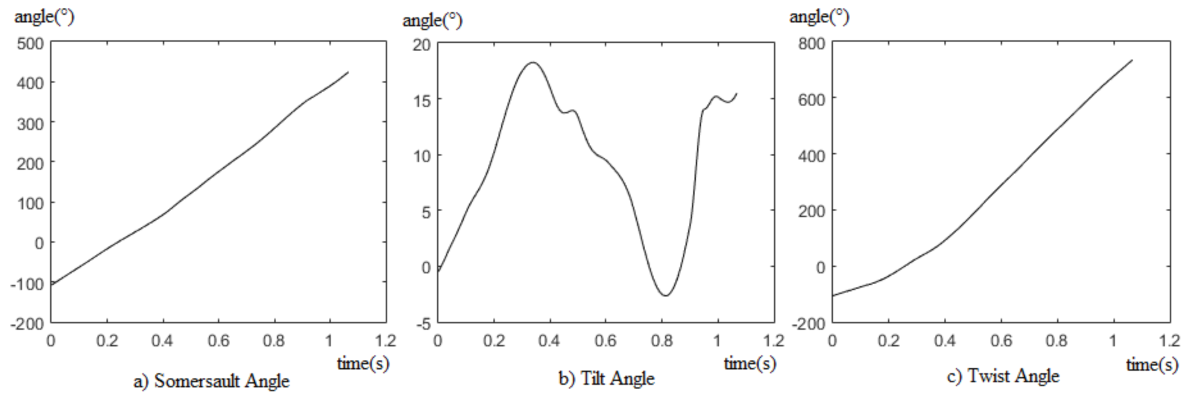


Figure 5. The trajectory of the body's orientation angles during simulation when initial conditions are $V_x = 3m/s, V_{y0} = 4.3m/s, \omega_{z0} = 525°/s, \omega_{x0} = 250°/s$.

Table 2 shows simulation results when initial horizontal velocity V_{x0} varies from 2.6m/s to 3.2m/s with an increment of 0.2m/s. Increasing initial horizontal velocity results in an increased maximal flight distance X_{max}, but has no connection with T_{end}, Y_{max}, Φ_T and θ_{end}.

Table 2
Simulation results with the variation of V_{x0} $V_{y0} = 4.3m/s, \omega_{z0} = 525°/s, \omega_{x0} = 250°/s$

V_{x0}	T_{end}	X_{max}	Y_{max}	Φ_T	θ_{end}
2.6	1.068	2.087	2.906	740.7	60.09
2.8	1.067	2.299	2.906	740.2	60.09
3	1.068	2.514	2.906	740.7	60.09
3.2	1.068	2.727	2.906	740.9	60.15

The flight duration of a particle is related with its vertical velocity in parabolic movement. Simulation results show the initial vertical velocity of pelvis segment V_{y0} effects on every five resultant variables (Table 3).

Table 3

Simulation results with the variation of V_{y0}.

$V_{x0} = 3m/s, \omega_{z0} = 525°/s, \omega_{x0} = 250°/s$

V_{y0}	T_{end}	$X_{\max}$	$Y_{\max}$	Φ_T	θ_{end}
3.9	1.007	2.398	2.7485	698.3	30.36
4	1.022	2.431	2.7842	704.4	38.03
4.1	1.037	2.461	2.822	713.3	45.5
4.2	1.052	2.488	2.863	725.3	52.68
4.3	1.068	2.514	2.906	740.7	60.09
4.4	1.084	2.542	2.9525	756.4	66.93
4.5	1.101	2.569	2.9995	769.5	74.24
4.6	1.12	2.603	3.0473	782.2	82.68
4.7	1.135	2.628	3.096	796.2	92.29

The simulation results, as changing the other two initial angular velocity conditions, are shown in Table 4 and 5, respectively. If the initial angular velocity about transversal axis ω_{z0} increases, the flight duration T_{end} , maximal flight distance $X_{\max}$ and maximal flight height $Y_{\max}$ are decreased., but the twist angle Φ_T and touchdown angle θ_{end} are increased. Also, the total rotation angle Φ_T is related with initial angular velocity about longitudinal axis ω_{x0} .

Table 4
Simulation results with the variation of ω_{z0}.

$V_{x0} = 3m/s, V_{y0} = 4.3m/s, \omega_{x0} = 250°/s$

ω_{z0}	T_{end}	$X_{\max}$	$Y_{\max}$	Φ_T	θ_{end}
450	1.087	2.758	2.937	692.6	-20.22
475	1.08	2.683	2.923	704.2	0.63
500	1.073	2.6	2.912	714.8	34.24
525	1.068	2.514	2.906	740.7	60.09
550	1.07	2.442	2.9053	753.3	82.54
575	1.058	2.318	2.9059	774.1	109.1
600	1.059	2.212	2.907	803	142.7

Table 5
Simulation results with the variation of ω_{x0}.

$V_{x0} = 3m/s, V_{y0} = 4.3m/s, \omega_{z0} = 525°/s$

ω_{x0}	T_{end}	$X_{\max}$	$Y_{\max}$	Φ_T	θ_{end}
200	1.066	2.489	2.9079	691.7	63.03
225	1.067	2.505	2.9076	712.5	58.98
250	1.068	2.514	2.906	740.7	60.09
275	1.067	2.517	2.9057	756.4	58.62
300	1.068	2.525	2.9059	756.2	52.92
325	1.068	2.527	2.9065	761.7	51.01

From simulation results for various initial conditions, the cross correlation coefficients between initial conditions and flight results are obtained (Table 6). If the variation of flight result, when changing an initial condition was very small, this correlation coefficient was neglected (marker '- 's).

Table 6
The cross correlation coefficients between initial conditions and flight results.

	T_{end}	$X_{\max}$	$Y_{\max}$	Φ_T	θ_{end}
V_{x0}	-	1.000	-	-	-
V_{y0}	1.000	1.000	0.999	0.995	0.999
ω_{x0}	-0.961	-0.996	-0.838	0.937	0.999
ω_{z0}	-	0.958	-	0.937	-0.936

DISCUSSION

The aim of the present study was to build a simulation model of the gymnast who performed Yurchenko layout vault by using ADAMS software and to study relations between initial conditions and flight results in the second flight phase. The customized dialog box was designed for gymnasts and coaches to use the simulation model easily and conveniently.

Initial conditions of second flight are related to linear and angular velocities at vault table touchdown and their changes in contact with the table. Among these initial conditions, the linear velocities and angular velocity about transversal axis are concerned with the first flight phase, while the angular velocity about longitudinal axis is related with body configuration during table contact phase (Yeadon 1993a, b).

The results show that the initial horizontal velocity does not affect a gymnast's vaulting performance, but it is related to maximal flight distance in second flight phase. When the gymnast lands on mat, the landing position should be at appropriate distance from the vault table to avoid accidents, so this horizontal velocity condition cannot be reduced to zero.

The one of important flight results is the rotation angle about longitudinal axis of body which is associated with initial vertical velocity and angular velocities (Table 6). Consequently, the flight duration gets increased by an average of 16 ms and the twist angle about longitudinal axis by an average of 12°, as the initial vertical velocity gets increased by 0.1m/s. And the twist angle gets almost increased by 28°, when both initial angular velocities about transversal and longitudinal axes are increased by 50°/s.

Simulation results also shows that the flight duration was decreased with increase of initial angular velocity about transversal axis. Generally, the flight duration is related with the initial vertical velocity of a body's CM. The linear initial velocities used in this paper are horizontal and vertical velocities of gymnast's pelvis CM, not those of the whole human body's CM. The vertical velocity of the whole human body's CM can be determined by pelvis CM velocities and angular velocity about transversal axis, hence the flight duration may be related with this initial angular velocity.

The landing on mat is a final phase of vault and the suitable touchdown angle is important for successful landing. The touchdown angle is increased with increase of initial vertical velocity and angular velocity about transversal axis of gymnast, but when the angular velocity about longitudinal axis increases, this angle is decreased slightly.

CONCLUSION

From these results, it can be seen that the important technique on vault table is to change the linear horizontal momentum of the first flight phase to the linear vertical momentum of the second flight.

Through the simulation model in this paper, the twist somersaulting flight result can be shown by intuition, as the initial conditions and flight body configurations are changed by users. Gymnasts and coaches can get the sufficient initial conditions and correct their own shortcomings in body configuration to perform any aerial movements including Yurchenko layout vaults.

REFERENCES

Amirouche, F. (2006). *Fundamentals of Multibody Dynamics,* Birkhäuser.

Atiković, A. & Smajlović, N. (2011). Relation between vault difficulty values and biomechanical parameters in Men's Artistic Gymnastics. *Science of Gymnastics Journal*, *3*(3), 91-105.

Čuk, I.& Karacsony, I. (2004). *Vault: methods, ideas, curiosities, history*. Ljubljana: ŠTD Sangvinčki.

Delbridge, M. (2015). *Motion Capture in Performance*. Palgrave Macmillan.

Huang, S. C. (1998). Analysis of human body dynamics in simulated rear-end impacts. *Human Movement Science, 17*, 821-838.

King, M. A. & Yeadon, M. R. (2015). Advances in the development of whole body computer simulation modelling of sports technique. *Movement & Sport Sciences - Science & Motricité*, *90*, 55-67.

Koh, M. & Jennings, L. (2003). Dynamic optimization: inverse analysis for the Yurchenko layout vault in women's artistic gymnastics. *Journal of Biomechanics, 36*, 1177–1183.

Koh, M., Jennings, L., & Elliott, B (2003). Role of joint torques generated in an optimised Yurchenko layout vault. *Sports Biomechanics*, *2*, 177–190.

Koh, M., Jennings, L., Elliott, B., & Lloyd, D. (2003). A predicted optimal performance of the Yurchenko layout vault in women's artistic gymnastics. *Journal of Applied Biomechanics*, *19*(3), 187–204

Liu, Y. S., Tsay, T. S., Chen, C. P. & Pan, H. C. (2013). Simulation of riding a full suspension bicycle for analyzing comfort and pedaling force. *Procedia Engineering, 60*, 84 – 90.

Prassas, S. (2002). *Vaulting mechanics*. Retrieved September 12, 2007 from: http://coachesinfo.com/category/gymnastics /315/.

Takei, Y. (1998). Three-dimensional analysis of handspring with full turn vault: deterministic model, coaches beliefs, and judges Scores. *Journal of Applied Biomechanics*, *14*(2), 190-210.

Winter, D. A. (2005). *Biomechanics and Motor Control of Human Movement*, 3rd edn Wiley, New York.

Yeadon, M. R. (1990). The simulation of aerial movement - II: A mathematical inertia model of the human body. *Journal of Biomechanics*, *23*, 67-74.

Yeadon, M. R. (1993a). The biomechanics of twisting somersaults. Part I: Rigid body motions. *Journal of Sports Sciences*, *11*, 187–198

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

Yeadon, M. R. (1993c). Twisting techniques used by competitive divers. *Journal of Sports Sciences, 11*, 4, 337-342.

Yeadon, M. R. & Hiley, M. J. (2000). The mechanics of the backward giant circle on the high bar. *Human Movement Science*, *19*, 153-173.

Yeadon, M. R., & King, M. A. (2008). Biomechanical simulation models of sports activities. In Y. Hong & R. Bartlett (2008). *Routledge Handbook of Biomechanics and Human Movement Science* (pp. 367-379). New York, NY: Routledge.

Yeadon, M.R. & Kerwin, D.G (1999). Contributions of twisting techniques used in backward somersaults with one twist. *Journal of Applied Biomechanics, 15*, 152-165.

Corresponding author:

Kum-Hyok Hwang
Faculty of Mechanics
Kim Il Sung University
Pyongyang, Democratic People's Republic of Korea
Email: mech2@ryongnamsan.edu.kp

ROLE STRAIN THEORY: APPLICABILITY IN UNDERSTANDING DEVELOPMENTAL EXPERIENCES OF INTERNATIONAL JUNIOR ACROBATIC GYMNASTS

Rick Hayman[1], Remco Polman[2], Karl Wharton[1] & Erika Borkoles[3]

[1]Department of Sport, Exercise and Rehabilitation, Northumbria University, Newcastle, United Kingdom
[2] School for Exercise and Nutritional Sciences Queensland University of Technology, Brisbane, Australia
[3]School of Public Health and Social Work, Queensland University of Technology, Brisbane, Australia

Original article

Abstract
It is well established that elite sports performers encounter multiple stressors during their careers. However, limited research has specifically investigated developmental, organisational, and competitive transitional experiences of international junior elite athletes. Through the application of Role Strain Theory (RST), this study extended the sport talent development literature by providing key insights into the experiences of five highly successful Great Britain (GB) junior international acrobat gymnasts, aged 14-17. It explored how they simultaneously combined multiple sport, family and educational role demands during their pre-elite to elite transition and coped with these complex demands. Derived themes from semi-structured retrospective interviews identified a presence of chronic, but low level and manageable role strain during all transitional stages, which enabled positive acrobatic development, life satisfaction, physical and mental well-being and educational progress. All reported how severity and regularity of role strain, specifically overload and conflict, at times fluctuated intermittently during the early teenage years. It was at this point when increased role strain was reported to meet family commitments due to increased training and competition schedules. Challenges faced in maintaining healthy and compatible friendships, particularly with peers outside of acrobatics and school settings, were further sources of role strain during this time. Three key factors which regulated role strain were present in all participant narratives: early internalised acrobatic identity, acrobatic specialisation by very young age and social and tangible guidance from teachers and coaches in support of the athletes' holistic development. Potential further research and limitations are discussed.

Keywords: *acrobatic gymnasts, elite junior, role strain theory, transitions.*

INTRODUCTION

Sport talent development research spanning several decades and disciplines has revealed the complex, idiosyncratic and non-linear pathways travelled by international junior and senior athletes (Coutinho, Mesquita & Fonseca, 2016; Huxley, O'Connor & Larkin, 2017). A comprehensive literature base, which retrospectively explored the sport participation histories of elite junior and senior international athletes, showed that they accumulated extensive sport-specific practice over many years, but also engaged in different sports during childhood and adolescence (Rees et al., 2016). In addition, a recent systematic review of the limited literature available showed that early youth sport specialisation is not a prerequisite to achieve success at the elite level (Kliethermes et al., 2019). A position statement by the Australasian College of Sport and Exercise Physicians (2019) further supports this notion, but does however state that the only sport for which there might be an exception is rhythmic gymnastics. A number of recent studies have continued to extend this knowledge base by specifically exploring the 'dual-careers' phenomenon, defined by Geraniosova and Ronkainen (2014, p.53) as 'the challenge of combining a sports career with education or work'.

Historically, this literature has been theoretically underpinned by the Holistic Athlete Career Model (HACM) (Wylleman, De Knop & Reints, 2011). Informed by research and applied work across multiple sports with athletes of varying age and abilities, this model summarised what physical, psychological, psychosocial, financial and academic transitions athletes are likely to encounter during their sports careers. The model is internationally acknowledged and well established in the literature. Previous research suggests sufficient time and resources should be made for junior athletes to balance sport training and competition demands with other life roles, including friendships, school, paid and voluntary work plus other sport and leisure interests, so they are less likely to experience high stress levels, burnout, social isolation, athletic identity foreclosure or dropout. Recent empirical research found that applying Role Strain Theory (RST) (Fenzel, 1989) to explore transitional experiences of elite adolescent Australian Rules Football (AFL), tennis and gymnastics performers directly explained how they combined and coped with the competing role demands of sport and education arising from the different roles they fulfilled as developing elite adolescent athletes (Hayman, Polman, Taylor, Hemmings & Borkoles, 2019, Van Rens, Borkoles, Farrow, Curran & Polman, 2016; Van Rens, Borkoles, Farrow & Polman, 2018;). Role Strain, defined as a 'felt difficulty in fulfilling role obligations' (Goode, 1960, p.483), is a widely accepted psychological concept that in previous research has been applied across educational and organisational psychology settings to explain problems and barriers faced by individuals when fulfilling multiple role demands. Role strain is further defined by Goode (1960, p.483) as 'a consequence of role bargains and as a continuing process of selection among alternative role behaviours in which each individual seeks to reduce his role strain'.

RST focuses on four interrelated stressors: overload, conflict, underload and ambiguity arising from life role demands (Fenzel, 1989; Holt, 1982). Fenzel (1992; 2000) provided empirical evidence that role strain was frequently experienced by young adolescents when transitioning from primary to secondary school, with consequent reductions in self-esteem, self-worth and academic achievement. The study by Van Rens et al., (2016) was the first to apply RST within a sport context and investigated how elite adolescent Australian Rules Footballers (aged 13-17 years) simultaneously undertook multiple life roles as identified by the theory. A key finding was that all participants frequently encountered multiple instances of role ambiguity, role overload and role conflict as they pursued their ambition of transitioning to international senior sport performance levels. Van Rens, Borkoles, Farrow and Polman (2018) also found overload, conflict, underload and ambiguity were all negatively associated with total life satisfaction of 112 junior international Australian Rules Footballers. Hayman et al., (2019) investigated the experiences of elite adolescent golfers who all had concurrently undertaken multiple sport, family, peer and educational roles during the pre-elite to elite junior transition period. Applying RST enabled for the nature, intensity and temporal aspects of role strain experienced to be identified. Chronic but low level and manageable role strain was reported during childhood, only increasing intermittently in severity and regularity during the early teenage years until the very final stages of the pre-elite transition period. This was particularly noticeable around the ages of 15-16 years, when for the first time, participants encountered difficulties in combining training, competition and other sports commitments with their basic educational requirements. The findings suggested a complex developmental transition, especially when the junior athletes were considered as 'talented' in several sports. It was soon after they made the decision to specialise in golf when role strain gradually subsided, combined with cessation of educational strain upon completion of formal secondary education. These research findings demonstrate the suitability of RST in explaining the temporal nature of role strain during key transitional periods and how junior athletes cope with multiple competing role demands throughout this particular developmental stage.

When applying RST principles within a sport context, overload would occur when demands exceed personal resources, such as participating regularly in several sports all at once and/or leaving limited or insufficient time to see friends and/or complete school work (Van Rens et al., 2016). Conflict would transpire when disagreement occurred between what an individual wishes to do and the demands imposed by others. An example would be contrasting athlete and coach beliefs towards prescribed training load and frequency (Van Rens et al., 2016). The underload element of RST emphasises a perceived underutilisation of an individual's capabilities and lack of challenge, including frequently competing for schools teams (Hayman et al., 2019). The final concept with RST is ambiguity and refers to limited understanding or clarity of one's responsibilities such as the mixed messages presented to young athletes about the different priorities in their sport or life (Van Rens et al., 2018).

Acrobatic Gymnastics (AG) is an internationally recognised artistic discipline performed by both genders. Its global popularity had increased significantly over the past two decades with multiple countries now hosting regular international, national and regional competitions. GB is one of the leading nations in the sport and has a global reputation for excellence in the discipline, having amassed multiple successes at World and European levels across various age categories and disciplines. For example, GB was represented in every medal ceremony at the 2019 European Age Group Championships. This was followed by 13 medals at the 2019 European Junior and Senior Championships. At developmental level, a world age group competition is held every two years and has the following age categories: 11-16, 12-18 and 13-19. The 13-19 age range is also considered the Junior level. For the first time in 2018, AG formed part of the Youth Olympic Games in Argentina. Formal routines must last up to 150 seconds, contain a mixture of static, dynamic and combined elements, be choreographed to music and performed on a sprung floor surface. Five different partnership combinations are permitted in official competitions: male, female, mixed pairs, female groups (3 gymnasts) and male groups (4 gymnasts) (British Gymnastics, 2013).

Surprisingly, limited talent development research specific to gymnastics, and especially AG, exists. The few studies to do so demonstrate many international talent programmes follow early specialised approaches to development, with young children annually completing significant hours of physically and mentally demanding deliberate practice training regimes (Arkaev & Suchilin, 2004;

Krane, Greenleaf & Snow, 1997; Nunomura, Okade & Carrara, 2012). Law, Côté and Ericsson (2007) compared participation histories of Canadian Olympic and international (non-Olympic) rhythmic gymnasts. They found Olympians accumulated three times the amount of gymnastic specific deliberate practice, as well as reduced enjoyment, poorer physical health and increased numbers of injuries by 16 years of age when compared with non-Olympians. Elite gymnasts have also reported difficulties in developing an identity outside their sport and having limited power and control within the coach-gymnast relationship (Kerr & Dacyshyn, 2000; Krane et al.,1997; Lavallee & Robinson, 2007).

Extending upon the work of Van Rens et al., (2016; 2018) and Hayman et al., (2019), the primary aim of this unique qualitative study was to apply RST for the first time to explain transitional experiences of 5 junior international acrobatic gymnasts, who each combined concurrent sport, education, family and peer role demands. The study is timely, because creating evidence informing how best to develop and retain the next generation of world class acrobats is a strategic priority for gymnastics governing bodies globally. Findings will provide coaches, parents, talent developers and policy makers with stronger evidence for how best to promote healthy development, whilst preserving physical (e.g., fewer injuries) and psychological welfare (e.g., reduced likelihood of burnout, dropout and identity foreclosure) of aspiring elite and elite junior international acrobatic gymnasts.

METHODS

The sample comprised 5 (male = 3, female = 2) international junior acrobatic gymnasts (mean age = 16.2 years). All had specialised in acrobatics before the age of 7 and competed regularly across a range of standards (e.g., regional, national and international competition levels). Experts have been defined within the extant literature as those who compete at international and/or national levels (e.g., Helsen, Starkes & Hodges, 1998). In this paper, the term 'elite junior acrobat' was used to categorise participants aged between 14 and 17 who had secured 4th place or higher for Great Britain (GB) Junior Acrobatic Gymnastic representative teams (under 12's - 19's category) in mixed pairs or quartet disciplines at either European or World Junior Championships over the past decade. Once institutional ethical clearance was granted, face-to-face debriefs addressing the study aims, objectives and procedures to follow were completed. All participants were aged under 18, so parental consent permitting their child's involvement was obtained in all instances.

Participants were approached in person to participate in the study in by the third author who had established contacts within GB Junior Acrobatic Gymnastics representative teams. Participants were informed how they could withdraw from the study at any time without giving any reasons, provided written informed consent prior to any data collection commencing and assigned numerical pseudonyms to protect anonymity. For all consenting participants, interviews were recorded and undertaken at a convenient time, date and location for them. In all cases, this was within a safe, private and comfortable room within the grounds of a Gymnastics Academy based in Northern England. When undertaking qualitative research, it is important that the interviewer builds rapport and trust with the interviewee. The lead author was previously an elite junior athlete meaning he possessed contextual knowledge concerned with the demands and terminology used in such settings, which he used to aid the process of establishing a positive and empathetic bond with participants (Patton, 2002).

To ensure participants felt relaxed, comfortable and at ease to share personalised and sensitive information, each interview started with an informal discussion on how they first became involved in acrobatic gymnastics (Rapley, 2004). The proposed interview schedule was pilot tested by 2 regional level junior acrobatic gymnasts aged 15 and 16 years respectively. This confirmed duration of approximately 45 minutes and strengthened the lead authors interviewing techniques. The interview format was specifically designed to explore how demands arising from combining sport and other role commitments impacted the participants and whether RST was applicable to their specific experiences. The lead author undertook the role of 'active listener' to assist participants in telling their unique stories in their own particular way. Participants were encouraged to talk about all their life roles, including sports, school, friends, family and other hobbies (e.g., art or music). In the first instance, the interviewer explored the acrobatics involvement and experiences of participants throughout childhood and adolescence. Follow up questions probed how they fulfilled other sport, educational, extracurricular and family commitments during this time.

In the second stage, specific challenges encountered in meeting role demands were explored. Example questions included 'were there any difficulties you faced in carrying out the various roles in your life' and 'what did you do to manage this process'. To elicit richer data, supplementary probing was used, such as 'why was this so important to you', 'why did you do these things' and 'how did this make you feel'. This flexible questioning approach ensured participant centeredness, making it possible to follow up conversations where appropriate (Lincoln & Gubba, 1985). Every attempt was made to follow participants' stories and to understand their unique experiences and accounts of the pathways they travelled, rather than following a standardized list of questions.

Each interview lasted approximately 40 minutes, was audio-taped, transcribed verbatim and subjected to similar thematic analysis guidelines published by Braun and Clarke (2006). Each transcript was read on several occasions by the first and fourth authors with notes placed within margins reflecting theme statements and their meanings. The same authors then independently annotated each interview transcript with their personalised thoughts and interpretations of the data. Initial thematic coding employed a deductive approach, which is recommended for qualitative analysis when exiting theories are being tested (Elo & Kyngas, 2008). Once the deductive approach was complete, an inductive approach was undertaken to ensure any additional higher order themes were included and to allow for lower order themes to be derived. There were marginal differences between the two separate coding results, with discrepancies discussed and agreed. Primary associations and connections based on similarities and patterns between derived themes were made, resulting in the development of four main themes.

When finalised, interview extracts representing each theme were selected. The final analysis stage involved developing written accounts from identified themes. These were reviewed and redrafted several times. Five weeks post-interview, 3 of 5 participants undertook a brief member-checking telephone conversation with the first author to establish if they were satisfied that the findings were accurate reflections of their transitional experiences (Lincoln & Gubba, 1985). All 3 participants corroborated their personal journey within the wider context of the finalised data set. The remaining 2 declined to go through the member checking process.

RESULTS

The data analysis yielded four themes that were subsequently grouped within two categories.

Pre-Elite Role Strain Experiences

Theme 1: Benefit of Early Internalised Acrobatic Identity

All participants reported a commitment to their sport, resulting in development of early acrobatic identity. Participants of this study viewed themselves as having 'lived and breathed' the sport at their own free will and successfully combined educational and sport related commitments. For example, they found that the reduced sport organisational demands such as reduced personal sacrifices, less financial impact, more family and friend's time and fewer logistic problems of participating in multiple sports made their experiences far less complex. This simpler transition period allowed them to find acrobatics to be a more enjoyable, fulfilling and naturally rewarding experience, consequently reducing role strain overload, ambiguity, and conflict. Interviews revealed participants were normally successful in managing role strain during this early period of their life. As dedicated and highly ambitious young children, they reported a very single-minded focus and commitment to securing world class junior acrobat status. Each participant (and their parents) invested significant time, money and resources to become an elite international acrobatic gymnast.

During their childhood, acrobatics had taken centre stage and they prepared for this life by specialising early, aged either 6 or 7 years. The decision to make a sole commitment to acrobatics early in their sporting careers freed up crucial organisational resources (e.g., less time spent training and competing in other sports and pursuing other identities plus reduced travel time and financial outlay). Other developmental stressors were also mitigated at this stage, such as not missing out as much on other developmental opportunities (e.g. playing in a band). To illustrate, Participant 1 said '*I may not have played many other sports when growing up but I was fine with this as it left me more time to get on with my gymnastics'* (RST: reduced overload) and Participant 5 stated '*doing gymnastics is all I have known and it (specialising) made things easier as I could just focus on this one main sport in my life'* (RST: reduced overload, ambiguity and conflict).

Table 1
Category and Theme Classification.

Category	Theme
Pre-Elite Role Strain Experiences	(1) Benefit of Early Internalised Acrobatic Identity (reduced overload, conflict and ambiguity) (2) Role Strain Fluctuation during Pre-Elite to Elite Junior Transition (increased overload, conflict and ambiguity
Minimising Role Strain throughout the Elite Adolescent Context	(3) Sacrifices Made to Pursue Junior International Acrobatic Career (reducing overload by making adjustments & prioritising sport over family & friends) (4) Influential Teacher and Coach Support (Social & Tangible)

This training pattern and early specialisation in sports like gymnastics and/or acrobatics are common. Participants reported this helped reduce potential sources of role strain, such as overload and conflict of training and competitions from other sports. Participants considered their improved consistency and quality of acrobatic performance to be a direct consequence of this dedicated and systematic approach to achieving international junior status, impacting significantly on their intrinsic motivation, self-efficacy and perceived competence. For example, Participant 3 said '*the fact I was improving every year and getting better was so motivating*'. This quote indicated that they were able to monitor their physical and psychological readiness to make the next level transition, which is inherently a difficult and complex process in developing athletes. It appeared to be motivational for the junior athletes. Each sport has different physical, psychological, and social demands, which is difficult to monitor when competing at multiple sports simultaneously.

Theme 2: Role Strain Fluctuation during Pre-Elite to Elite Junior Transition

By late childhood, becoming an international level junior acrobat had become a primary life goal for all, causing an upsurge in strain from educational, friendships and family commitments. After entering the early teenage years, junior athletes in the study reported increased role strain frequency and intensity. At this stage of transition, physical and mental fatigue remained chronic but low-level and manageable, but it was at late childhood when participants reported to experience elevated role strain for the first time. They attributed the rise to when they simultaneously had to combine increased periods of training (frequency and volume) with competition and school work for the first time. They explained how the physically demanding and time intensive training regimes, particularly in the lead up to international competitions, left them feeling more mentally and physically fatigued than ever before. The development of role strain was clearly explained by Participant 2 who said:

'It can get stressful, especially leading up to an international competition when training is at its highest. It's just really nice to be able to have a break and I get so much more social time so I am able to see my friends much more and sleep more and not have to worry about having to fit homework in and I just like being less physically tired from all the training' (RST: increased overload, ambiguity and conflict).

These experiences indicate that had they been too involved in other sports, they may have experienced significantly more role strain. The rise of role strain was also well explained by Participant 4 during the immediate build up to international competition, who stated:

'Training leaves me feeling absolutely exhausted both physically and mentally, especially in lead up to competitions. I absolutely love it, but sometimes when I am tired and sore it is intense and a bit too much' (RST: increased overload).

Minimising Role Strain throughout the Elite Adolescent Context

Theme 3: Sacrifices Made to Pursue Junior International Acrobatic Career

It was noticeable how living the life of an international junior acrobat had the potential to restrict participants' day-to-day social lives, especially during the early teenage years. All discussed challenges they faced in maintaining healthy and compatible social relationships, particularly outside of acrobatics and school settings. The following quotes capture the essence of such experiences:

'*I only see my non gymnastics friends in college and if there is the odd party I can attend which is not very often. Then there are my friends here at gymnastics but I never get to see them outside of being here and then also it is hard when you are making new friends because they don't understand the level of commitment or what I do really. I do sometimes think I miss out on a really fun social life'* (P1) (RST: increased conflict).

'I do not see my family that much apart from a bit at home and then with my school friends I feel like I am missing out a lot of the time for the sake of my training' (P5) (RST: increased overload and conflict).

They reported difficulties in maintaining a particular body shape expected of world class junior acrobats, with most opening up about having to comply with strict nutritional guidelines and conditioning programmes from early childhood to preserve a hidden, but required look (e.g., Douda, Toubekis, Avloniti & Tokmakikdis, 2008). During a transitional period of physical growth and psychological maturity, it is difficult to judge whether the athletes are able to cope with the demands of the sport, such as new routines based on their previous body composition. The extract below illustrates a participant's specific experience:

'You have to basically look and be the best you possibly can, like the strongest you possibly can, and leanest you possibly can so you really have to watch the diet but at the same time push the weights and get stronger and more toned' (P4) (RST: increased overload and conflict).

It is unknown how junior athletes monitor and manage these developments, but the above quote indicates that they do, and those who make this transition successfully, appear to become elite. It maybe that it is easier for adolescents to better understand these encounters when they specialise early in a sport.

Theme 4: Influential Teacher and Coach Support

All athletes in the study reported a positive relationship and receiving a significant social support from school teachers and acrobatic coaches, who fully understood the competing role demands placed on the day-to-day lives of their acrobats. Participants highly valued their teachers' and coaches' guidance during their early international careers, viewing them as significant sources of support, which helped them to attenuate role strain frequency and intensity encountered:

'I have a really good relationship with my coach especially as he has coached me ever since I was six years old and I can talk to him about literally anything and he helps me plan my days so I get everything done' (P1) (RST: reduced overload and conflict).

It appears that having a stable and continuous relationship with a coach reduced role strain arising from organisational, developmental, and competition stressors experienced. Furthermore, a participant specifically explained how the coach played a significant role in reducing their day to day stress levels. They said:

'My coach is great and I have known him for years like and we have a mutual respect and he takes a lot of the stress off me like always having my routines planned out and tells me what my conditioning programmes are like and sometime takes me home when my mum has to get off early' (P5) (RST: reduced overload and conflict).

Participants' school teachers had always shown keen interest towards their students' sports careers and were tremendously impressed and proud of all their national and international accomplishments. It appears that developmental stressors may be mitigated by the significant social support from the teachers of these junior athletes.

'My teachers are interested in my progress and always asking what I am doing next in terms of competitions and just to ask if I need any extra time or help for things' (P4) (RST: reduced conflict).

School teachers were extremely considerate to all participants because of escalating sport and education commitments, regularly extending assignment deadlines and provided tangible support to complete school work. This was especially common during the lead up to formal secondary education examinations. This approach not only helped to reduce role strain severity and frequency, but also enabled more time to focus on their acrobatic development.

'School is so supportive because they know how demanding all my training is, so they are quite lenient with me and if homework was due in on a Tuesday and I did not manage to do it they would say ok

we know you are very busy so can you do it for Friday instead' (P2) (RST: reduced overload and conflict).

'If I am going to miss a lesson due to training or competitions then the teachers all understand and we arrange to meet before I have to leave so I fully know the work that I have to do and they help me when I get back also by making sure I understand the work and they are just really supportive in everything' (P3) (RST: reduced overload and conflict).

DISCUSSION

It is well recognised that international junior athletes encounter multiple stressors whilst fulfilling dual careers (Christensen & Sorensen, 2009; Godber, 2012; Pink, Saunders & Stynes, 2015; Van Rens et al., 2016). Examples include time management barriers and pressures (e.g., limited study time due to daily training commitments and ensuring homework and assessment deadlines are met), extended periods of school absence to attend overseas training camps and competitions, sport related injuries and illness and dealing with poor performance, de-selection and failure. Recent research has clearly demonstrated the effects of competing role demands can cause role strain and have a significant effect on aspiring junior elite athlete's sports performance, academic progress, life satisfaction and well-being (Hayman et al., 2019; Van Rens et al., 2016, 2018). This exploratory study extended the sport talent development literature by utilising RST to investigate how combining sport, education, family and social role demands impacted upon the experiences and development of 5 elite junior international acrobatic gymnasts.

Previous research found that RST further explained the challenges encountered by junior international athletes in undertaking multiple roles and how it impacted upon their psychological and physical development and the temporal nature of role strain experienced (Van Rens et al., 2016). In this study, we were able to highlight how applying RST can yield further unique findings and explain some of the key factors that helped the participating 5 junior athletes to make the transition from pre-elite to elite. The key finding compared to other research (e.g. Van Rens et al., 2016; 2018) was that athletes in this study reported relatively low role strain at various transitional stages of their sport careers. To our knowledge, no other studies have reported positive influences of early specialisation in sport for successful transition from pre-elite to elite junior status. From a very early age, all 5 participants were committed to becoming an elite acrobat, shaping their athletic identity. In early childhood, these junior acrobats were identified by coaches as 'talented'. This helped them and their family to make acrobatics the focus of their athletic development, which led to them all striving to compete at international level in this sport. As their status and reputation as an emerging national acrobatic talent increased, their commitment became ever stronger and they decided to specialise early.

In general, there is limited support for early sport specialisation in most sports, and playing multiple sports at this stage of their talent path and movement skill development is now an accepted requirement for securing international status in junior sports (Exeter et al., 2018). Previous research by Brenner (2016) highlighted the association between early sport specialisation and its potentially detrimental impact upon an athlete's physical, psychological and social development (e.g., earlier cessation of sporting activity and possible burnout, less fun derived from playing sport and 'psychological needs' dissatisfaction). In this study we only interviewed athletes who successfully achieved elite junior status and recognise that because of their strong commitment expressed to their role as a gymnast, they may be also at risk of athletic identity foreclosure in the future if they do not successfully transition to adult elite status. This is particularly relevant if there is no scope for additional exploratory behaviours (e.g., becoming a musician or artist) at this crucial developmental stage (Gray & Polman, 2004).

However, we would argue that our study has significantly contributed to the adolescent talent development and management literature. By applying RST to explore the transitioning process and experiences from pre-elite to elite junior athlete, the study showed that early sport specialisation led to reduced role strain which is a significant finding and contribution to the literature. We hypothesise that having a less complex and a much simpler and less complicated pathway enabled the successful transition from pre-elite to elite junior status. In the case of these athletes, it appeared easier to meet the physical and psychological demands of high volumes of purposeful, deliberate and physically taxing acrobatic training, tailored specifically to improving overall sport performance. Competitive, organisational and developmental stressors (Harwood & Knight, 2009) were significantly reduced in the case of these participants. Further research needs to investigate for example, how the child's physical and psychological readiness (e.g., competitive stressor), and the child missing out on other opportunities, including the prolonged effect of uncertainty of which sport they will or not make a successful transition when participating in multiple sports, (e.g., developmental stressors) affect transitions in adolescence.

Following an early specialised pathway also reduced personal sacrifices from family and friends plus financial resources and travel time associated with other sports. The study also revealed no participant had ever reached a point where they felt unable to cope with living the life of an elite junior acrobat, whereas athletes in previous studies did (e.g., Van Rens et al., 2016). This finding warrants more quantitative and qualitative studies to explore these effects on talent development in adolescence.

Nevertheless, there was evidence which showed how transitioning through this developmental stage was occasionally stressful and problematic for participants, with all experiencing levels of role strain, but not something they found overly detrimental to their performance or talent paths. For example, participants encountered intermittent role conflict and overload on an ad-hoc basis during the early teenage years. This was caused by feeling unable to spend as much time as they would have liked socialising with family and friends, because of competing role demands caused byto training, competition, school, and social commitments.

Role conflict and overload was also present at this stage from having to comply with formal dietary guidelines to maintain the expected aesthetic look of international acrobats and the mental and physical demands associated with high volumes of training resulting in fatigue and tiredness. With regards to maintaining an aesthetic look, there is some evidence that anthropometric components explain the largest variance (45%) albeit in rhythmic gymnastics performance and include lean body mass, chest, biiliac, bitrochanteric, shoulder chest waist abdominal hip, calf, arm and midthigh circumference (Douda, Toubekis, Avloniti, & Tokmakidis, 2008). Research has also indicated that both artistic and rhythmic female gymnasts have broad shoulders, narrow hips, long and slim upper and lower limbs, very low body fat and show symmetrical values in sitting and standing height ratio (Douda, Tokmakidis, & Tsigilis, 2002; Russell, 1987). There is also some evidence that such a physique is more pleasing to judges (Hume, Hopkins, Robinson, Robinson, & Hollings, 1993). Although this is mainly based on studies in rhythmic gymnasts, we would assume that findings would not be dissimilar in artistic gymnasts, although this requires further examination.

In this study, fully supportive coaches, teachers, parents and a close-knit community of fellow acrobats played a key part in moderating athletes' perceptions of role strain frequency and severity. Throughout all stages of their careers, participants reported how they had developed and maintained excellent working and personal relationships with all their coaches. This is a very unusual but important finding because it fails to support previous gymnastics talent development research, which revealed frequent power dynamics and issues of control between athletes and their coaches (Kerr & Dacyshyn, 2000; Lavallee & Robinson, 2007). This needs to be explored further in relationship to role strain in future studies. In addition, the focus on a single sport from a young age is likely to make time management and planning easier, reducing role strain.

This study was not without limitations. Participant recollections were retrospective, thus liable to forgetfulness and bias. The sample was also sport specific, elite in nature, small, and homogeneous, thus limiting generalisability of findings to other disciplines and levels of performance. Validation of participants' retrospective accounts with those of coaches, peers and parents would have further strengthened the study.

To assist them, it would be useful for junior international acrobats to be taught appropriate self-regulatory skills and for national governing bodies to provide social and financial support at this crucial developmental stage. From a practically applied perspective, RST provides an essential framework to explore the psychological implications of roles and role demands in adolescence. It is therefore very important for coaches, parents, teachers and policy makers involved in AG to be educated on how to best safeguard the welfare of high performing athletes from excessive levels of role strain and the potentially negative impact upon their psychological (e.g., greater likelihood of identity foreclosure) and physical health (e.g., more chance of injury and/or burnout).

Although existing gymnastics talent development research is limited, the study findings provide a firm foundation on which future research may build. For example, longitudinal research combining semi-structured interviews, self-report diaries and the Role Strain Questionnaire for Junior Athletes (Van Rens et al., 2016) would enable day-to-day training loads, experiences, feelings and behaviours of aspiring and current male and female international junior acrobats fulfilling dual-careers to be established over time. This would enable identification of any key differences in role strain experienced by those who are successful and unsuccessful in transitioning from pre-elite to elite junior a status. Research monitoring role strain in acrobats who specialise early with those who diversify and undertake additional sports is also warranted.

CONCLUSION

This study applied RST to explore potential physical and psychological health risks encountered by elite international junior acrobats at key transition periods of their development. Essentially, the critical period of combining school, sport, and social commitments simultaneously posed the most threat to their well-being. During early childhood up to 11-12 years, they generally only experienced low level but chronic role strain. By the early teenage years, this had increased both in frequency and volume but remained manageable during all stages of their successful transition from pre-elite to elite status. Three key factors attenuated junior athletes' retrospective perceptions of role strain intensity and regularity (particularly overload and conflict). They were 1) early identification with wanting to become an elite acrobat; 2) early sport specialisation in acrobatics during young childhood; and 3) influential parental, teacher and coach support.

REFERENCES

Arkaev, L. & Suchilin, N. (2004). *Gymnastics: how to create champions*. Oxford: Meyer & Meyer Sport.

Australasian College of Sport and Exercise Physicians Position Statement: Sport Specialisation in Young Athletes (2019). Retrieved from https://www.acsep.org.au/content/Document/Early%20Specialisation%20Position%20Statement.pdf.

Braun, V. & Clarke, V. (2006) Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*, 77-101.

Brenner, J. (2016). Sports specialization and intensive training in young athletes. *Paediatrics*, *138*, 1-10.

Brown, D., Fletcher, D., Henry, I., Borrie, A., Emmett, J., Buzza, A. & Wombwell, S. (2015). A british university case study of the transitional experiences of student athletes. *Psychology of Sport and Exercise*, *21*, 78-90.

Christensen, M. & Sorensen, J. (2009). Sport or school? dreams and dilemmas for talented youth Danish footballers. *European Physical Education Review*, *15*, 115-133.

Coutinho, P., Mesquita, I. & Fonseca, A. (2016). Talent development in sport: a critical review of pathways to expert performance. *International Journal of Sports Science & Coaching*, *11*, 279-293.

Douda, H., Tuoubekis, A., Avloniti, A., & Tokmakidis, S. (2008). Physiological and anthropometric determinants of rhythmic gymnastics performance. *International Journal of Sports Physiology and Performance, 3*, 41-54.

Douda, H., Tokmakidis, S. & Tsigiis, N. (2002). Effect of specific training on muscle strength and flexibility of rhythmic sports and artistic female gymnasts. *Coaching Sport Science Journal, 4*, 23-27.

Elo, S. & Kyngas, H. (2008). The qualitative analysis process. *Journal of Advanced Nursing*, *62*, 107-115.

Exeter, D., Jowett, A., Broderick, C., Murphey, I., Fulcher, M. & Praet, S. (2018). *Sport specialisation in young athletes*. Melbourne: Australasian College of Sport and Exercise Physicians Position Statement.

Fenzel, L. (1989). Role strains and the transition to middle school: longitudinal trends and sex differences. *Journal of Early Adolescence*, *9*, 211-226.

Fenzel, L. (1992). The effect of relative age on self-esteem, role strain, grade point average, and anxiety. *The Journal of Early Adolescence, 12*, 253-266.

Fenzel, L. (2000). Prospective study of changes in global self-worth and strain during the transition to middle school. *Journal of Early Adolescence*, *20*, 93-116.

Geraniosova, K., & Ronkainen, N. (2014). The experience of dual career through slovak athletes eyes. *Physical Culture and Sport Studies and Research*, *14*, 53-64.

Godber, K. (2012). The life-worlds of elite young athletes: a lens on their school/sport balancing act. *The New Zealand Journal of Gifted Education*, *17*, 161-178.

Goode, W. (1960). A theory of role strain. *American Sociological Review, 25*, 483-496.

Gray, J. & Polman, R. (2004). Craft idiocy, erikson and footballing identities. In H. Marsh, J. Baumert, G. Richards & U. Trautwein (Eds.), *Self-concept, Motivation and Identity: Where to from here*? (pp. 288-293). Sydney: Self Research Centre, University of Western Sydney.

Harwood, C. & Knight, C. (2009). Understanding parental stressors: an investigation of British tennis parents. *Journal of Sports Sciences*, *27*, 339-351.

Hayman, R., Polman, R., Taylor, J., Hemmings, B. & Borkoles, E. (2019). The utility of role strain theory in facilitating our understanding of elite adolescent golfers developmental trajectories. *International Journal of Golf Science*. Retrieved from: https://www.golfsciencejournal.org/article/9492-the-utility-of-role-strain-theory-in-facilitating-our-understanding-of-elite-adolescent-golfers-developmental-trajectories?article_token=bqNgx8wJa1qMxgKozt_B

Helsen, W., Starkes, J. & Hodges, N. (1998) Team sports and the theory of deliberate practice. *Journal of Sport and Exercise Psychology*, *20*, 12-34.

Holt, R. (1982). Occupational stress. In L. Goldberger, & S. Brezniz (Eds,) *Handbook of stress: Theoretical and Clinical Aspects* (pp. 419-444). New York: Free Press.

Hume, P., Hopkins, W., Robinson, D., Robinson, S. & Hollings, S. (1993). Predictors of attainment in rhythmic sportive gymnastics. *Journal of Sports Medicine and Physical Fitness, 33*, 367-377.

Huxley, D. J., O'Connor, D. & Larkin, P. (2017). The pathway to the top: key factors and influences in the development of australian olympic and world championship track and field athletes. *International Journal of Sports Science & Coaching*, *12*, 264-275.

Kliethermes, S., Nagle, K., Côté, J., Malina, R., Faigenbaum, A., Watson, A., Feeley, B., Marshall, S., LaBella, C., Herman, D., Tenforde, A., Beutler, A. & Jayanthi, N. (2019). Impact of youth sports specialisation on career and task-specific athletic performance: a systematic review following the american medical society for sports medicine (AMSSM) collaborative research network's 2019 youth early sport specialisation summit. *British Journal of Sports Medicine*, 1-11.

Kerr, G. & Dacyshyn, A. (2000) The retirement experiences of elite female gymnasts. *Journal of Applied Sport Psychology, 12*, 115-133.

Krane, V., Greenleaf, C. & Snow, J. (1997). Reaching for gold and the price of glory: a motivational case study of an elite gymnast. *The Sport Psychologist, 11*, 53-71.

Lavallee, D. & Robinson, H. (2007). In pursuit of an identity: a qualitative exploration of retirement from women's artistic gymnastics. *Psychology of Sport and Exercise*, *8*, 119-141.

Law, M., Côté, J. & Ericsson, A. (2007). Characteristics of expert development in rhythmic gymnastics: a retrospective study. *International Journal of Sport and Exercise Psychology, 5,* 82-103

Lincoln, Y. & Gubba, E. (1985). *Naturalistic Inquiry*. London: Sage.

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

Park, J. & Liao, T. (2000). The effect of multiple roles of south korean married women professors: role changes and the factors which influence potential role gratification and strain. *Sex Roles*, 43, 571-591.

Patton, M. (2002). *Qualitative Research and Evaluation Methods*. Thousand Oaks, Sage.

Pink, M., Saunders, J. & Stynes, J. (2015). Reconciling the maintenance of on-field success with off-field player development: a case study of a club culture within the Australian Football League. *Psychology of Sport and Exercise*, *21*, 98-108.

Rapley, T. (2004). Interviews. In C. Seale, G. Gobo, J. Gubrium & D. Silverman (Eds.), *Qualitative research practice* (pp.15-33). London: Sage.

Rees, T., Hardy, L., Gullich, A., Abernethy, B., Côté, J., Woodman, T., Laing, S. & Warr, C. (2016). The great british medalists project: a review of current knowledge on the development of the world's best sporting talent. *Sports Medicine*, *46,* 1041-1058.

Russell, K. (1987). Gymnastic talent from detection to perfection. In B. Petiot, J. Salmela, & T. Hoshizaki (Eds), *World*

Identification systems for gymnastic talent (pp. 4-13). Montreal: Sport Psyche Editions.

Spencer-Dawe, E. (2005). Lone mothers in employment: seeking rational solutions to role strain. *Journal of Social Welfare and Family Law*, *27*, 251-264.

Van Rens, F., Borkoles, E., Farrow, D. & Polman, R. (2016). Development and initial validation of the role strain questionnaire for junior athletes (RSQ-JA). *Psychology of Sport and Exercise*, *24*, 168-178.

Van Rens, F., Borkoles, E., Farrow, D. & Polman, R. (2018). Domain specific life satisfaction in the dual careers of junior elite football players: the impact of role strain. *Journal of Clinical Sport Psychology*, *12*, 302-315.

Wylleman, P., De Knop, P., & Reints, A. (2011). Transitions in competitive sports. In N. Holt & M. Talbot (Eds.), *Lifelong Engagement in Sport and Physical Activity: Participation and Performance across the Lifespan* (pp. 63-76). New York: Routledge. Retrieved from: www.british-gymnastics.org

Corresponding author:

Dr Rick Hayman
Northumbria University
237 Northumberland Building,
Northumbria University
Newcastle, NE1 8STG
United Kingdom
Email: rick.hayman@northumbria.ac.uk
Phone + 0191 243 7338

ANTHROPOMETRIC PROFILE OF GYMNASTS PARTICIPATING IN THE EUROPEAN GAMES 2015 IN BAKU, AZERBAIJAN

Maria-Raquel G. Silva[1-3], Hugo-Henrique Silva[4], Teresa Luemba[1]

[1]Faculty of Health Sciences, University Fernando Pessoa, Oporto, Portugal.
[2]Research Centre for Anthropology and Health, University of Coimbra, Coimbra, Portugal.
[3]Scientific Commission of the Gymnastics Federation of Portugal, Lisbon, Portugal.
[4]Ministry of Education, Lisbon, Portugal

Original article

Abstract
Sports performance is strongly influenced by the athletes' anthropometric profile. In the specific case of Gymnastics, body weight assumes particular relevance, given the aesthetic character of this sport. Anthropometric data were collected from 309 gymnasts (20.9 ± 4.1 years old) participating in the 2015 European Games: age, body weight and height, from a database of the organization of this competition available online in the 5 disciplines of the Gymnastics included in the competition, namely Men´s and Women´s Artistic Gymnastics, Rhythmic Gymnastics, Acrobatic Gymnastics and Aerobic. Body mass index was calculated. Female gymnasts were significantly younger and lighter than male gymnasts and had a lower body mass index than males (P = 0.000). Female athletes were in the 25th percentile for weight and BMI and in the 15th percentile for height, according to their age. Male gymnasts were in the 25th percentile for weight, height and BMI. Female acrobatic gymnasts were younger and lighter (25th percentile) than other gymnastics disciplines; rhythmic gymnasts presented the lowest BMI (5th percentile). Male artistic gymnasts were the lightest (15th percentile) and with the lowest BMI (25th percentile) within the male participants. BMI was dependent on weight, height and gender, with exception for exclusive-gender disciplines and, surprisingly, also in Aerobics. Gymnasts presented an anthropometric profile with results for body weight, height and body mass index below the normal for their age.

Keywords: *body weight, gymnastics, athlete, gender-participation, European Games.*

INTRODUCTION

Gymnastics is an aesthetic sport in which a reduced body weight is important for the athlete's performance in training, and especially, in competition given the artistic component strongly associated with the performance of competition routines (Silva, 2015).

Although it is a sport whose sporting career is usually short, the International Gymnastics Federation has shown some concern about the anthropometric profile of gymnasts from various competition disciplines (Binder, 2011) with a particular emphasis on Men's Artistic Gymnastics (MAG), Women´s Artistic Gymnastics (WAG), Rhythmic Gymnastics (RG), Acrobatic Gymnastics (ACRO) and Aerobic Gymnastics (AERO).

Depending on the discipline, the duration of the exercises is slightly variable, that is a competition exercise can last 4-5s (for example, in vault), or 60 to 90s (for example, a routine in RG). Some athletes need a more muscular body, as is the case of MAG's athletes (Mkaouer et al., 2018), while others need a lighter and more flexible body (Binder, 2011), as is the case of rhythmic and acrobatic gymnasts.

Regardless of the routine's duration, its intensity is high, mostly appealing to anaerobic metabolism, and resulting from the combination of body technique combined with the mastery in apparatus technique (Silva & Paiva, 2015a). Flexibility combined with strength are the most obvious capabilities when performing a routine, in addition to high levels of coordination and motor control.

Thus, a thin body becomes more appealing in the eyes of the public, judges (Donti et al., 2016) and coaches (Mkaouer et al., 2018; Silva & Paiva, 2015a; Michopoulou et al., 2011), specifically in RG and ACRO. However, a reduced body weight can lead to imbalances in the energy availability, which may compromise gymnast´s growth and development, as well as, her/his performance in daily and sport demands (Silva & Paiva, 2015b).

In a study that evaluated dietary intake and body composition of elite RG athletes prior to a World competition (Silva & Paiva, 2015a), gymnasts demonstrated low energy availability (31.5±11.9kcal/kg fat-free mass/day), and mean body mass (48.4±4.9kg) and body mass index (BMI, 17.4±1.1kg/m^2) below the normal for age; mean height for age (1.66±0.05m) was normal or slightly above normal and higher than in previous data (Georgopoulos et al., 2012). In a research study with high performance RG gymnasts, no significant differences (P=0.102) were found in BMI according to athletes' ranking in an international competition; however, in both groups, this variable was below the normal for gymnasts' age (Silva & Paiva, 2015b). Considering another recent study about precompetitive sleep behaviour in RG gymnasts (67.1% adolescents and 32.8% adults) competing at a high level (36.6±7.6 hours of training/week), BMI<18.5kg/m^2 was not a risk factor for gymnasts' short sleep duration; however, it was, indeed, a risk factor for reduced sleep quality and abnormal daytime sleepiness prior to competition (Silva & Paiva, 2019).

From the five Gymnastics disciplines aforementioned, ACRO and AERO have been less studied with ACRO presenting an increasing number of athletes around the world in the last decade. Additionally, in a research with Portuguese acrobatic gymnasts, significant differences between children and adolescents were observed for BM, height and BMI according to gender, with exception for BMI in males; adolescents' mean BM was below the normal for age and gender (25th to 50th percentiles) and only female children showed a normal height for age (Silva, Silva & Paiva, 2018).

According to the experience of Silva & Paiva (2015a), in high intensity gym training, energy restriction is a common practice in female athletes aiming to reduce body weight (Baldari & Guidetti, 2001; Deutz et al., 2000). On the other hand, daily or frequent assessment of gymnasts' body weight is not a reliable or accurate way of assessing their energy balance, being even a particularly delicate/stressful moment for the gymnast, which may encourage poor eating and hydration behaviors (Binder, 2011). Research on acrobatic gymnasts' body composition and eating habits related to training habits and energy availability is much needed due to the recent ascending character of ACRO.

The aim of this study was to analyze the anthropometric profile (weight, height and body mass index according to age) of gymnasts participating in the 2015 European Games in Baku, Azerbaijan.

METHODS

From the 309 gymnasts (20.9±4.1years old, 57.8±10.7kg, 1.47±0.51m, 21.1±2.6kg/m^2) who participated in the European Games 2015, 59.2% (n=183) were female (19.4±3.5 years old, 50.4±7.9kg, 1.31±0.62m, 19.5±2.2kg/m^2) and 40.8% (n=126) were male

(23.0±4.0years old, 66.6±6.3kg, 1.31±0.72m, 22.9±1.2kg/m^2).

Anthropometric data were collected from gymnasts participating in the 2015 European Games: age (years), weight (kg) and height (m). These data come from a credible database of the organization of this European competition available online (European Games, 2015). It should be said that, although, this was the official competition website, the reliability and validity of data are dependent on the accuracy of data collection, which was not from the authors' responsibility. The five Gymnastics disciplines covered in the competition were accessed, namely ACRO, RG, MAG, WAG and AERO. A database was created and the BMI was calculated according to the formula: BMI = Weight (kg)/Height^2 (m^2) and interpreted according to public and research data from Frisancho (2008). In this study, informed consent was not required as all data were publicly available.

Results will be presented as mean, standard deviation, minimum and maximum. Spearman correlation coefficient was used to determine associations between variables. The significance level was 5% ($P <0.05$). Statistical treatment was performed using the statistical program SPSS for Windows, version 25.0 (New York, USA).

RESULTS

Artistic Gymnastics was the most represented discipline at the competition (28.5% of MAG and 27.5% of WAG) and RG was the least represented with only 6.1% of participants (Figure 1).

The discipline most represented by both genders was the Artistic Gymnastics (MAG = 69.8% and WAG = 46.4%). The less represented by male athletes was the ACRO (7.1%), and the AERO in females (19.1%, Figure 2). Excluding the RG (female-only discipline, n = 19), there were significant gender differences ($P <0.05$) in ACRO. However, in Artistic Gymanstics and AERO no significant gender differences were observed ($P\geq0.05$) (Figure 2).

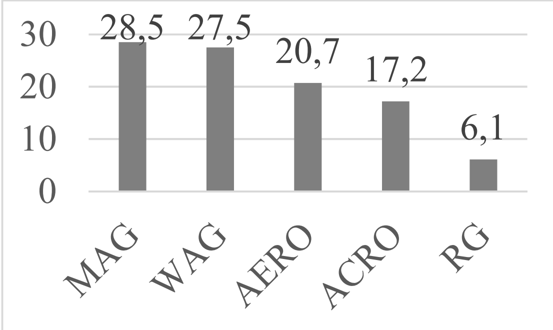


Figure 1. Gymnastics disciplines represented at the 2015 European Games. ACRO: Acrobatic Gymnastics. AERO: Aerobics Gymnastics. MAG: Men´s Artistic Gymnastics. RG: Rhythmic Gymnastics. WAG: Women´s Artistic Gymnastics.

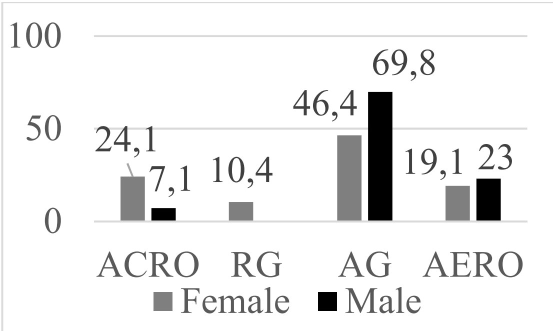


Figure 2. Gymnastics disciplines represented at the 2015 European Games, according to the participants' gender. ACRO: Acrobatic Gymnastics. AERO: Aerobics Gymnastics. AG: Artistic Gymnastics. RG: Rhythmic Gymnastics.

Female gymnasts were significantly younger, lighter and had a lower BMI than males (P=0.000) (Table 1). Male gymnasts were in the 25th percentile for weight, height and BMI according to their age (Frisancho, 2008), as well as female gymnasts, with exception for the height, that was in the 15th percentile.

Analysing by gender, and according to the disciplines of Gymnastics, female ACRO gymnasts were younger and lighter (ranked in the 25th percentile) than other female participants, while WAG athletes were the shortest (in the 25th percentile); rhythmic gymnasts had the lowest BMI (in the 5th percentile).

In males, ACRO gymnasts were younger than other athletes, while AERO gymnasts were the shortest (ranked in the 25th percentile); MAG were the lightest (15th percentile) and with the lowest BMI (25th percentile) (Table 2). As expected, Person correlation coefficients (r) indicated that BMI was positively correlated with age (r=0.458, p=0.000), weight (r=0.875, p=0.000) and height (r=0.487, p=0.000).

Table 1
Age, body weight, height and body mass index of gymnasts (n = 280), according to gender (female: n = 183 and male: n = 97).

	Total (n=280)		**Female** (n=183)		**Male** (n=97)		***P***
	Mean±sd	*Min.-Max.*	*Mean±sd*	*Min.-Max.*	*Mean±sd*	*Min.-Max.*	
Age (years)	20.9±4.1	14-37	19.4±3.5	14-37	23.0±4.0	17-34	0.000*
Weight (kg)	57.8±10.7	29-85	50.4±7.9	29-72	66.6±6.0	54-85	0.000*
Stature (m)	1.47±0.51	1.26-1.93	1.55±0.62	1.46-1.75	1.70±0.06	1.58-1.93	0.997
BMI (kg/m^2)	21.1±2.6	14.3-27.6	19.5±2.2	14.3-25.5	22.9±1.5	17.4-27.6	0.000*

*P<0.01.

Table 2
Age, body weight, height and body mass index (BMI) according to gymnasts' gender (female: n = 183 and male: n = 97).

	Female (n=183)				**Male** (n=97)		
	ACRO (n=44) *Mean±sd (min-max)*	RG (n=19) *Mean±sd (min-max)*	WAG (n=85) *Mean±sd (min-max)*	AERO (n=35) *Mean±sd (min-max)*	ACRO (n=9) *Mean±sd (min-max)*	MAG (n=88) *Mean±sd (min-max)*	AERO (n=35) *Mean±sd (min-max)*
Age (years)	17.5±2.5 (14-22)	20.3±3.2 (16-29)	19.3±3.1 (15-31)	21.3±4.3 (17-37)	20.7±4.2 (17-30)	23.5±4.0 (17-34)	22.5±3.7 (17-31)
Weight (kg)	48.5±11.3 (29-65)	50.0±5.0 (40-58)	51.4±6.0 (35-72)	53.5±2.1 (52-55)	76.1±6.5 (64.0-85.0)	65.7±5.4 (54-83)	66.6±5.0 (57-77)
Stature (m)	1.60±0.09 (1.40-1.73)	1.68±0.04 (1.60-1.75)	1.59±0.06 (1.40-1.74)	1.65±0.39 (1.62-1.66)	1.79±0.06 (1.70-1.93)	1.70±0.05 (1.58-1.83)	1.69±0.53 (1.60-1.83)
BMI (kg/m^2)	18.7±2.70 (23.1-18.7)	17.6±1.5 (14.9-20.7)	20.4±1.67 (16.2-25.5)	19.8±0.3 (19.6--20)	23.6±1.4 (21.6-26.2)	22.8±1.2 (19.4-25.6)	23.3±2.2 (17.4-27.6)

DISCUSSION AND CONCLUSIONS

This is the first work that compares at the same time more than two Gymnastics disciplines in terms of the gymnasts' anthropometric profile. Currently available data on the height and weight of elite gymnasts are not extensive. Athletes in question are considered high performance athletes, given the European character of the competition. As reported in two recent studies conducted by the Portuguese Gymnastics Federation (Silva & Barata, 2016; Silva et al., 2017), also in this competition female gymnasts (59.2%) were represented in a greater number than male gymnasts (40.8%) and were significantly younger than the latter.

A research with high performance gymnasts (Silva & Paiva, 2015b) concluded that the performance of these athletes in competition was positively influenced by age and other variables that were not available for the present study (number of daily training hours and daily sleep duration, and negatively due to low energy availability, reduced sleep quality, daytime sleepiness and daily protein intake).

According to the anthropometric data evaluated, gymnasts of both genders were below normal for age, namely between the 15th and 25th percentiles, which may reflect aesthetic and physical demands of this sport on the athletes' body composition.Although BMI is a relative indicator of body composition, because it does not differentiate between the various components of an individual's body composition (fat mass, muscle mass, total body water, bone mass, etc.), it is often used in scientific publications that evaluated this type of high-performance athletes.

Thus, and although this is a limitation of the study, there seems to be a tendency for a lower BMI-for-age in gymnasts than average, according to recent scientific publications (Taboada-Iglesias, Gutiérrez-Sánchez & Santana, 2017; Silva & Paiva, 2015a).

In a study with 67 elite rhythmic gymnasts (18.7 ± 2.9 years), who trained 36.6 ± 7.6 hours per week, it was found that their body weight (48.4 ± 4.9kg) and BMI (17.4 ± 1.1kg/m^2) were below normal for age (between the 10th to 50th percentiles), while height (1.66 ± 0.05m) was normal or slightly elevated for age (between 50th to 75th percentiles, Silva & Paiva, 2015a).

Arazi et al. (2013) found average BMI values in Iranian artistic junior male gymnasts (19.6kg / m2), which were lower than those found in our study.

In another study with 82 Portuguese ACRO gymnasts (48 children and 34 adolescents), 23 female adolescents gymnasts (16.1 ± 2.1 years) training 17.6 ± 5.3 hours/week and 11 male adolescents (16.3 ± 2.7 years) training 19.9 ± 5.9 hours per week showed 21.0 ± 2.3kg/m^2 and 21.3 ± 3.1kg/m^2 for BMI, respectively (Silva, Silva & Paiva, 2018), which were below the normal for their age.

In contrast, Taboada-Iglesias, Gutiérrez-Sánchez & Santana (2017) evaluated 151 Spanish ACRO gymnasts (13.31 ± 3.1 years) and found that the tops suffered from underweight, especially female ones, and female bases had a normal body weight for their age.

It is noteworthy that Silva, Silva & Paiva (2018) found that 8.5% of the bases suffered from overweight (BMI> P85 and> P95 and fat mass> P50) and 2.4% also of the bases were obese (BMI> P95 and fat mass> P75) (Silva, Silva & Paiva, 2018), which may translate to a different evolution in ACRO than usual in other Gymnastics disciplines.

In a study evaluating the risk factors associated with the sleep of elite rhythmic gymnasts just before a major competition, BMI <18.5kg / m^2 was found to be a risk factor for: short-term sleep (OR = 2.05; 95% CI 0.49-8.70), reduced sleep quality (OR = 4.16; 95% CI 1.47-11.75) and abnormal daytime sleepiness (OR = 1.14 95% CI 0.93-1.38) (Silva & Paiva, 2019).

In the study of Galetta et al. (2015), in which 16 controls and 16 Italian rhythmic gymnasts were evaluated, it was found that the gymnasts' BMI was lower than controls' (16.9±1.1kg/m^2 vs. 18.7±1.0kg/m^2, P <0.001); this value is lower than that of our study. In addition, they concluded that intense training, eating behaviour and thinness were not associated with cardiac abnormalities, as is the pathological leanness.

Although the number of gymnasts' weekly training hours and their role in competition were not available, results from this study are in line with previous studies in other Gymnastics disciplines.

Differences observed may reflect an emphasis on a controlled body weight among gymnasts compared to the general population of adolescent girls and a reduced variation among gymnasts, which was also observed by Claessens et al. (2006), who considered elite gymnasts as a group being short compared to reference data for the general population. In fact, these authors have classified a small sample of the 17-year-old pre-menarcheal gymnasts as presenting idiopathic short stature as their mean stature was 153.8±8.7 cm, while the fifth percentile for the reference sample is 154.5 at 17.5 years (Simons et al., 1990). In addition, the mean mass for that group was 44.6±4.8 kg (Claessens et al., 2006), which was less than the fifth percentile of the Belgian reference sample, 46.3 kg (Simons et al., 1990).Gymnasts participating in the European Games 2015 presented an anthropometric profile below the normal for weight, height and BMI, according to their age. These results are based on a cross-sectional analysis of data from the official competition website, which reliability and validity are dependent on the accuracy of data collection, which was not from the authors' responsibility; therefore, caution is warranted in making inferences. Nevertheless, the trends apparent in this study highlight the need for longitudinal studies on the influence of body composition, food intake and regular training regime in high-performance gymnasts.

REFERENCES

Arazi, H., Faraji, H. & Mehrtash, M. (2013). Anthropometric and Physiological Profile of Iranian Junior Elite Gymnasts. *Physical Education & Sport*, *11*(1), 35-41.

Baldari, C. & Guidetti, L. (2001). VO2max, ventilatory and anaerobic thresholds in rhythmic gymnasts and young female dancers. *Journal of Sports Medicine and Physical Fitness*, *41,* 177-182.

Binder, A.J. (2011). *Medical information: weight management, nutrition and energy needs for gymnastics*. Féderation Internationale de Gymnastique, 1.

Claessens A.L., Lefevre J, Beunen G.P. & Malina R.M. (2006). Maturity-associated variation in the body size and proportions of elite female gymnasts 14-17 years of age. *European Journal of Pediatrics*, *165*(3):186-92.

Deutz, R. C., Benardot, D., Martin, D. E. & Cody, M. M. (2000). Relationship between energy deficits and body composition in elite female gymnasts and runners. *Medicine & Science in Sports & Exercise*, *32*, 659-668. doi:10.1097/00005768-200003000-00017

Donti, O., Bogdanis, G.C., Kritikou, M., Donti, A. & Theodorakou, K. (2016). The relative contribution of physical fitness to the technical execution score in youth rhythmic gymnastics. *Journal of Human Kinetics*, *2*(51), 143-152. doi:10.1515/hukin-2015-0183

European Games. (2015). *Baku 2015 – 1st European Games*. Available at: http://www.baku2015.com/

Frisancho, A. R. (2008). *Anthropometric standards: An interactive nutritional reference of body size and body composition for children and adults*. Ann Arbor: The University of Michigan Press. Retrieved from http://babel.hathitrust.org/cgi/pt?id=mdp.39015082696876;view=1up;seq=3

Galetta, F., Franzoni, F., D'Alessandro, C., Piazza, M., Tocchini, L., Fallahi, P., et al. (2015). Body composition and cardiac dimensions in elite rhythmic gymnasts. *Journal of Sports Medicine and Physical Fitness*, *55*(9), 946-52.

Georgopoulos, N.A., Theodoropoulou, A., Roupas, N.A., Rottstein, L., Tsekouras, A., Mylonas, P., et al. (2012). Growth velocity and final height in elite female rhythmic and artistic gymnasts. *Hormones*, *11*(1),61-9.

Mkaouer, B., Hammoudi-Nassib, S., Amara, S. & Chaabène, H. (2018). Evaluating the physical and basic gymnastics skills assessment for talent identification in men's artistic gymnastics proposed by the International Gymnastics Federation. *Biology of Sport*, *35*(4), 383-392. doi:10.5114/biolsport.2018.78059.

Michopoulou, E., Avloniti, A., Kambas, A., Leontsini, D., Michalopoulou, M., Tournis, S., et al. (2011). Elite premenarcheal rhythmic gymnasts demonstrate energy and dietary intake deficiencies during periods of intense training. *Pediatric Exercise Science*, *23*, 560-572.

Silva, M.-R.G. & Barata, P. (2016). Athletes and coaches’ gender inequality: the case of the Gymnastics Federation of Portugal. *Science of Gymnastics*, *8*(2), 187-196.

Silva, M.-R. G., & Paiva, T. (2015a). Low energy availability and low body fat of female gymnasts before an international competition. *European Journal of Sport Science*, *16*, 1-9. doi:101080/174613912014969323

Silva, M.-R.G., & Paiva, T. (2015b). Poor precompetitive sleep habits, nutrients' deficiencies, inappropriate body composition and athletic performance in elite gymnasts. *European Journal of Sport Science*, *27*, 1-10. doi:101080/1746139120151103316

Silva, M.-R.G. & Paiva, T. (2019). Risk factors for precompetitive sleep behavior in elite female athletes. *Journal of Sports Medicine and Physical Fitness*, *4*. doi:10.23736/S0022-4707.18.08498-0.

Silva, M.-R.G., Santos-Rocha, R., Barata, P., & Saavedra, F. (2017). Gender inequalities in Portuguese gymnasts between 2012 and 2016. *Science of Gymnastics*, *9*(2), 191-200.

Silva, M.-R.G., Silva, H.-H. & Paiva, T. (2018). Sleep duration, body composition, dietary profile and eating behaviours among children and adolescents: a comparison between Portuguese acrobatic gymnasts. *European Journal of Pediatrics*, *177*(6), 815-825. doi:10.1007/s00431-018-3124-z

Simons J., Beunen, G.P., Renson, R., Claessens, A.L., Vanreusel, B., & Lefevre, J.A.V. (1990) *Growth and fitness of Flemish girls.* Human Kinetics, Champaign, Ill.

Taboada-Iglesias, Y., Gutiérrez-Sánchez, Á. & Santana, M.V. (2016). Anthropometric profile of elite acrobatic gymnasts and prediction of role performance. *Journal of Sports Medicine and Physical Fitness*, 56(4), 433-42.

Corresponding author:

Maria-Raquel G. Silva*
Rua Carlos da Maia, 296
4200-150 Oporto
PORTUGAL
Tel: +351 22 5074630
Fax: +351 225074637
E-mail: raquel@ufp.edu.pt

RELATIONSHIP BETWEEN NUTRITION KNOWLEDGE AND AEROBIC FITNESS IN YOUNG GYMNASTS

Nazhif Gifari, Rachmanida Nuzrina, Mury Kuswari, Nabila Tri Hutami, Ayu Ghalda
Nutrition Department, Univesitas Esa Unggul, Indonesia

Original article

Abstract
This study aimed to analyze the nutrition knowledge, nutritional status, body composition, nutrient intake and physical fitness of young gymnasts. The study used a cross-sectional design with 20 subjects comprising rhythmic and artistic gymnasts in Raden Inten, Jakarta. Nutritional status and body composition were measured using anthropometric measurements, macronutrient and micronutrient intakes were measured with 3x24-h food recall, physical fitness was measured using the bleep test (20m shuttle run), and nutrition knowledge was assessed using questionnaires consisting of 30 questions on macronutrients, micronutrients and water. The results indicated that the gymnasts (n=20, 13.7±2.1 y.o, 37.8±8.2 kg and 147.3±10 cm) generally had a fairly good nutrition knowledge score (73.2%); i.e. 10 people in the good nutrition-knowledge group and 10 people in the poor nutrition-knowledge group. The majority of the macronutrient and micronutrient intakes were below the nutritional requirements, in both the good and poor nutrition-knowledge groups. The nutrition knowledge scores were low for hydration-related knowledge (66%), while the scores for macronutrient and micronutrient knowledge were 73.8% and 84.2%, respectively. This study found that nutrition knowledge had a positive correlation with physical fitness ($p<0.05$). A sports nutrition-related education intervention is needed for those gymnasts that still have poor nutrition knowledge. Sports nutrition knowledge needs to be provided for athletes and coaches so that athletes' intakes meet their nutritional requirements in order to maximise their performance.

Keywords: *nutrition knowledge, nutrient intake, physical fitness, young gymnasts.*

INTRODUCTION

Gymnastics is a type of sport characterised by unique movement skills. It is a form of physical exercise involving the systematic arrangement of selected and planned movements to achieve certain goals. As a sport, it relates to motor components such as strength, speed, balance, flexibility and accuracy (Douda, Toubekis, Avloniti & Tokmakidis, 2008; Suchomel, Nimphius & Stone, 2016). A nutrient intake that meets the nutritional requirement is needed in order to maximise the motor components and improve performance. Sleep quality, body composition and food intake are all factors that affect fitness (Silva & Paiva, 2016).

The nutrient intakes of gymnasts often do not meet their nutritional requirements, and this will have a negative impact on their body condition. Calcium and vitamin D deficiencies will also lead to bone health problems among athletes (Lovell, 2008). Athletes' nutritional requirements are influenced by many factors, such as their nutrition knowledge. Adequate nutrition knowledge will affect the ability to select good food for athletes. A previous study by Nikolaidis and Theodoropoulou (2014) demonstrated that good nutrition knowledge had an impact on the high levels of fitness and performance among soccer athletes in Australia.

From the results of research conducted by Silva and Paiva (2014) involving young gymnasts, most of them had macronutrient and micronutrient deficiencies that would have a negative effect on their growth and development. Thus, nutrition knowledge needs to be improved among both athletes and their coaches. The results of scientific reviews indicate that nutrition knowledge has a positive correlation with nutrient intake, although this correlation is still weak. Thus, it is necessary to conduct a follow-up study using more valid measurement tools in order to better describe these two variables (Desbrow & Mccormack, 2014; Naughton, Gifford, Michael, O'Connor & Heaney, 2016; Spronk, Kullen, Burdon & O'Connor, 2014).

Young gymnasts are a group at risk of micronutrient problems such as calcium, iron, folic acid, vitamin D and zinc deficiencies. Nutrition knowledge and nutrient intake arrangements that are appropriate to their requirements are needed to prevent these problems and help improve young gymnasts' immune systems and post-injury recovery (Dallas, Dallas, Simatos, & Simatos, 2017; Desbrow & Mccormack, 2014). Therefore, this study aimed to analyse the nutrition knowledge, nutritional status, body composition, nutrient intake and aerobic fitness of young gymnasts.

METHODS

This study used a cross-sectional design. The population in this study comprised 20 adolescent athlete gymnasts (5 male and 15 female) who trained at the Raden Inten Gymnastics Building in East Jakarta. The individuals in the research sample were rhythmic and artistic gymnasts aged 10–18 years that had participated in national and international championships. This study protocol was approved by the Ethics Committee of the Faculty of Health Sciences, Esa Unggul University (Number: 0014-19.595/DPKE-KEP/FINAL-EA/UEU/I/2019).

The anthropometric measurements performed consisted of height and weight measurements, while the percentage of body fat was determined using a body composition measurement. Height was measured using a microtoise (GEA SH-2A), while the WHO AnthroPlus standards were used to assess nutritional status. Weight and body fat percentage were measured using an Omron HBF-375.

The gymnasts' nutrient intakes were assessed using the 3x24-h food recall method taken for two days of training time and one day's rest. The macronutrient intakes included were carbohydrates, protein, fat and water, while the micronutrients were iron and calcium. Macronutrient and micronutrient intake were calculated by Indonesia Food Composition database.

The nutrition knowledge questionnaire was a modified questionnaire containing 30 questions on macronutrients, micronutrients and hydration. It comprised 13 macronutrient-related questions, 7 micronutrient-related questions and 10 hydration-related questions. The questionnaire was assessed for internal consistency and determined the level of nutrition knowledge of the young gymnasts. Nutrition knowledge was assessed as low if correct answers were given for less than 70% of the total questions, and high if correct answers were given for ≥70% of the total questions.

The aerobic fitness data were collected using the bleep test (20m shuttle run) in order to obtain the VO_2max scores (ml/kg/min). The VO_2max data (ml/kg/min) in this study were secondary data obtained from the strength and conditioning (SC) team at the Sports

Training Center for Students (STCS) and the Regional Training Center (RTC) in the Special Capital Region of Jakarta.

The data were analysed using Microsoft Excel 2010 and SPSS version 20. Univariate analysis was performed to obtain the distribution and proportion of the variables studied. This analysis was used to determine the association between the independent variables (i.e. nutrition knowledge, nutrient intake and body composition) and the dependent variable (fitness). The confidence interval used was 95%, and the association between the independent and dependent variables was significant if the p-value (Sig.) was ≤0.05. A p-value greater than 0.05 indicated there was no significant association between the independent and dependent variables.

RESULTS

A total of 20 subjects participated in this study, consisting of 8 rhythmic gymnasts and 12 artistic gymnasts. The main findings were that the young gymnasts had a good level of nutrition knowledge (74%). Overall, the artistic gymnasts had a higher level of nutrition knowledge than the rhythmic gymnasts. This study found that the gymnasts had a low level of hydration-related knowledge (66%). However, their levels of macronutrient and micronutrient knowledge were found to be relatively good (i.e. 73.8% and 84.2%, respectively). The nutrition knowledge categories can be seen in Table 1.

Based on the nutritional status data, most of the subjects had a normal nutritional status (-0.8±0.7 SD). The subjects' mean body fat percentage was 15.9±5.1%. The statistical analysis revealed no significant differences in nutritional status and body fat percentage between the two nutrition knowledge groups. Based on their nutrient intake, most of the gymnasts did not meet the adequate nutritional requirement in areas such as protein, fat, carbohydrates, iron and calcium. The nutritional status and nutrient intake data for each group are shown in Table 2.

Table 1
Nutrition knowledge categories.

No	Nutrition knowledge categories	All (n=20)	
		Mean (SD)	%
1	Macronutrient-related questions (13 points)	9.6 (0.3)	73.8
2	Micronutrient-related questions (7 points)	5.9 (0.2)	84.2
3	Hydration-related questions (10 points)	6.6 (0.2)	66.0
	Total	7.3 (0.2)	74.6

Table 3 shows the results of the correlation analysis between some of the variables and nutrition knowledge. The variables analysed were age, weight, height, body fat percentage, energy, protein, fat, carbohydrates, iron, calcium, water and VO_2max.

Table 2
Nutritional status, nutrient intakes and aerobic fitness by nutrition knowledge.

Variables	All (n=20)	Good NK (n=10)	Low NK (n=10)	p-value (between groups)
Nutritional Status				
Age (year)	13.7 ± 2.1	13.7 ± 2.1	12.8 ± 2	0.357
Weight (kg)	37.8 ± 8.2	38.4 ± 9.1	37.1 ± 7.5	0.722
Height (cm)	147.3 ± 10	149.1 ± 10.5	145.5 ± 9.8	0.445
BMI-for-age (SD)	-0.8 ± 0.7	-1.1 ± 0.7	-0.6 ± 0.8	0.132
Body fat (%)	15.9 ± 5.1	17.9 ± 3.0	13.9 ± 6.1	0.082
Nutrient Intakes				
Energy intake (kcal)	1613 ± 189.5	1695 ± 171	1531 ± 177	0.058
Protein (g)	57 ± 14.4	60 ± 7.5	53 ± 19	0.326
Fat (g)	65 ± 15.4	60 ± 16.2	69 ± 13.6	0.159
Carbohydrates (g)	195 ± 36.2	206 ± 32.8	184 ± 37.6	0.174
Fe (mg)	8.4 ±2.7	8.5 ± 2.3	8.2 ± 3.1	0.310
Calcium (mg)	1017.5 ± 175.5	1034.6 ± 201	1000 ±153.6	0.275
Water (ml)	1327 ± 252	1390 ± 148	1264 ± 321	0.278
Aerobic Fitness				
VO_2max (ml/kg/min)	42.1 ± 4.4	44.3 ± 1.9	40.0 ± 5.2	0.028*

Note: BMI-for-age = body mass index-for-age
∗ Nutrition knowledge determined by independent-samples t tests, $p < 0.05$

Table 3
Pearson's correlation of nutrition knowledge.

Variable	Pearson r
Age (year)	- 0.006
Weight (kg)	- 0.035
BMI-for-age (SD)	- 0.225
Body fat (%)	0.441
Energy intake (kcal)	- 0.488
Protein (g)	- 0.213
Fat (g)	- 0.353
Carbohydrates (g)	- 0.264
Fe (mg)	0.180
Calcium (mg)	-0.192
Water (ml)	0.287
VO2max (ml/kg/min)	0.512*

Note: BMI-for-age = body mass index-for-age
$*p<0.05$

DISCUSSION

As a whole, the gymnasts' level of nutrition knowledge was good (73.2%). Based on the nutrition knowledge levels, 25% of the rhythmic gymnasts and 35% of the artistic gymnasts had good nutrition knowledge. All of the rhythmic gymnasts were female but their nutrition knowledge was low, while female athletes are at risk if their nutritional requirements are not met. In a previous study, Spronk *et al*. (2014) found that the nutrition knowledge of female athletes was higher than that of male athletes, and the correlation was statistically positive but weak. Based on its results, the study stressed the importance of increasing knowledge through education, especially among male athletes. Nutrition knowledge plays an important role in eating behaviour, and thereby it can be used as a method for improving performance (Holden, Forester, Smith, Keshock, & Williford, 2018; Trakman, Forsyth, Devlin, & Belski, 2016).

While body composition is one of the factors affecting an athlete's performance, body fat percentage is the main variable in young athletes. Muscle mass is one of the components of body composition and works to maximise movements during training and competition (Malina & Geithner, 2011). Body fat percentage is affected by growth, development, diet and exercise. The results of this study show that the mean body fat percentages for all athletes, the good nutrition-knowledge group and the poor nutrition-knowledge group were 15.9±5.1%,

17.9±3.0% and 13.9±6.1%, respectively. Compared to the standards, these body fat percentages fell within the normal cut-off (<20%) and were in the optimal category. The gymnasts had a normal body mass index (BMI), high muscle mass, low body fat percentage and better physical fitness. However, all the gymnasts were late for menarche (Ávila-Carvalho, Klentrou, Palomero, & Lebre, 2012).

The survey results from a previous study (Kolimechkov, Yanev, Kiuchukov, Petrov, Alexandrova, Zaykova & Stoimenov, 2019) indicated that protein intake was sufficient but carbohydrate intake needed to be increased, while fat intake from food was reduced due to excessive intake. However, based on the statistical analysis, there was no difference in energy intake among the Bulgarian gymnasts in the study. In the current study, the good nutrition-knowledge group had better energy intake (1695±171 kcal) than the poor nutrition-knowledge group (1531±177 kcal). The statistical analysis indicated that there was no significant difference (p>0.05) in energy intake among the gymnasts based on nutrition knowledge. Overall, the good nutrition-knowledge group had better energy intake, although both groups were below the recommended levels for gymnasts' energy requirements (Desbrow (McCormack, 2014). The results of a study on soccer athletes (Devlin, Leveritt, Kingsley, & Belski, 2017) showed that while nutrition knowledge was positively correlated with nutrient intake, the correlation was not consistent. Thus, an education intervention focusing on increasing sports nutrition knowledge in athletes is needed. In addition to this, the factors that can help increase their performance need to be studied. Another study (Hoogenboom, Morris, Morris, & Schaefer, 2009) indicated that swimmers had low levels of nutrition knowledge; therefore, they were not achieving a balanced diet, which results in macronutrient and micronutrient deficiencies. Therefore, athletes, whether adolescents or adults, should have good nutrition knowledge.

Vitamin D and calcium intakes play a very important role in bone density. The results of a study on gymnasts in Australia (Lovell G, 2008) indicated both vitamin D deficiency and low calcium intake. The current study also found a relatively low calcium intake. The mean iron intake of both groups was 8.4±2.7 mg, with neither group meeting the nutritional requirement. Previous research (M., O., & H., 2004) indicated that gymnasts were at risk of iron deficiency, one of the causal factors for which was exercise. The current study found higher levels of calcium and iron intake in the good nutrition-knowledge group, although these were still below the recommended nutritional requirements. The results of a previous study (Karabudak, Köksal, Ertaş, & Küçükerdönmez, 2016) showed that gymnasts in Turkey had not implemented a balanced diet and they therefore experienced nutrient deficiencies. Thus, sports nutrition education is needed to maximise performance through a balanced diet.

While the gymnasts had good nutrition knowledge regarding macronutrients with a score of 84.2%, the scores for sports nutrition supplements for athletes were low. If this result is associated with the previous study (Marco Malaguti, Michele Scarpino, Cristina Angeloni, 2019), then the nutrition supplement knowledge of the soccer athletes was still low. Thus, education is also needed with regard to knowledge of the nutritional contents of sports supplements that are useful for improving performance.

Water is one of the important macronutrients required by the body. Dehydration of ≥2% has an impact in terms of decreased fitness and performance. From the results of this study, the gymnasts had a low nutrition knowledge score regarding hydration (66%). Based on the 24-h food recall, water intake was low in both groups with a mean of 1327±252 ml. Nutrition education is one of the methods that can be used to increase nutrition knowledge about hydration. The results of a previous study (Pamela, Gallagher, & Jacqueline M. McCormack, 2011) showed that most athletes with low nutrition knowledge about hydration experienced dehydration of less than 1%, resulting in decreased performance and cognitive function. Special nutrition education for athletes is thus needed in order to both enhance performance and prevent bad performance.

This study found a moderate correlation between the nutrition knowledge and aerobic fitness of the gymnast participants. Although the same result has been reported elsewhere (Nikolaidis & Theodoropoulou, 2014), it was also indicated by that study that good nutrition knowledge would contribute to the high fitness levels and performance of soccer athletes in Australia. It is possible to improve the nutrient intake and nutrition knowledge of athletes through sports nutrition education delivered by sports nutritionists (Valliant, Pittman, Wenzel, & Garner, 2012). As such, there is a need for optimal nutrition education to be provided by registered sports nutritionists.

The limitation of this study is that the nutrition knowledge questionnaire did not fully cover the nutrition knowledge of the gymnasts. Measurements of nutritional status such as muscle mass and biochemical indicators (e.g. hemoglobin and serum ferritin measurements) can also be undertaken to obtain optimal results. The results of this preliminary study may be used as a reference for sports nutrition education intervention, especially for gymnasts.

CONCLUSION

Most of the gymnasts in this study had good nutrition knowledge, although they had low scores with respect to the hydration-related questions. The study found a moderate positive correlation between the nutrition knowledge and aerobic fitness of the gymnasts. Good nutrition knowledge is required to ensure sufficient nutrient intake that meets the nutritional requirements and to achieve good nutritional status.

ACKNOWLEDGMENTS

We would like to thank all of the athletes, parents and coaches for their participation in and commitment to the study. The authors also express their gratitude to Ovie and the sports nutrition team for their technical assistance with the diet analysis and data collection.

REFERENCES

Ávila-Carvalho, L., Klentrou, P., Palomero, M. da L. & Lebre, E. (2012). Body composition profile of elite group rhythmic gymnasts. *Science of Gymnastics Journal*, *4*(1), 21–32.

Dallas, G.C., Dallas, C.G., Simatos, E.J. & Simatos, J.E. (2017). Nutritional recommendations and guidelines for women in gymnastics: Current aspects and critical interventions. *Science of Gymnastics Journal*, *9*(1), 27–40.

Desbrow, B. & Mccormack, J. (2014). *Sports Dietitians Australia Position Statement: Sports Nutrition for the Adolescent Athlete Medical aspects of Olympic diving View project PEACH™ Queensland View project*. 570–584. https://doi.org/10.1123/ijsnem.2014-0031

Devlin, B. L., Leveritt, M. D., Kingsley, M. & Belski, R. (2017). Dietary intake, body composition, and nutrition knowledge of Australian football and soccer players: Implications for sports nutrition professionals in practice. *International Journal of Sport Nutrition and Exercise Metabolism*, *27*(2), 130–138. https://doi.org/10.1123/ijsnem.2016-0191.

Douda, H.T., Toubekis, A.G., Avloniti, A.A. & Tokmakidis, S.P. (2008). Physiological and anthropometric determinants of rhythmic gymnastics performance. *International Journal of Sports Physiology and Performance*, *3*(1), 41–54. https://doi.org/10.1123/ijspp.3.1.41

Holden, S.L., Forester, B.E., Smith, A. L., Keshock, C. M. & Williford, H. N. (2018). Nutritional Knowledge of Collegiate Athletes. *Applied Research in Coaching & Athletics Annual*, *33*, 65–77.

Hoogenboom, B.J., Morris, J., Morris, C. & Schaefer, K. (2009). Nutritional knowledge and eating behaviors of female, collegiate swimmers. *N Am J Sports Phys Ther* *4*(3):139-48.

Karabudak, E., Köksal, E., Ertaş, Y. & Küçükerdönmez, Ö. (2016). Dietary intake of Turkish gymnast and non-gymnast children. *Nutrition and Dietetics*, *73*(2), 184–189. https://doi.org/10.1111/1747-0080.12191

Kolimechkov, S., Yanev, I., Kiuchukov I., Petrov, L., Alexandrova, A., Zaykova, D., & Stoimenov, E. (2019). Nutritional status and body composition of young artistic gymnasts from Bulgaria. *Journal of Applied Sport Science*, *1*, 39-52.

Lovell, G. (2008). Vitamin D Status of Females in an Elite Gymnastics Program. *Clinical Journal of Sport Medicine*, *18*(2), 159–161. https://doi.org/10.1097/JSM.0b013e3181650eee

Pouramir, M., Haghshenas, O. & Sorkhi H. (2004). Effects of gymnastic exercise on the body iron status and hematologic profile. *Iranian Journal of Medical Sciences*, *29*(3), 140–141.

Malina, R. M. & Geithner, C. A. (2011). Body Composition of Young Athletes. *American Journal of Lifestyle Medicine*, *5*(3), 262–278. https://doi.org/10.1177/1559827610392493

Malaguti, M., Scarpino, M., Angeloni, C. & Hrelia, S. (2019). The use of dietary supplements among soccer referees : How much do they know ? *Journal of Human Sports & Exercise*, *14*(4), 856-865. https://doi.org/10.14198/jhse.2019.144.14

Naughton, G., Gifford, J., Michael, S., O'Connor, H. & Heaney, S. (2016). Nutrition Knowledge in Athletes: A Systematic Review. *International Journal of Sport Nutrition and Exercise Metabolism*, *21*(3), 248–261. https://doi.org/10.1123/ijsnem.21.3.248

Nikolaidis, P. T. & Theodoropoulou, E. (2014). Relationship between Nutrition Knowledge and Physical Fitness in Semiprofessional Soccer Players. *Scientifica*, 1–5. https://doi.org/10.1155/2014/180353

Magee, P.J., Gallagher, A.M. & McCormack, J.M. High Prevalence of Dehydration and Inadequate Nutritional Knowledge Among University and Club Level Athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *27*(2), 158-168. http://dx.doi.org/10.1123/ijsnem.2016-0053

Silva, M.R.G., & Paiva, T. (2016). Poor precompetitive sleep habits, nutrients' deficiencies, inappropriate body composition and athletic performance in elite gymnasts. *European Journal of Sport Science*, *16*(6), 726–735. https://doi.org/10.1080/17461391.2015.1103316

Spronk, I., Kullen, C., Burdon, C., & O'Connor, H. (2014). Relationship between nutrition knowledge and dietary intake. *British Journal of Nutrition*, *111*(10), 1713–1726. https://doi.org/10.1017/S0007114514000087

Suchomel, T.J., Nimphius, S., & Stone, M. H. (2016). The Importance of Muscular Strength in Athletic Performance. *Sports Medicine*, *46*, 1419-1449. https://doi.org/10.1007/s40279-016-0486-0

Trakman, G. L., Forsyth, A., Devlin, B. L., & Belski, R. (2016). A systematic review of athletes' and coaches' nutrition knowledge and reflections on the quality of current nutrition knowledge measures. *Nutrients*, *8*(9), 570. https://doi.org/10.3390/nu8090570

Valliant, M.W., Pittman, H., Wenzel, R.K. & Garner, B.H. (2012). Nutrition education by a registered dietitian improves dietary intake and nutrition knowledge of an NCAA female volleyball team. *Nutrients*, *4*(6), 506–516. https://doi.org/10.3390/nu4060506

Corresponding author:

Nazhif Gifari
Universitas Esa Unggul
Jalan Arjuna Utara No.9, Blk. I No.2, RT.1/RW.2,
Duri Kepa, Kec. Kb. Jeruk, Kota Jakarta Barat,
Daerah Khusus Ibukota Jakarta 11510, Indonesia
Phone: +62 821-2362-4308
Email: nazhif.gifari@esaunggul.ac.id

ESTIMATING HORIZONTAL DISPLACEMENT DEDUCTION IN TRAMPOLINE GYMNASTICS BY MEANS OF CONSTANT AND VARIABLE ERRORS OF LANDING POSITIONS: A NEW GOLD STANDARD?

Katja Ferger[1], Fabian Helm[2] and Karen Zentgraf[2]

[1] Institute of Sport Science,University of Gießen, Germany
[2] Institute of Sport Science, University of Frankfurt, Germany

Original article

Abstract

The final result in competitive trampoline gymnastics is composed of different subscores. These contribute differentially to the final score and result in a gymnast's ranking. The present study was designed to investigate the impact that alternative score calculations of the horizontal displacement of the landing positions on the trampoline's cloth would have on the final competition result. Different approaches for determining a precision measure were compared to the current standard of horizontal displacement deduction. These approaches for calculating precision measures were: (a) "total distance," (b) the "convex-hull approach," and (c) the "error approach." Results showed that an alternative approach was more precise and differentiated better between gymnasts. The resulting changed rankings are compared to the official final score of the competition in order to demonstrate the impact of alternative calculations.

Keywords: *trampoline gymnastics, constant error, variable error, performance.*

INTRODUCTION

Trampoline competitions comprise three routines each containing 10 elements. In the qualifying rounds, gymnasts perform a set routine; in the finals, a voluntary routine. The first routine in the preliminary round (set) includes 10 stated skills. In a competition, the judges' task is to evaluate a particular routine and to generate a total score for this routine based on evaluating the overall degree of difficulty (DD), the overall skill execution (E), the measurement of time-of-flight duration (ToF), and the recently added measurement of horizontal displacement (HD; see regulations of the Fédération Internationale de Gymnastique, FIG Executive Committee (2017). According to the FIG regulations, the degree of difficulty, execution, time of flight, and horizontal displacement scores are added to produce a final total value by means of the following equation:

Total Value = DD + E (max. 20 pts) + ToF + HD (max. 10 pts) - penalty deductions

For a long time, the total value in trampoline competitions consisted of two variables: the degree of difficulty and the overall skill execution. To make trampoline gymnastics more attractive and the evaluation of gymnasts more objective, the technical committee of the FIG introduced the time of flight (ToF) as a new performance value in 2010. The intention was to provide an additional, objective criterion for evaluating athletes' performance. At the same time, trampoline device manufacturers improved the technology of top-class trampolines resulting in higher ejection forces of the trampoline bed and, in turn, longer ToF values. However, this also increased the risk as a result of performing more spectacular routines with potential injury-prone outcomes (Grapton, Lion, Gauchard, Barrault, & Perrin, 2013). To control this risk factor, the technical committee together with the device manufacturers defined a maximal extent of ejection force (see FIG Executive Committee, 2017, for more details). This definition should decrease injury risks while maintaining the sport's attractiveness. Unfortunately, however, numerous injuries demonstrated that defining a maximal extent of ejection forces did not suffice to reduce the risk of injuries (Edouard et al., 2018). As a consequence, the number of break-offs increased tremendously in the following years, making trampoline gymnastics rather less attractive than before. In response, the Technical Committee introduced another weighting criterion, the Horizontal Displacement (HD) value, to reward a jumping pattern closer to the center of the cloth. To measure this HD value, a device used for ToF measurement based on ground reaction forces of the trampoline rack (Horizontal Displacement Trampoline System, Lenk, Hackbarth, Mylo, Weigand, & Ferger, 2016) was now also installed to calculate the athletes' landing positions on the trampoline bed.

The idea behind introducing the HD deduction was to reconstitute a higher level of safety that should result in a lower number of break-offs. In addition, the HD value should make results more precise and fairer. However, the current computation of HD is based on deductions in defined rectangular landing zones on the trampoline bed (see Figure 1). This implies that merely a minor displacement in landing positions between two jumps could mean either a major deduction or none at all, thereby not representing a fine-scaled differentiation between athletes' performances. This article aims to suggest a more objective, precise, safe, and feasible way to include HD values from HDTS into the total evaluation of athletes' performance.

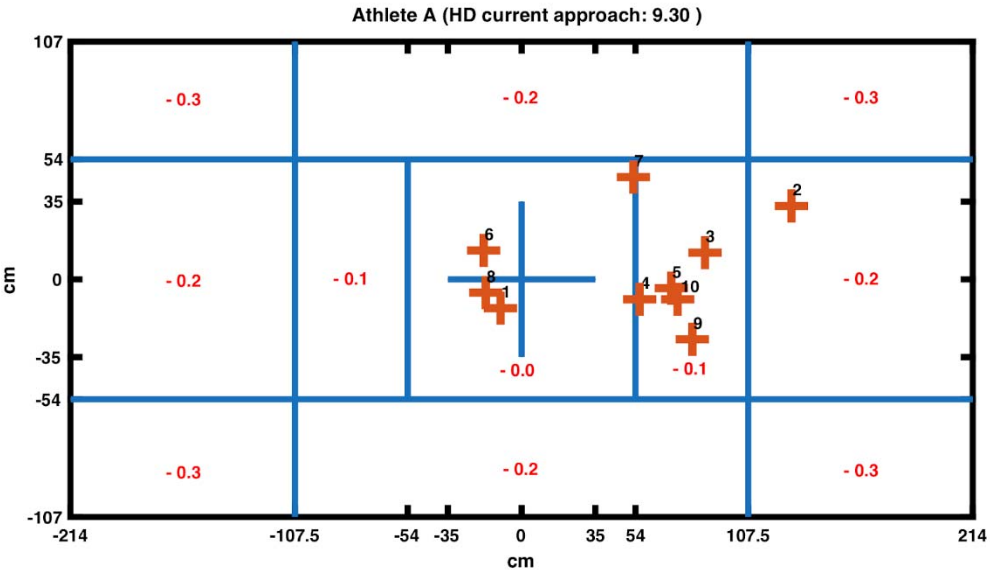


Figure 1. Current HD deduction. Visualization of the different deduction zones and their corresponding deduction value per jump when the landing position is located in the respective zone/rectangle. A representative distribution of jumps of a male athlete during the 2018 German Cup Final is added to the figure to visualize his HD deduction by means of the current "Code of Points" (FIG, 2017).

Two important questions arise when considering the history of implementation of the ToF and HD values in the past years (see Ferger, Zhang, Kölzer, Tiefenbacher, & Müller, 2013; Ferger & Hackbarth, 2017; Lenk et al., 2016): (1) Which role do each of the two variables play in the evaluation of routines in trampoline gymnastics? (2) Which impact does a new HD value have on the final result of a competition when different computations are based on measuring the landing position after each element? The current procedure for addressing Question 1 is as follows: According to the "Code of Points" in the FIG Executive Committee (2017) regulations, the HD value can reach a maximum of 10.0 points. Given the landing position after each element, HD-deduction values are subtracted from this maximum. The current calculation of HD is determined by the deduction of different values (from 0 to 0.3 per jump) derived from partitioning landing positions into different zones (see Figure 1). The landing position is calculated by the HDTS, which measures any force applied to the trampoline bed. The specific relation of ground reaction forces acting on the rack determines the specific landing position on the cloth (see Ferger & Hackbarth, 2017; Lenk et al., 2016, for more details). Using the landing positions of the HDTS, a deduction will apply for each element when any part of the body touches the cloth outside the outer line of the defined zones. Landing in a square zone in the center of the trampoline (108 cm in the longitudinal and 108 cm in the transversal axis; see Figure 1) is the safest landing position after a routine and results in no HD deduction. Landing outside this square zone but in a rectangle of 215 cm longitudinal and 108 cm transversal extent (centered with respect to the midpoint of the trampoline) results in an HD deduction of 0.1 points. Landing outside this rectangle (215 cm x 108 cm) but in a further rectangle of 428 cm longitudinal and 107 cm transversal extent results in an HD deduction of 0.2 points. Landing on the edges outside this rectangle (428 cm x 107 cm) results in an HD deduction of 0.3 points. If all 10 jumps are executed, the maximum possible HD-deduction score can reach 3.0 points, this being the case when all 10 jumps land in the edges outside the rectangle that spans 428 cm longitudinally and 107cm transversally. In comparison, and according to § 21.3 in the "Code of Points" of the FIG Executive Committee (2017), the greatest possible deduction for overall skill execution (E score) can be 5.0 points. Therefore, the current implementation of a precision criterion by means of HD has only a marginal impact on differentiating the final performance, because quite different positions on the bed can lead in sum to the same HD values.

For Question 2, two common measures of error for evaluating outcome in motor skills have been used (Chapanis, 1951, p. 1187). These two measures of error—constant (CE) and variable error (VE)—represent two distinct aspects of performance: bias and variability respectively. CE provides data on how far the outcome has shifted away from the target (i.e., in darts: the distance to bull's eye or the overall accuracy). VE yields information on how variable performance is based on several repetitions—without reference to the target, but with reference to all the other repetitions (i.e., in darts: the inconsistency of 10 throws in a row). In trampoline, both errors are relevant: Due to safety rules, the gymnast should land close to the center of the cloth (CE) as well consistently close to the center (VE, small variability).

Therefore, HD should be counted in terms of the real displacement from the central point. In the error approach proposed here, the displacement (CE) in the longitudinal direction with respect to the center of the trampoline increases from 0.1 to 0.3 points to the outside in all directions and not just in the corners as in the current approach. In addition, depending on the deviation from the midpoint, the displacement in the transverse direction

(VE) increases more rapidly to 0.3 points, because landing in lateral zones is more dangerous. Safety-relevant deviations from the midpoint would then be recorded in a more differentiated manner.

The present study aims to investigate the impact of different HD computations on to the total competition score in trampoline gymnastics. Three different approaches are presented and discussed with respect to the impact they may have on decreasing the risk of major injuries due to unsafe landing patterns by having a differentiating impact (with respect to safe and unsafe jumping patterns) on the total value of the routine performance. Hence, our aim is to determine a reliable, precise, objective, and differentiating HD value that also rewards gymnasts for safe landing patterns.

METHODS

In order to analyze the individual contribution of HD to the total value of a trampoline routine, we used the rankings of the 2017 World Cup Final (Men and Women) in Valladolid, Spain as well as the 2018 Germany Cup Final (Men and Women) in Hamburg. We then compared these rankings and HD values when applying different alternative approaches to compute a HD deduction. For all our computations, we used the HDTS data that reliably measure the horizontal landing position on the trampoline bed (Ferger, Hackbarth, Mylo, Müller, & Zentgraf, 2019). Based on the abscissa and ordinate of the landing positions, we applied three different measures to numerically evaluate the jumping pattern of a 10-jump trampoline routine. For all three measures, the total possible HD deduction amounts to 3.0 and the deduction from 0 points increases stepwise by 0.05 points. To transform the numeric measures of all three approaches into HD values, we used exemplary jumping patterns (see Figure 2) for a just near-to-optimal jumping distribution (see Figure 2A) and a maximally poor jumping distribution (see Figure 2B). We assumed that a just near-to-optimal jumping distribution would be distributed across the inner square around the center of the trampoline (108 cm in the longitudinal and 108 cm in the transversal axis), whereas a maximally poor jumping pattern would be distributed around the edges of the outer rectangle (428 cm x 214 cm).

1. Total Distance Approach

This approach calculates the sum of the distances of each individual landing position from the center of the trampoline resulting in a total distance value. Using our exemplary jumping patterns, we transformed the total distance of the near-to-optimal jumping pattern (d_{min}= 338.0 cm) into a HD deduction of 0.0 points, whereas the total distance of the maximally poor jumping pattern (d_{max}= 1991.7 cm) was transformed into a HD deduction of 3.0 points. Deduction increased stepwise from 0 points by 0.05 points. Distances between d_{min} and d_{max} were transformed linearly into HD deduction values between 0 and 3.0 points. Figure 3A shows a jumping pattern performed during the 2018 German Cup Final applying the total distance approach for HD deduction.

2. The Convex Hull Approach

This method uses the surface area of the convex hull (Hemmer & Schmidt, 2008) to calculate the size of the area used by the athletes. In this case, we defined the convex hull as the smallest area on the trampoline bed including all 10 landing positions. After defining the landing positions that form the convex hull, we calculated the size of the surface area of this hull. Using our exemplary jumping patterns, we transformed the size of the surface area of the just near-to-optimal jumping pattern (A_{min} = 4900 qcm) into an HD deduction of 0 points, whereas we transformed the total distance of the maximally poor jumping pattern (A_{max} = 91592 qcm) into an HD deduction of 3.0 points. We increased deduction stepwise by 0.05 points, and transformed area sizes between A_{min} and

A_{max} linearly into HD deduction values between 0 and 3.0 points. Figure 3B shows a jumping pattern performed during the 2018 German Cup Final applying the convex hull approach for HD deduction.

3. The Error Approach

This approach is based on two common accuracy measures evaluating performance results in motor skill execution (Chapanis, 1951, p. 1187). The first measure to be considered is the constant error (CE) of the landing position in relation to the center of the trampoline bed. We defined CE as the sum of all distances from the target (center of the trampoline bed) divided by the total number of jumps performed: the higher the CE, the poorer the jumping performance with respect to the precision of the jumping pattern. The second measure is the variable error (VE) of the landing position. We defined VE as the square root of the sum of squares of the mean landing position subtracted from the landing position of each jump divided by the total number of jumps performed: the higher the VE, the poorer the jumping performance with respect to the stability of the jumping pattern.

In our approach, we combined both accuracy values to compute an accuracy score that integrates the precision and stability of performance regarding the HD on the trampoline bed. We double-weighted the ordinate of each landing position to control the differences of the bed length in the abscissa (428 cm) versus the ordinate (214 cm) axes. This adjustment in weighting was necessary in order to guarantee that the extent of deviation would be of equal value in both directions. We also double-weighted landing positions that were 107.5 cm off-center in the abscissa and/or 54 cm off-center in the ordinate axes in order to penalize certain unsafe landing areas in a stronger way.

To determine the calculation of the error approach precisely, we carried out the following steps: (a) Prior to all CE or VE measures, we controlled differences in bed length by multiplying the landing position in the ordinate by 2. (b) Using these adjusted landing coordinates, we calculated the distance D of each landing position with regard to the coordinate center (D = sqrt[xi^2 + 2 * yi^2]). We gave double weight to the y-axis in order to penalize certain unsafe landing areas in this direction in a stronger way (safety adjustment). (c) Using the distance measures for each individual jump, we calculated CE and VE with the following equations: CE = sum(Di)/N, VE = sqrt(sum((Di-Mi)^2/N)). Using CE and VE, we calculated an error value E = CE + VE.

Taking all these requirements into account, we calculated an accuracy value and transformed it into an HD deduction between 0 and 0.3 points after each individual jump. We increased deduction stepwise by 0.05 points. We used the exemplary jumping patterns shown in Figure 2 as references for no HD deduction (see Figure 2A) and maximum HD deduction (see Figure 2B). Figure 3C shows a jumping pattern performed during the 2018 German Cup Final applying the accuracy (precision and stability) approach for HD deduction.

At last, we used the data of the preliminary contest of both competitions to review the different approaches. We hypothized to find differences in the approaches based on stable and variable conditions. The first routine in the Qualifying Round are often the basic exercises, characterized by more stable jumping patterns and less degree of difficulty. The second routine in the Qualifying Round are voluntary routines with a higher degree of difficulty and variable jumping pattern. Therefore, individual trampoline results were collected for men and women from different age groups (N=172 routines). The individual results for the two requirements (stable und variable pattern) were gathered from the HD measurement device. Overall, four different HD scores for each participant of qualification were noted for later data analysis.

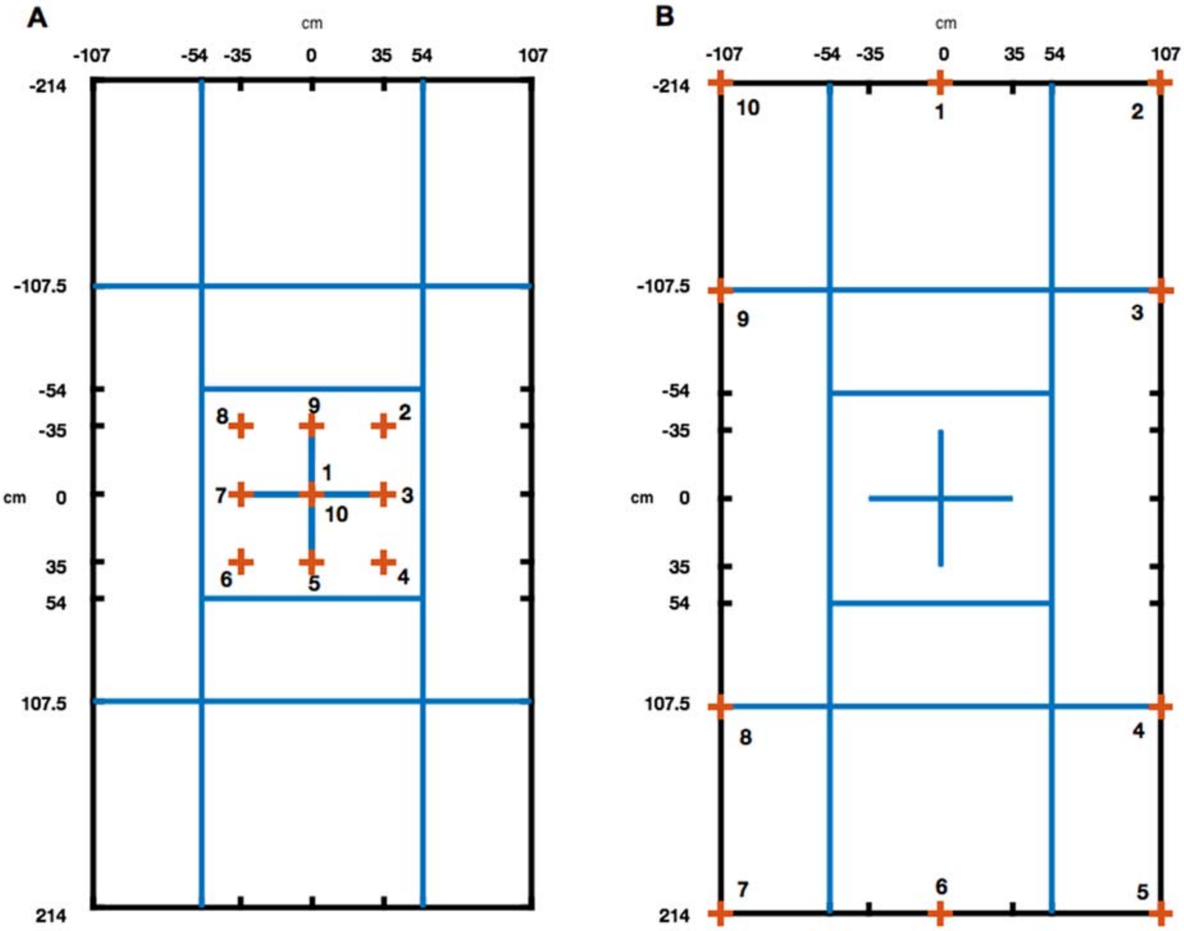


Figure 2. Exemplary jumping patterns. The pattern in Figure 2A represents a just near-to-optimal jumping pattern that does not result in any HD deduction. We suggest using this pattern as the no-deduction reference to scale the metrics computed in Approaches 1 to 3. The pattern in Figure 2B represents a maximally poor jumping pattern that results in maximum HD deduction. We suggest using this pattern as the maximum deduction reference to scale the metrics computed in Approaches 1 to 3.

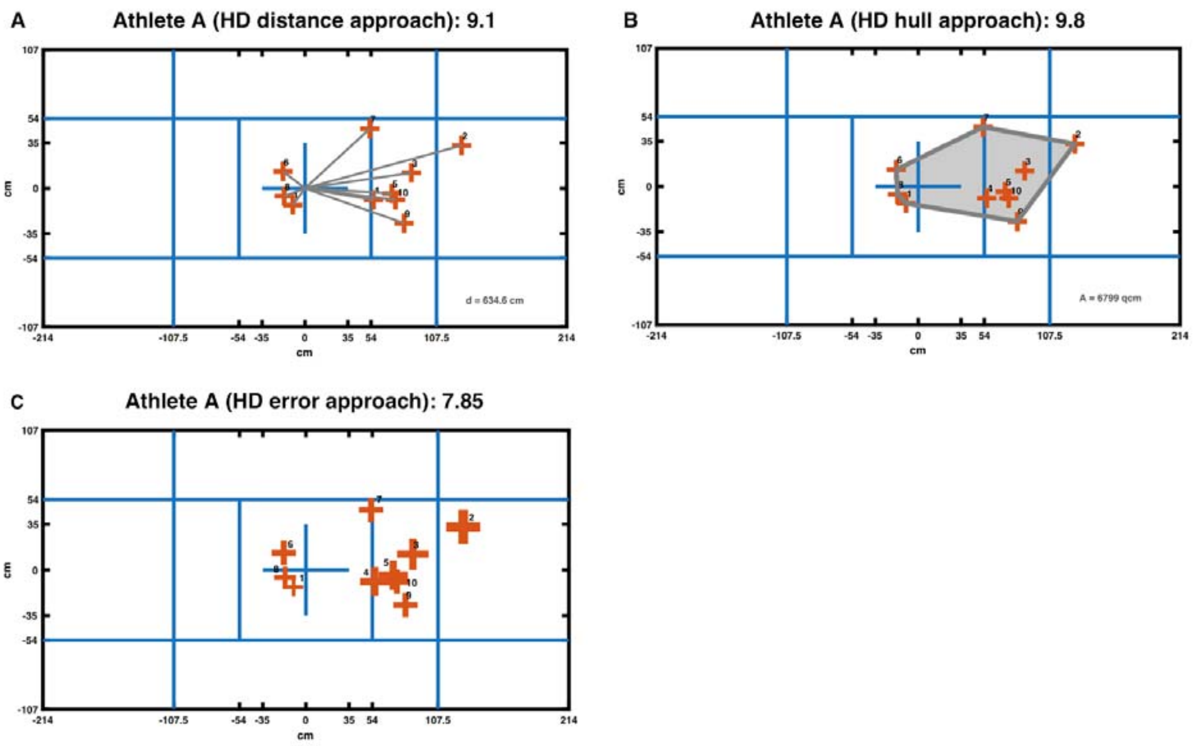


Figure 3. Alternative HD calculation approaches.

Figure 3A. Total distance approach. Visualization of a male athlete's jumping distribution during the 2017 German Cup Final illustrating the total distance measurement approach. According to the transformation of the numerical distance value (d = 634.6 cm), this jumping distribution would result in an HD value of 9.1.

Figure 3B. Convex hull approach. Visualization of a male athlete's jumping distribution during the 2017 German Cup Final illustrating the convex hull approach. The grey area illustrates the trampoline bed area used by the athlete. According to the transformation of the numerical size of the surface area of the convex hull (6799 qcm) including all 10 jumps, this distribution of landing positions would result in an HD value of 9.8.

Figure 3C. Error approach. Visualization of a male athlete's jumping distribution during the 2017 German Cup Final illustrating the precision and stability measurement approach based on common accuracy measures used in motor skill learning. Size and thickness of the red crosses indicate the amount of deduction for the corresponding jump. Bigger and thicker crosses indicate a higher deduction. According to the transformation of the numerical accuracy value after all 10 jumps, this distribution of landing positions would result in a HD value of 7.85.

RESULTS

Looking at the distributions of HD values for the calculations using Approaches 1 to 3 for both competitions, it became obvious that the different approaches demonstrated significant differences in the distributions of HD values across all athletes taking part in the finals (see Tables 1–2 and Figures 4–5).

During the 2017 World Cup finals in Valladolid, two judges who were responsible for evaluating the horizontal displacement determined the HD value. Their marks were averaged and used as a score for the horizontal displacement as provided in §18.2.6.3 Code of Points. The electronic measurement device HDTS was in use at the same time, but these values were not included in the final evaluation. Furthermore, the table indicates differences between the judges' scores and the measurement device. These differences will be taken into account and explained in the discussion.

Table 1
Athlete's Results in the 2017 World Cup Final Competition in Valladolid, Spain.

Rank	Female athletes	E	DD	ToF	HD	HDTS	P	Total	HDTS cur	HD dist.	HD hull	HD error
1	ZHU X.	17.60	14.4	16.305	9.45	9.5		57.755	9.5	9.55	9.95	9.40
2	PAVLOVA Y.	16.20	15.0	16.495	9.10	9.3		56.795	9.3	8.70	9.90	9.15
3	PIATRENIA T.	16.10	15.0	16.265	9.05	9.3		56.415	9.3	8.95	9.85	9.00
4	GALLAGHER L.	16.70	14.2	16.190	9.20	9.4		56.290	9.4	9.00	9.90	9.15
5	MORI H.	17.40	12.0	16.685	8.95	9.5		55.035	9.5	9.25	9.75	9.10
6	KOCHESOK S.	15.50	14.4	15.970	9.20	9.2	0.2	54.870	9.2	8.80	9.80	9.25
7	GOLOVINA L.	15.10	11.5	15.145	7.75	9.1		49.495	9.1	8.65	9.30	8.80
8	ZHONG X.	4.80	4.9	5.025	2.50	3.3		17.225	3.3	3.30	3.80	3.25
Rank	Male athletes											
1	DONG D.	16.90	17.8	17.760	8.80	9.5		61.260	9.5	9.45	9.75	9.35
2	SCHMIDT D.	17.00	17.8	17.965	8.50	9.3	0.4	60.865	9.3	8.95	9.70	8.90
3	USHAKOV D.	17.00	17.3	17.765	8.60	9.4		60.665	9.4	9.20	9.80	9.30
4	KISHI D.	16.60	17.1	17.485	8.65	7.9		59.835	7.9	8.00	8.55	7.90
5	TU X.	15.60	17.8	16.945	8.65	9.0	0.4	58.395	9.0	9.00	9.90	9.15
6	HERNANDEZ A.	14.00	17.6	16.775	8.95	9.1		57.325	9.1	9.00	9.65	8.95
7	MARTIN J.	14.60	16.1	17.520	8.80	8.7		57.020	8.7			
8	HANCHAROU U.	10.00	11.4	10.875	5.35	5.3		37.625	5.3	5.35	5.80	5.25
9	AZARIAN S.	9.90	10.7	11.130	5.30	6.0		37.030	6.0	6.05	6.65	5.95

Note: HD was determined by judges as well as by the HDTS during this competition. In the calculation of the result, however, only the values of the judges were included.

Table 2
Athlete's results in the 2018 Germany Cup Final Competition in Hamburg, Germany.

Rank	Female 11/12	E	DD	ToF	HD	HDTS	P	Total	HDTS cur	HD dist.	HD hull	HD error
1	MÖLLER M.	16.5	8.9	14.180	9.5	9.5		49.080	9.5	9.15	9.95	9.50
2	RONSIEK H.	16.1	6.5	14.725	9.3	9.3		46.625	9.3	8.90	9.60	8.95
3	EISLÖFFEL A.	15.3	7.8	13.135	9.5	9.5		45.735	9.5	8.95	9.70	9.35
4	KELM J.	13.8	6.7	14.095	9.5	9.5		44.095	9.5	9.25	9.80	9.45
5	VOLIKOVA E.	15.3	5.8	13.190	9.0	9.0		43.290	9.0	9.10	9.90	8.85
6	TUTTAS S.	13.2	7.2	12.780	9.1	9.1		42.280	9.1	9.30	9.80	8.90

7	SAPRAUTZKI I.	5.8	4	5.360	3.7	3.7	18.860	3.7	3.60	3.85	3.70
Rank	Female 13/14										
1	IMLE V.	17.3	8.6	14.820	9.2	9.2	49.920	9.2	9.15	9.85	9.25
2	BRAAF L.	17.4	8.7	13.825	9.6	9.6	49.525	9.6	9.10	9.85	9.20
3	FREY L.	16.8	8.4	14.550	9.5	9.5	49.250	9.5	9.25	9.85	9.30
4	DONECHEVA P.	15.6	8.8	14.510	9.8	9.8	48.710	9.8	9.35	9.95	9.50
5	LANGNER S.	16.3	8.2	14.220	9.5	9.5	48.220	9.5	9.20	9.70	9.25
6	RADFELDER M.	16.4	7.2	13.420	9.4	9.4	46.420	9.4	9.10	9.65	9.20
7	KOLA S.	15.8	7.6	13.840	9.1	9.1	46.340	9.1	8.90	9.60	8.75
8	SCHNEIDER F.	15.0	8.0	13.635	9.1	9.1	45.735	9.1	8.60	9.75	8.50
Rank	Female 15/16										
1	ZIMMERHA J.	16.7	8.6	14.350	9.7	9.7	49.350	9.7	9.50	9.90	9.50
2	SCHULDT C.	16.9	8.1	14.905	9.4	9.4	49.305	9.4	9.50	9.95	9.50
3	PAPE N.	16.5	8.4	14.410	9.4	9.4	48.710	9.4	9.30	9.90	9.20
4	LUEG F.	16.3	8.2	13.705	9.5	9.5	47.705	9.5	9.20	9.80	9.30
5	LAUHÖFER S.	14.8	8.9	14.270	9.6	9.6	47.570	9.6	9.15	9.75	9.15
6	SEIDEL L.	17.1	6.1	14.435	9.4	9.4	47.035	9.4	9.10	9.60	9.20
7	SCHWARTZ N.	14.9	8.6	13.075	9.3	9.1	46.760	9.1	8.95	9.80	9.05
7	HENSELEIT N.	15.2	8.4	13.860	9.3	9.3	46.760	9.3	9.00	9.80	9.10
Rank	Female 17+										
1	BAUMANN I.	17.9	8.1	15.335	9.5	9.5	50.835	9.5	9.50	9.70	9.50
2	BUCHHOLZ C.	16.4	10	14.680	9.5	9.5	50.580	9.5	8.80	9.70	8.85
3	MÜLLER S.	17.1	8.6	15.675	9.1	9.1	50.475	9.1	9.30	9.85	9.45
4	SCHÜLLER F.	16.8	9	13.990	9.5	9.5	49.290	9.5	9.05	9.90	8.85
5	STAIBER S.	17.1	8.2	14.515	9.0	9.0	48.815	9.0	8.85	9.70	8.85
6	MAYER M.	18.2	5.8	14.785	9.6	9.6	48.385	9.6	9.50	10.00	9.55
7	SÜß A.	14.7	7.6	14.020	9.1	9.1	45.420	9.1	8.95	9.90	9.00
8	ADAM L.	8.5	6.9	7.965	4.7	5.5	28.065	5.5	5.65	5.95	5.55
9	SCHOLZ A.	3.0	2.5	2.955	1.8	3.4	10.255	3.4	3.30	3.90	3.40
Rank	Male 11/12										
1	ESCHKE R.	15.8	8.0	13.620	9.3	9.3	46.720	9.3	9.20	9.80	9.10
2	BAUSCHKE J.	13.6	8.1	13.510	9.4	9.4	44.610	9.4	9.25	9.80	9.30

3	THOMSON A.	15.6	8.2	13.705	9.11	9.1		46.605	9.1	9.00	9.90	8.80
4	STRIESE H.	14.8	7.2	11.920	7.2	9.6		43.520	9.6	9.25	9.90	9.50
5	DROBINOHA D.	14.80	6.6	12.405	9.5	9.5		43.305	9.5	9.00	9.85	9.50
Rank	Male 13/14											
1	HAGEN L.	15.7	9.5	15.320	9.4	9.4		49.920	9.4	8.80	9.85	8.90
2	GARMAN L.	16.5	8.5	14.705	9.6	9.6		49.305	9.6	9.45	9.85	9.50
3	RISCH V.	16.4	8.2	14.850	9.4	9.4		48.850	9.4	9.30	9.85	9.25
4	GLADJUK M.	14.8	6.9	13.265	9.3	9.3		44.265	9.3	9.05	9.90	9.50
5	LITTERS L.	13.7	7.8	13.050	9.3	9.3		43.850	9.3	9.10	9.90	8.95
6	BRAMMANN L.	12.4	8.0	14.000	9.3	9.3		43.400	9.3	9.00	9.75	9.45
7	FAHRON .	13.3	8.1	12.715	9.0	9.0		43.115	9.0	8.95	9.65	9.05
8	DANNENBER J.	13	7.1	11.350	8.7	9.6		40.150	9.6	9.50	9.95	9.60
Rank	Male 15/16											
1	RÖSLER M.	15.7	13.3	15.440	9.6	9.6		54.040	9.6	9.40	9.85	9.50
2	LAUXTERM C.	15.8	13.4	15.800	9	9.0	0.3	53.700	9.0	8.95	9.55	8.95
3	BUDDE Max	15.9	10.8	15.335	9.3	9.3		51.335	9.3	8.95	9.85	8.85
4	GASCHE J.	15.2	9.7	15.355	8.9	8.9		49.155	8.9	9.10	9.55	8.95
5	HOFMANN S.	15.3	10.4	14.945	8.8	8.8	0.3	49.145	8.8	8.95	9.60	8.70
6	MELNICHUK E.	14.5	10.3	14.810	9.2	9.2		48.810	9.2	9.15	9.65	9.00
7	EHLERT P.	9.5	11.1	14.385	9.1	9.1		44.085	9.1	9.05	9.80	8.80
8	FRAHM J.	4.1	3.8	4.765	2.8	3.6		15.465	3.6	3.35	3.70	3.35
Rank	Male 17+											
1	PFLEIDERER M	15.2	16.2	16.770	9.8	9.8		57.970	9.8	9.55	9.90	9.60
2	SONN K.	16.2	15.8	16.570	9.3	9.3	0.3	57.570	9.3	9.00	9.70	9.00
3	VOGEL F.	15.7	15.6	16.750	9.6	9.6		57.650	9.6	9.45	9.90	9.50
4	SCHMIDT D.	15.9	15.4	16.290	9.6	9.6		57.190	9.6	9.45	9.75	9.50
5	HARTMANN F.	14.9	14.6	15.755	9.2	9.2		54.455	9.2	8.75	9.60	8.95
6	KUHNERT C.	14.9	14.2	15.970	9.3	9.3		54.370	9.3	9.00	9.85	8.95
7	SCHULDT M.	14.7	14.0	16.300	9.3	9.3		54.300	9.3	8.75	9.65	8.60
8	BRANDT D.	11.9	11.8	15.550	8.8	8.8		48.050	8.8	8.90	9.45	9.00
9	WREN D.	12.4	10.5	13.260	7.1	7.9		43.260	7.9	8.20	8.60	7.85
10	BEST M.	11.1	10.1	10.025	5.7	6.5		36.925	6.5	6.35	6.80	6.30

11	NOWAK T.	3.2	3	3.490	1.8	2.6		11.490	2.6	2.60	2.95	2.55
12	EMIR C.	1.6	1.8	1.750	0.8	2.2		05.950	2.2	2.50	3.00	2.85

Relating the jumping patterns of all athletes (see appendix) to the HD values based on the *current* and *Convex Hull* approaches, Figure 4 and Figure 5 clearly demonstrated that these approaches did not really differentiate between the jumping performances (regarding the horizontal displacement) of the athletes.

In contrast, the *Total Distance* and *Error* approaches produced a stronger differentiation between athletes as shown in Figure 6. They also addressed the issue that only jumping patterns that were distributed precisely around the center of the trampoline bed (108 cm in the longitudinal and 108 cm in the transversal axis) would be rewarded by a high HD value. When comparing the *Total Distance* with the *Error* approach, we saw that the *Error* approach displayed a higher degree of differentiation that might due to implementing a stability measure for the jumping patterns in this approach.

Figure 6 shows the impact of the *Error* approach based on nearly identical results in the part scores (execution, difficulty, and ToF). The *current* approach clearly differentiated between the jumping patterns, whereas the *Error* approach differentiated better by rewarding jumping in the middle of the device. In addition, this better differentiation led to a changed ranking order despite identical results in the part scores.

The MANOVA showed significant main effects of the requirement jumping pattern F (1, 680) =107.140, $p < .01$ and the different approaches, F (3, 680) = 231.474, $p < .01$. There was an additonal significant interaction effect of jumping pattern x approach F (3, 680) = 5.279, $p < .01$. All four approaches varied as a function of the jumping pattern. In particular, error approach exhibited in average lower scores for stable and variable patterns.

As a consequence of this, the total score varied as a function of the error approach. In particular, there is a shift in the podium of the world cup in Spain (see Table 3 and figure 6).

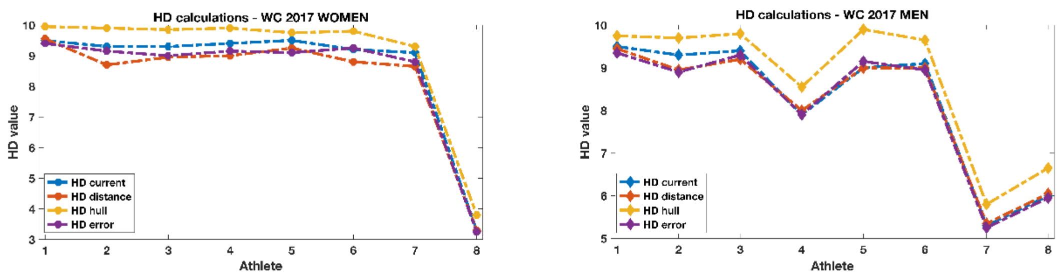


Figure 4. Distribution of HD values for WM 2017. The HD values of all athletes at the World Cup Final 2017 are plotted separately for the different calculation approaches including the currently valid HD calculation. Subfigure 4A shows the distribution of HD values for the women’s final; Subfigure 4B, for the men’s final.

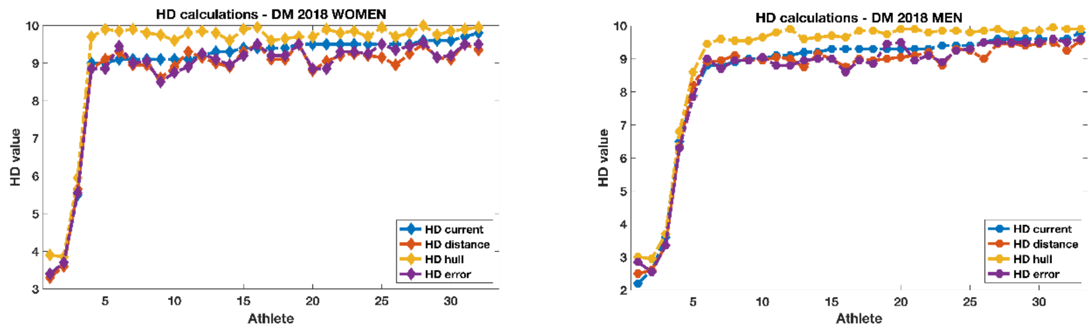


Figure 5. Distribution of HD values for DM 2018. The HD values of all athletes of the German Cup Final 2018 are plotted separately for the different calculation approaches including the currently valid HD calculation. Subfigure 5A shows the distribution of HD values for the women's final; Subfigure 5B, for the men's final. The HD values of the athletes (x-scale) ordered on decreasing HD current deductions.

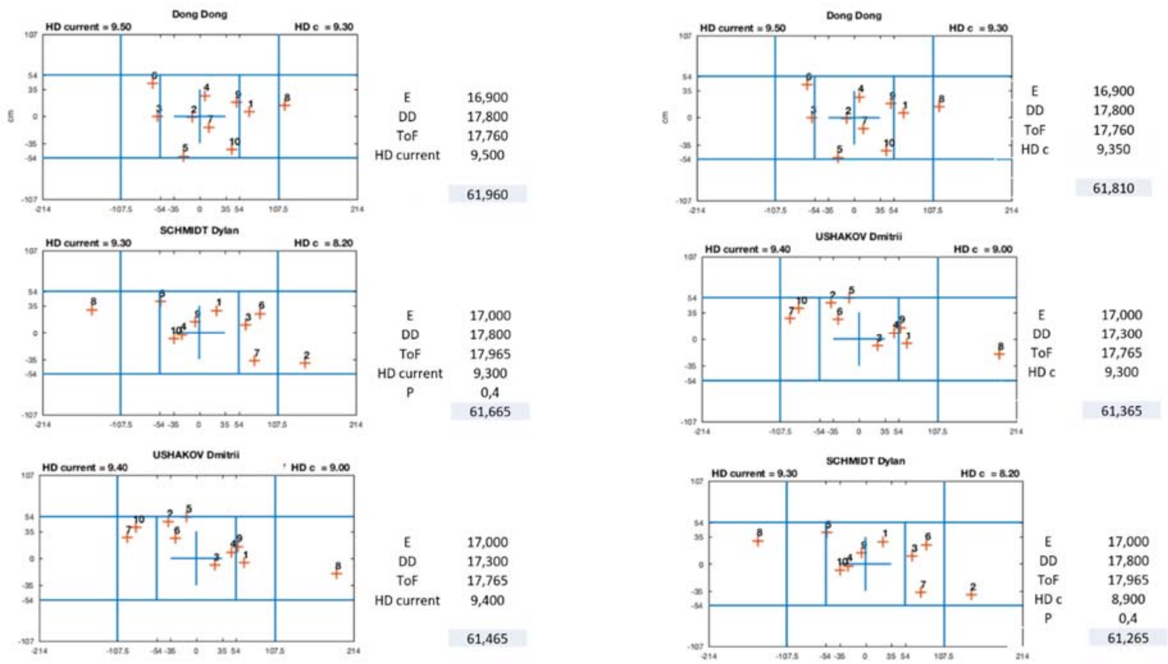


Figure 6. Impact of the error approach on the result in the World Cup 2017 in Spain. Using the Error approach changes the order on the podium.

Table 3

Shifted ranking in the 2017 World Cup Final Competition Men in Valladolid, Spain.

Rank	Male athletes	curr	distance	hull	error
1	DONG D.	61.960	61.910	62.210	61.305
2	SCHMIDT D.	61.665	61.315	62.065	60.780
3	USHAKOV D.	61.465	61.265	61.865	60.850

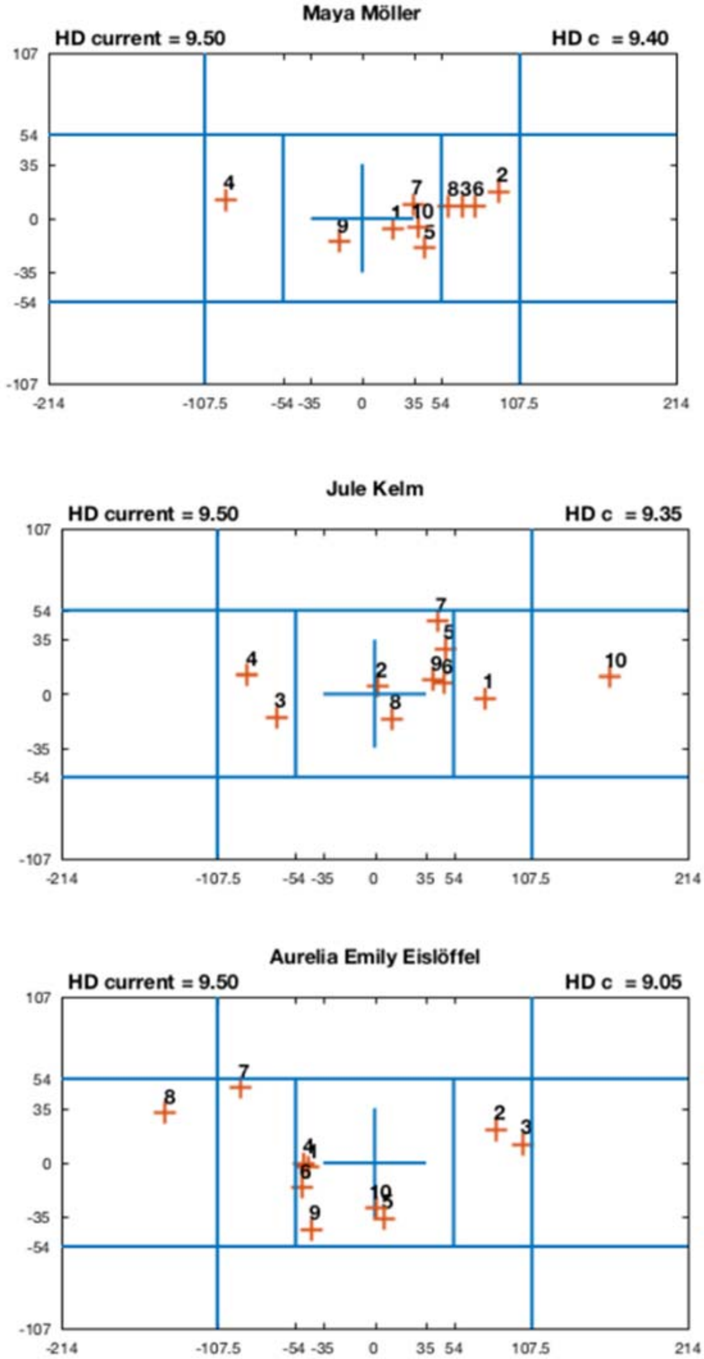


Figure 7. Changing the HD value using the Error approach.

DISCUSSION

This article introduced different approaches to scoring overall performance of trampoline routines based on different bases of calculation. The motivation for using different bases of calculation was to differentiate better between overall performances.

During competitions, athletes have to perform so-called routines that are made up of sequences of jumps. A routine starts with a number of straight jumps to gain momentum. After this preparation, the athlete has to perform a sequence of 10 jumps from a set of predefined jump classes. Then, the judges' task is to assess the routine with respect to its execution and its degree of difficulty. Time of flight and horizontal displacement are measured by the HDTS device. The initial point is the different weighting of the partial values in the overall performance. We evaluated the overall performance depending on HD in a realistic trampolining scenario. Furthermore, we discussed how the use of alternative HD measures affects the overall results. As our main contribution, we discussed suitable calculations of HD. Based on real data from several competitions, we introduced real-valued calculations. Furthermore, we presented a strategy to enhance the influence of certain parameters. In this evaluation, we considered three different bases of calculation:

1. The Total Distance approach
2. The Convex Hull approach
3. The Error approach

As Tables 1 and 2 show, the impact of calculation methods varies. This shows that the proposed Approach 3 is capable of capturing overall performance in a more differentiated manner. When using Approach 3, results are generally more distinguishable than when using the other approaches. Hence, athletes benefit from the use of Approach 3. A good example of how Approach 3 generally improves the overall results is shown in Figure 7. Here, the variances within the routine are similar among athletes (1/2) and result in similar HD values, even though the jump pattern is different with respect to accuracy and stability.

If jumping patterns lead to identical results in the HD value using the current approach, the Error approach then produces a better differentiation between the patterns, determines the precise information on overall performance, and provides a fairer assessment of the performance of gymnasts (see Figure 7). Ultimately, the *Error approach* will reward stable jump patterns in the middle of the device and thus support safe jumping.

Furthermore, the table indicates differences between the judges' scores and the measurement device. When no measurement system is available in FIG competitions, judges need to determine the HD score visually (FIG Executive Committee, 2017). The observed disagreement between judge and system in a few cases (Golovina and Mori see Table 1) is neither an error of technology nor an error of judges. It is rather a problem arising from the different translation of the Code of Points. The judges are instructed to look for the athletes' feet during bed contact. The judge indicates a deduction when one foot is out of the neutral zone. In the same case, the system detects the center of mass inside the neutral zone and makes no deduction (see Ferger & Hackbarth, 2017, for more details). These are the cases in which different deductions can occur.

CONCLUSION

We conclude that adjusting the amount of HD score up to 5.0 pts (similar to the E score), the error approach should be preferred and implemented in the Code of Points. The advantage would be that gymnasts would then jump in a more controlled fashion in the middle of the device and show consistent and stable patterns. This would be a further step toward being able to show a greater differentiation in final performance. All other approaches provoke a higher risk of injury through trying to maximize time of flight (ToF) and E score. The aim of the suggested scoring is to evoke consistent patterns of low variability and high accuracy while simultaneously implementing passive injury prevention measures.

REFERENCES

Chapanis, A. (1951). Theory and methods for analyzing errors in man-machine systems. *Annals of the New York Academy of Sciences, 51*(7), 1179–1203. doi:10.1111/j.1749-6632.1951.tb27345.x

Edouard, P., Steffen, K., Junge, A., Leglise, M., Soligard, T. & Engebretsen, L. (2018). Gymnastics injury incidence during the 2008, 2012 and 2016 Olympic Games: Analysis of prospectively collected surveillance data from 963 registered gymnasts during Olympic Games. *British Journal of Sports Medicine*, 52(7), 475–481. doi:10.1136/bjsports-2017-097972

Ferger, K., Zhang, H., Kölzer, S., Tiefenbacher, K., & Müller, H. (2013). Time of Flight – ein objektives Bewertungskriterium im Trampolinturnen [Time of flight: An objective criterion for judging trampoline gymnasts]? In F. Mess, M. Gruber, & A. Woll (Eds.), *Sportwissenschaft grenzenlos*?! (pp. 25–27). Konstanz, Germany: dvs-Hochschultag, September 2013: Abstracts. Hamburg: Feldhaus, Edition Czwalina (Schriften der Deutschen Vereinigung für Sportwissenschaft, Bd. 230).

Ferger, K. & Hackbarth, M. (2017). New way of determining horizontal displacement in competitive trampolining. *Science of Gymnastics Journal*, 9(3), 303–310.

Ferger, K., Hackbarth, M., Mylo, M. D, Müller, C. & Zentgraf, K. (2019). Measuring temporal and spatial accuracy in trampolining. *Sports Engineering*, *22*(3–4), 63. doi:10.1007/s12283-019-0310-9

FIG Executive Committee (2017). 2017-2017-2020 Code of Points. Retrieved from https://www.gymnastics.sport/publicdir/rules/files/en_TRA%20CoP%202017-2020.pdf

Grapton, X., Lion, A., Gauchard, G. C., Barrault, D. & Perrin, P. P. (2013). Specific injuries induced by the practice of trampoline, tumbling and acrobatic gymnastics. *Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA*, *21*(2), 494–499. doi:10.1007/s00167-012-1982-x

Hemmer, M. & Schmidt, C. (2008). Convex hulls. In Ming-Yang Kao (Ed.): *Encyclopedia of algorithms* (pp. 446–449). New York, NY: Springer (Springer reference).

Lenk, C., Hackbarth, M., Mylo, M., Weigand, J. & Ferger, K. (2016). Evaluation of a measurement system for determining flight times in trampoline sports. In J. Wiemeyer & A. Seyfahrt (Eds.), *Human movement and technology*. (Berichte aus der Sportwissenschaft, 1st ed., pp. 117–124) Herzogenrath, Germany: Shaker.

Corresponding author:

Katja Ferger
Institute of Sports Science
Justus-Liebig-University Gießen,
Kugelberg 62, 35394
Germany
tel and fax num: +49 641 99 25232
+49 641 99 25209
Email: katja.ferger@sport.uni-giessen.de

SHORT HISTORICAL NOTES XVIII

Anton Gajdoš, Bratislava, Slovakia

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

VLADIMIR IVANOVIČ SILIN (2 June 1921, Pokrovsk, Russia – 16 March 2015, Sankt Peterburg, Russia)

After secondary school Vladimir Ivanovič Silin started to study history at Saratoska University in 1938. When entered university he started to do swimming, gymnastics and athletics. He was very succesful at gymnastics among university students. In 1941 Germany invaded Soviet Union and he volunteered in 1941 in Red Army to defend Moscow. After he fight for Moscow, he was transferred to Army Faculty of Physical Culture in 1942, where he became a lecturer at Department of Gymnastics and developed training plan of physical conditioning for Red Army soldiers and also teach it in practice during war times.

At the end of the war, he took part at the Victory Parade in Moscow. He stayed in the Army until retired as professor of gymnastics at Leningrad Lesgaft Army Faculty of Physical Culture.

After the war he earned category Master of Sport in gymnastics, and started to coach gymnasts. In 1945 he performed with his team mates on Red Square in Moscow his high bar exercise, but not on just ordinary high bar, **he performed his exercise on high bar, which was placed 8.5 meter above the ground.**

Photos above from his performance on Red Square in 1945

He coached Dmitri Leonkin, Josif Bedriev and Mikhail Perlman, gymnasts who were members of wining Soviet Union team at Helsinki Olympic Games in 1952.

Later he was for 20 years international judge. Most important is his work in area of sport psychology, where he was in charge of psychological preparation of soviet gymnasts between 1956 and 1968, when soviet gymnasts showed their excellence and domination.

He wrote many articles and books, probably most important is his book: Psychological preparation of gymnasts: methodic recommendations from 1974, where his expert knowledge and practical knowledge working with gymnasts have been described.

He was decorated with many rewards in Soviet Union and Russia. Besides war ordens, the most important reward was in 1996, when he earned title of Emeritus of Physical Culture in Russian Federation.

Besides all work he wrote also poems about gymnastics. Below is poem to celebrate Gymnastics Day with professor's signature.

День гимнастики

Нас на века объединяла,
К гимнастике родной любовь!
Вела к помостам, пьедесталам,
Трудиться заставляла вновь.

Нам руки жали, награждали,
Призы давали иногда!
А мы мозоли все срывали,
Накладок не было тогда.

Крутились и группировались,
А тренер нас не страховал,
В те годы мы тренировались,
В пыли малюсеньких спортзал.

Круги крутили и «окрошку»,
Ломались о паркетный пол,
Тогда ведь не было дорожки,
Не клали в ямы поролон!

В кресте рвал мышцы Алекперов,
А где-то Ложкин подрастал.
На перекладине он первым,
Прямым дубль-сальто выполнял!

Гимнастике мы все отдали,
Ее мы любим всей душой,
Побед мы терпеливо ждали,
И к нам пришел успех большой!

Где чемпионы. Где награды.
Где олимпийцы – мастера,
Все это в славном Ленинграде,
Поздравить Вас всех здесь пора!

Есть и в гимнастике кумиры,
Им дали множество наград,
В честь СССР, Европы, Мира,
И золото Олимпиад!

Мы встретились, поговорили,
Что пролетело много лет,
А чтоб Вы встречу не забыли,
Шлем гимнастический совет!

Чтоб были Вы аэробичны,
Чтоб каждый был силен, атлет!
Юны, стройны и гимнастичны,
Здоровы много, много лет!

И девушек мы поздравляем,
И любим Вас от всей души,
Чистосердечно заявляем –
Вы – гимнастично хороши!

Сегодня есть у нас причина
Поднять за девушек бокал,
Ну, и за Вас – орлы, мужчины,
Чтобы никто не унывал!

ноябрь 2003 г. профессор Владимир Силин

Slovenski izvlečki / Slovene Abstracts

Pia M. Vinken, Thomas Heinen

ZAZNAVANJE LEPOTE GIBANJA PRI RAZLIČNIH VRSTAH ZAHTEVNIH PLESNIH SPRETNOSTIH

Raziskave lepote gibanja raziskujejo lastnosti in značilnosti predmetov, nastale mehanizme odzivanja na take predmete v opazovalcu in medsebojno vplivanje dejavnikov predmeta in opazovalca v danem okvirju. Ta študija se osredotoča na dejavnike, povezane s predmetom, kot je biološko gibanje. Vprašanje je, ali obstajajo zaznane lepotne značilnosti, ki razlikujejo med zapletenimi umetniškimi veščinami, ki jih izkušeni opazovalci uvrščajo med najbolj in najmanj lepe. Zato so 18 udeležencev s plesnimi izkušnjami prosili, naj ocenijo zaznano lepoto kinogramov s paličnimi figurami treh različnih sestavljenih gibanj, in sicer plesnih skokov, drž in obratov. Kot rezultat, so tri posebne lepotne značilnosti izpostavljene kot osnove pri dojemanju in vrednotenju lepega športa in uprizoritvenih umetnosti: 1) zunanja smer stran od dolžinske osi plesalca in telesa, 2) osredotočenost na zunanje vrtenje okončin in 3) (nasprotno) širjenje gibov telesa, kar ustvarja vtis podolgovatega telesa plesalca. Zlasti lepotne lastnosti, ki zahtevajo izvajalčevo sposobnost in izzivajo fizične zakone, se zdijo močni parametri, kadar želimo ustvariti lepotne dražljaje gibanja. Zaključno je treba poudariti specifičnost spretnosti za lepotne lastnosti in potrebo po razlikovanju medsebojno različnih lepotnih lastnosti - vidike, ki se zdijo še posebej očitni pri bioloških dražljajih gibanja.

Ključne besede: umetniški šport, uprizoritvena umetnost, video-sekvence, dvostranska naloga s prisilno izbiro, zaznavanje gibanja.

Frederike Veit

KAKO VPLIVAJO SLUŠNI PODATKI NA OPAZOVALČEVO ZAZNAVO IN OCENJEVANJE ZAHTEVNIH PRVIN

Zaznavanje in zbiranje podatkov iz okolja sta osnovni sposobnosti človeka, zlasti v športu. Posamezno dojemanje vidikov, kot so okoliški pogoji ali gibanje drugih športnikov, je lahko odločilno za uspešno predstavo. Postavlja se vprašanje, ali posameznikova strokovna znanja vplivajo na njegovo sposobnost uporabe podatkov, posebnih za posamezne naloge. Poleg tega je treba ugotoviti, ali se vrsta zbranih podatkov razlikuje med ljudmi z različnimi športno posebnimi izkušnjami. Cilj študije je bil raziskati vlogo slušnih podatkov pri opazovanju in ocenjevanju zahtevnih prvin pri telovadbi. Udeleženci z različnimi količinami izkušenj so bili pozvani, da v upravljanih slušnih pogojih ocenijo trajanje leta salta nazaj stegnjeno. Rezultati trenutne študije kažejo, da so udeleženci brez posebnih izkušenj s telovadbo opravili slabše od udeležencev z vidnimi ali gibalnimi izkušnjami. Poleg tega so trenutni telovadci presegli ostale udeležence. Lahko bi ugibali, da imajo sedanji telovadci koristi od svojih gibalnih izkušenj, ki vodijo do izboljšane občutljivosti zaznavanja in boljše sposobnosti prepoznavanja razlik med dvema znakoma. Za zaključek bi bilo lahko obogateno upoštevanje slušnih podatkov pri nalogah učenja gibanja.

Ključne besede: skupno kodiranje, parna primerjava, zaznavna občutljivost, akrobatske serije na tleh, primerjava strokovnjaka-nepoznavalca.

Antonio Pineda-Espejel, Marina Trejo, Lucía Terán, Lourdes Cutti, Edgar Galarraga

POSLEDICE FIZIOLOŠKIH IN TESNOBNIH ODGOVOROV NA DRUŽBENE ZAHTEVE TELOVADNE ODLIČNOSTI NA TEKMOVANJIH: ŠTUDIJ PRIMERA

Namen te raziskave je bil razčleniti psihofiziološke odzive (tesnoba, kortizol, srčni utrip, kožna prevodnost) na enkratni psihični stres med predstavljanjem sotekmovalcev, pod vplivom pritiska na popolnost, ki ga izvajajo starši, in pritiska na popolnost, ki ga izvajajo vaditelji. Udeležili so se orodni telovadci (3 moški in 3 ženske) s starostnim razponom od 13 do 15 let, ki so bili prisotni na štirih meritvah, ki so vključevale meritve kortizola v slini, srčni utrip in kožno prevodnost. Prva meritev je bilo izhodišče, kjer smo uporabili vprašalnik o tesnobi pred sotekmovalci in pritisku na popolnost. Preostale tri meritve so vključevale voden ogled; druga ustvarjanje miselnih podob in podoživljanje telovadnega tekmovanja; tretji izpostavlja pritisk na popolnost, ki ga je ustvaril vaditelj (PPE); četrti pa poudarja pritisk na popolnost, ki so ga ustvarili starši (PPP). Rezultati so pokazali, da predstave sotekmovalcev povzročajo stres in tesnobo, čeprav je bil porast kortizola v slini v običajnem dnevnem nivoju. Fiziološke spremembe so bile večje pri tistih telovadcih, ki so zaznali visoko PPE in PPP. Vendar pa se je za nekatere telovadce stanje zdelo grozeče (zmanjšanje kožne prevodnosti in majhno povečanje srčnega utripa), za druge pa zahtevno (povečanje kožne prevodnosti in srčnega utripa). Pritisk na popolnost vključuje povezavo med različnimi fiziološkimi odzivi.

Ključne besede: stres, popolnost, starši, trener.

Kum-Hyok Hwang, Yong-Song Kim, Dong-Chol Choi, Mun-Il Choi

DINAMIČNO MODELIRANJE DRUGEGA LETA PRI STEGNJENEMU »JURČENKU« NA PRESKOKU S PROGRAMOM MSC.ADMS

Telovadke poskušajo povečati količino vrtenja okoli čelne in dolžinske osi med letom, le-to pa jo povezano z različnimi mehanskimi lastnostmi. V tej študiji je uporabljen 3D računalniški simulacijski model telovadke, ki izvaja »jurčenko« programsko opremo ADAMS. Začetni pogoji simulacije so vodoravna in navpična hitrost težišča medenice telovadca in kotne hitrosti v čelni in dolžinski osi, ki jih je mogoče enostavno izmeriti. Začetni pogoji linearne in kotne hitrosti simulacijskega modela se spreminjajo v določenih korakih iz merilnih podatkov, zbranih od vrhunskih telovadk. Povečanje začetne vodoravne hitrosti povzroči povečano vodoravno razdaljo leta, vendar nima povezave s trajanjem leta in kotom obrata. Skupni kot obrata se nanaša na začetno navpično in kotno hitrost čelne in dolžinske osi. Tudi povečanje začetne navpične hitrosti in kotne hitrosti okoli čelne osi vodi do povečanja kota obrata.

Ključne besede: let, dinamika, ADAMS.

Rick Hayman, Remco Polman, Karl Wharton in Erika Borkoles

TEORIJA DRUŽBENE VLOGE: UPORABNOST IN RAZUMEVANJE RAZVOJA IZKUŠENJ MLADIH AKROBATOV MEDNARODNE KAKOVOSTI

Vrhunski športniki se srečujejo z več stresi. Vendar pa je v omejenih raziskavah posebej raziskano razvojno, organizacijsko in tekmovalno prehodno doživetje mednarodnih mladinskih vrhunskih športnikov. Z uporabo teorije družbenih vlog (RST) je ta študija razširila literaturo o razvoju športnih talentov, tako da je zagotovila ključni vpogled v izkušnje petih zelo uspešnih mladinskih akrobatov iz Velike Britanije (GB), starih od 14 do 17 let. Odgovarjali so na vprašanja kako so hkrati združevali več zahtev glede vloge v športu, družini in vzgoji v času od začetnika do vrhunskega športnika in se spopadali s temi zahtevami. Izpeljane teme iz pol-strukturiranih pogovorov so pokazale prisotnost neprestane, vendar nizke stopnje in obvladljive obremenitve vlog v vseh prehodnih obdobjih, kar je omogočilo pozitiven akrobatski razvoj, zadovoljstvo z življenjem, telesno in duševno počutje ter izobraževalni napredek. Vsi so poročali o tem, kako resnost in pravilnost obremenjevanja vlog, zlasti preobremenjenosti in prepiri, so včasih v zgodnjih najstniških letih nihali. Na tej točki so poročali o povečanem obremenjevanju vlog zaradi izpolnjevanja družinskih obveznosti zaradi povečanega urnika vadbe in tekmovanj. V tem času so bili izzivi pri ohranjanju zdravih in združljivih prijateljstev, zlasti z vrstniki zunaj akrobacije in šole. V vseh pripovedih udeležencev so bili prisotni trije ključni dejavniki, ki so uravnavali obremenitev vloge: zgodnja mednarodna akrobatska uspešnost, akrobatska usmerjenost v zelo nizki starosti in družbene in oprijemljive smernice učiteljev in vaditeljev v podporo celostnemu razvoju športnikov. Razpravlja se o morebitnih nadaljnjih raziskavah in omejitvah.

Ključne besede: teorija obremenitve vlog, prehodi, starši vaditelji.

Maria-Raquel G. Silva, Hugo-Henrique Silva, Teresa Luemba

TELESNE ZNAČILNOSTI TELOVADCEV IN TELOVADK NA EVROPSKIH IGRAH V BAKUJU, AZERBEJDŽAN, 2015

Na športne rezultate močno vplivajo telesne značilnosti športnikov. V primeru telovadbe ima telesna teža poseben pomen, glede na lepotni značaj tega športa. Zbrani so bili podatki telesnih značilnosti 309 telovadcev (20,9 ± 4,1 leta), ki so sodelovali na evropskih igrah 2015: starost, telesna masa in višina, iz baze podatkov organizacije tega tekmovanja, ki je na voljo na spletu v 5 disciplinah telovadbe, vključenih v tekmovanje in sicer za orodno telovadbo za moške in ženske, ritmiko, akrobatiko in telovadne plese. Izračunali smo indeks telesne mase, telovadke so bile bistveno mlajše in lažje od moških, in so imele nižji indeks telesne mase (ITM) kot moški (P = 0,000). Ženske so bile v 25. centilu za maso in ITM v 15. centilu glede na svojo starost. Telovadci so bili v 25. centilu za maso, višino in ITM. Akrobatke so bile mlajše in lažje (25. centil) kot druge telovadne discipline; ritmičarke so imele najnižji ITM (5. centil). Orodni telovadci so bili najlažji (15. centil) in z najmanjšim ITM (25. odstotek) med moškimi. ITM je bil odvisen od mase, višine in spola, razen pri disciplinah s samo enim spolom in presenetljivo tudi pri telovadnih plesih. Telovadke z rezultati telesne mase, višino in ITM so nižji od običajnih za njihovo starost.

Ključne besede: telesna masa, telovadba, udeležba med spoloma

Nazhif Gifari, Rachmanida Nuzrina, Mury Kuswari, Nabila Tri Hutami, Ayu Ghalda

ODNOS MED VEDENJEM O PREHRANI IN GIBALNIMI SPOSOBNOSTMI MLADIH TELOVADCEV

Raziskava je bila namenjena razčlenitvi prehranskega znanja, prehranskega stanja, telesne sestave, vnosa hranil in telesne pripravljenosti mladih telovadcev. Vzorec merjencev je predstavljalo 20 ritmičark in telovadk v Raden Intenu v Džakarti. Prehranski status in telesna sestava sta bili izmerjeni, makro hranila in mikro hranila zaužitja so bili izmerjeni s 3x24-urnim beleženjem vrste hrane, telesna pripravljenost je bila izmerjena s testom pospeševalnim tempom teka 20m, prehransko znanje pa je bilo ocenjeno s pomočjo vprašalnikov, sestavljenih iz 30 vprašanj za makro hranila, mikro hranila in vodo. Rezultati so pokazali, da so telovadke (n = 20, 13,7 ± 2,1 let, 37,8 ± 8,2 kg in 147,3 ± 10 cm) na splošno imele precej dobro prehransko znanje (73,2%); to je 10 ljudi v skupini o dobrem znanju o prehrani in 10 ljudi v skupini s slabim prehranskim znanjem. Večina vnosov makro hranil in mikro hranil je bila pod prehranskimi potrebami v obeh skupinah. Rezultati prehranskega znanja so bili nizki za znanje o potrebah vode (66%), in boljša za vedenje o makro hranilih in mikro hranilih (73,8% oziroma 84,2%). Znanje o prehrani ima pozitivno povezano s telesno pripravljenostjo (p <0,05). Potreben je šolski poseg v zvezi s športno prehrano za tiste telovadce, ki še vedno slabo poznajo prehrano. Za športnike in vaditelje je treba zagotoviti znanje o športni prehrani, tako da vnosi športnikov izpolnjujejo njihove prehranske potrebe, da bi povečali svojo uspešnost.

Ključne besede: prehransko znanje, vnos hranil, telesna pripravljenost, mladi telovadci.

Katja Ferger, Fabian Helm in Karen Zentgraf

OCENA NAPAK VODORAVNEGA POTOVANJA PO PONJAVI GLEDE NA SREDINO PONJAVE IN MESTOM DOSKOKA: NOVI ZLATI STANDARD?

Končni rezultat v tekmovanju na ponjavi je sestavljen iz različnih dejavnikov. Ti različno prispevajo h končnemu rezultatu in vodijo do uvrstitve akrobata. Ta raziskava je bila zasnovana za preučitev vpliva, ki bi ga imeli na končni rezultat tekmovanja novi izračuni vodoravnega premika doskokov na mreži ponjave. Primerjali smo različne pristope za določitev natančnosti s trenutnim načinom odbitka vodoravnega premika. Ti pristopi za izračun natančnih ukrepov so bili: (a) „skupna razdalja“, (b) „pristop izbočenega trupa“ in (c) „pristop napak“. Rezultati so pokazali, da je bil novi pristop natančnejši in bolje loči akrobate. Tako spremenjena uvrstitev se primerja z uradnim končnim rezultatom tekmovanja, da se prikaže vpliv novih izračunov.

Ključne besede: velika prožna ponjava, napaka, spremenljivost, zmogljivost.