# Science of Gymnastics Journal

vol. 13, num. 3, year 2021

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.



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ScGYM® (ISSN 1855-7171) is an international – online journal published three times a year (February, June, October). ® Department of Gymnastics, Faculty of Sport, University of Ljubljana. 

**Front page design:** Sandi Radovan, Slovenia.

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

Fundacija za šport

Slovenian Research Agency

F.I.G.

# CONTENTS

In Slovenia town Maribor - where World Cup and World Challenge competitions were held - mair Saša Arsenovič and Ivan Gorjup (president of Society to build statue of Jože Primožič) open to the public statue of gymnast Jože Primožič – Tošo, world champion in all around in 1930, second at OG 1928 on parallel bars and third with team. Foto: MP PRODUKCIJA, Marko Pigac, s.p.

At World Challenge competition in Koper Science of Gymnastics Journal took part. From right: FIG president Morinari Watanabe, prof. Ivan Čuk, Editor in Charge of Science of Gymnastics Journal and Sašo Bertoncelj , the best Slovene gymnast in last decade.

# EDITORIAL

Dear friends,

All gymnastic disciplines were excellent at this year's Summer Olympic Games. Great achievements of our athletes in artistic gymnastics, rhythmic gymnastic and trampolining! From my subjective point of view, Nikita Nagorny made a huge step forward to further our sport. It took all this time since OG 1988 in Seoul, when Valery Ljukin from the former Soviet Union performed a triple salto backward tucked, to see Nikita Nagorny perform a triple salto backward piked at a major competition. It will take some more time before followers start performing the triple backward piked. However, our science supports and facilitates improvements in apparatus, the development of better methods of strength training, psychological readiness, and so on, and all this leads to further developments in our sport.

Having the Olympic Games and the World Championships within three months of the same year created many challenges for everyone involved in competitive gymnastics. On one hand, there is gymnasts' tiredness, on another, new faces bring in new energy.

There are new challenges for researchers too. In the middle of October, Flavio Bessi organised International Freiburg Gymnastics Congress online. You can find it at https://www.sport.uni-freiburg.de/en/events/international-gymnastics-congress.

Contributing authors in this issue are from Tunisia, Oman, Brazil, Germany, United Kingdom, Slovenia, Russia and Greece. Again, many different aspects of gymnastics are presented.

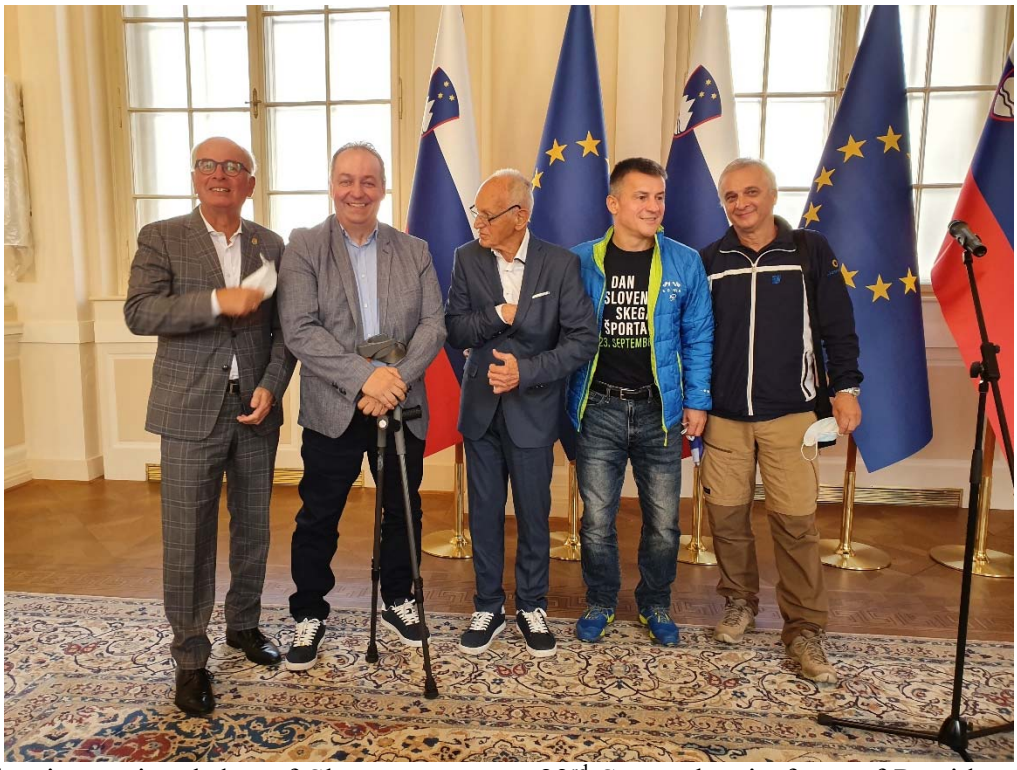
Anton Gajdoš and Michal Babela drafted the 22nd short historical note introducing Samulel Piasecky from Slovakia.

Sadly, we lost a gymnastic friend. Aljoša Demjanov who competed for Russia and Croatia passed away last summer. R.I.P., Aljoša.

Just to remind you, if you cite the journal, its abbreviation in the Web of Knowledge is SCI GYMN J.

I wish you enjoyable reading and many new ideas for research projects and articles.

Ivan Čuk
Editor-in-Chief

For celebrating national day of Slovene sport on 23rd September in front of President's palace Exhibiton about Slovene Phycisal Culture was opened by (from left) Wolgang Baumann TAFISA Secretary General, Franček Gorazd Tiršek – Slovene paralympic silver medal holder, Miroslav Cerar – Olympic winner in the name of Slovene President Borut Pahor, Janez Sodržnik – vice president of Slovene Olympic Committee – Association of Sports Federations and Prof. Ivan Čuk, exhibition author.

# EFFECT OF DIFFERING EXERCISE INTENSITIES ON THE RESPONSE TIME OF GYMNASTS AND NON-GYMNASTS IN 3D CUBE MENTAL ROTATION TASK

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*Original article* *DOI:10.52165/sgj.13.3.301-309*

***Abstract***

*The purpose of the present study was to examine the effect of different levels of exercise intensity on mental rotation performance in gymnasts vs. non-gymnasts'. Forty-one participants (18 females; mean age 20.94±0.89 years, height 1.65±0.03 m, body mass 58.94±5.67 kg, and 23 males; mean age 21.26±0.99 years, height 1.70±0.05 m, body mass 66.87±4.52 kg) divided into two groups (i.e., gymnasts and non-gymnast) voluntarily took part in the present study. The two groups performed a 3D cube mental rotation task at rest, and then performed the same task preceded by short bouts of intense exercise at 60%, 80%, 100% and 120% of their maximum aerobic speed (MAS). The analyses of response times showed that gymnasts performed the mental rotation task faster following bouts of intense exercise than in rest condition, especially in 60% and 80% of MAS, whereas non-gymnasts increased their response times after moderate exercises (i.e., 60 et 80 % of MAS) and stabilized their performance (i.e., equally at the rest) after intense exercises. This finding highlights the specific physical expertise as a variable that can affect the influence of exercise on cognitive processing.*

***Keys words***: *mental rotation, cognitive processing, exercise intensity, gymnastics expertise.*

## INTRODUCTION

Mental rotation (RM) is a mental operation in which mental representations of objects are rotated around a three-dimensional (3D) axis space. The concept of mental rotation was introduced by Shepard and Metzler (1971). In their famous experiment, they presented the participants with pairs of misoriented figures of asymmetric 3D cube assemblies and asked them to determine whether they depicted similar or mirror-reversed objects. The authors recorded Response Time (RT) of the participants and found that it increased as a function of the angular

disparity between the two objects, revealing an analogy between real and imagined rotations (Shepard & Metzler, 1988).

Mental rotation is one of the most solicited mental abilities in everyday life. One of the domains that particularly involves mental rotation is sport. Sports practice is an ideal context to develop spatial capacities, in particular visualization, orientation, and mental rotation (Bangert, Parlitz, & Altenmüller, 1999; Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2005; Cross, Hamilton, & Grafton, 2006; Ozel, Larue, & Molinaro, 2002; Pietsch & Jansen, 2012). In sports, mental rotation is used in different forms. For example, one could constantly rotate the spatial presentation of her/his own body in order to find it's bearings in space, to make a good reception or to avoid injuries. This strategy relies mainly on egocentric motor processes (Habacha, Lejeune-Poutrain, & Molinaro, 2017). However, team sports would encourage the use of a visual strategy since the athlete is trained to perceive and analyze moving objects, with relation to his partners and opponents. Accordingly, gymnastics seem to encourage the use of an egocentric motor strategy since the athlete trains by moving his frame of reference in space (rotating body) while objects and the environment remain fixed.

Gymnastics include a wide range of motors skills that require developed spatial and mental abilities, which makes gymnasts quite efficient in mental rotation compared to non-gymnasts (Dehghanizadeh, Mohammadzadeh, & Hosseini, 2013; Habacha, Lejeune-Poutrain, & Molinaro, 2017; Jansen & Lehmann, 2013; Schmidt, Egger, Kieliger, Rubeli, & Schüler, 2016; Steggemann, Engbert, & Weigelt, 2011). In addition, several studies reported that gymnasts have shorter RT than non-gymnasts during the mental rotation of a body image and not with 3D objects (Habacha et al., 2017; Jansen & Lehmann, 2013; Jola & Mast, 2005; Steggemann et al., 2011). Further, Guillot, Louis, Thiriet, and Collet (2007) showed no difference between athletes and non-athletes in a mental rotation task. These contradictory results can be due to several factors including the type of task and the stimulus used which would imply different mental strategies (egocentric strategy vs. visual strategy), consequently influencing the performance in mental rotation.

In this regard, one way to better understand the link between sport movement execution and its cognitive processing is to investigate the effect of exercise intensity on cognitive performance. The fact that physical exercise is associated with elevations in mood states and increased psychological well-being (Berger, 1996; Shephard, 1996), and that physical exercise is positively related to several indices of mental health (Morgan, 1984), suggest that physical exercise can enhance cognitive performance. However, no support for this assumption was found in some reviews of the literature (Etnier et al., 1997; McMorris & Graydon, 2000; Tomporowski & Ellis, 1986). This could be explained by the assumption that exercise can affect cognitive performance in an inverted-U shape with better performance corresponding to submaximal exercise intensity and poorer performance corresponding to minimal and maximal exercise (McMorris & Graydon, 2000). Nonetheless, other studies showed that cognitive performance was not always negatively affected by maximal intensity exercise sessions (McMorris & Graydon, 1996a, 1996b) and that it was even improved (Hogervorst, Riedel, Jeukendrup, & Jolles, 1996; Winter et al., 2007). Such discrepancies may be related to the fact that the sport expertise level of the participants have rarely been taken into consideration, especially knowing that physical activity level seems to be an important variable that may affect

cognitive performance following intense exercise (Brisswalter, Arcelin, Audiffren, & Delignières, 1997; Zervas, Danis, & Klissouras, 1991).

In the present study we tried to control the expertise level variable by recruiting elite gymnasts and compare their cognitive performances to non-gymnasts after differing exercise intensities. A 3D cube mental rotation task was used to assess cognitive performance (Habacha et al., 2017; Jansen & Lehmann, 2013; Metzler & Shepard, 1974; Shepard & Metzler, 1971; Shepard & Metzler, 1988). We hypothesized that gymnasts will be more capable of maintaining their cognitive skills after bouts of intense exercise than non-gymnasts.

## METHODS

Forty-one participants (18 females; mean age 20.94±0.89 years, height 1.65±0.03 m, body mass 58.94±5.67 kg, and 23 males; mean age 21.26±0.99 years, height 1.70±0.05 m, body mass 66.87±4.52 kg) voluntarily took part in the present study. They all have normal or corrected-to-normal vision (i.e., based on their medical records) and were naïve to the purpose of the experiment.

The Gymnasts group was composed of twenty-one participants (8 females; mean age 20.63±0.70 years, height 1.65±0.04 m, body mass 60.00±5.61 kg, $VO_{2max}$ 34.82±5.80 ml/min/kg, MAS 11.06±0.78 km/h, and 13 males; mean age 21.43±1.15 years, height 1.69±0.04 m, body mass 66.85±5.86 kg, $VO_{2max}$ 44.56±3.01 ml/min/kg, MAS 12.69±0.48 km/h). The inclusion criteria for this group were to be a gymnast at a national or international level, to have at least 10 years of experience and to have participated in at least one international competition. The Non-Gymnasts group was composed of twenty participants (10 females; mean age 21.19±0.99 years, height 1.65±0.03 m, body mass 58.10±5.88 kg, VO2max 38.52±6.56 ml/min/kg, MAS 11.75±1.03 km/h, and 10 males; mean age 21.05±0.74 years, height 1.71±0.06 m, body mass 66.90±2.02 kg, $VO_{2max}$ 45.18±2.24 ml/min/kg, MAS 12.75±0.26 km/h). The inclusion criteria for this group were to be non-gymnast, to practice recreational sport for at least 3 years and to have never participated in a national or international competition.

After being informed in advance on the procedures, methods, benefits and possible risks involved in the study, each participant had to review and sign a consent form to participate in the study. The experimental protocol was performed in accordance with the Declaration of Helsinki for human experimentation and was approved by the Ethical Committee. The subjects were assured of the principles of anonymity and volunteering. They were informed that the only use of the data was for scientific research purposes.

After a warm-up of 15 minutes (5 minutes of light running and 10 minutes of specific exercises), participants performed a 20m shuttle run test (Leger, Mercier, Gadoury, & Lambert, 1988). A portable gas analysis system (i.e., Cosmed K4b2) and a heart rate monitor (i.e., Polar time) was used to determine the maximal oxygen uptake ($VO_{2max}$), the maximal heart rate (HRmax) and the maximum aerobic speed (MAS) for each participant.

The stimuli used in the mental rotation task included pairs of standard and comparison images. The standard image consisted of three-dimensional rotation shapes of "3D cube" (Shepard & Metzler, 1971).

There are 6 models of the cubes (i.e., 3 correct and 3 false) × 8 times × 2 response possibilities (i.e., same and different) = 48 stimuli. The order of stimuli presentation was counterbalanced, and each rotation angle could not appear 2 times successively. Stimuli were displayed and response times were recorded via the free software 3D Imagine® version 1.1.1 2001 (Opensource software for free download at:

https://sourceforge.net/projects/imagine3d/ ). Participants placed their left and right index fingers on two keyboard buttons that were coloured and labelled as "same" and "different" and were asked to judge whether the two images of a stimulus depicted were the same or different 3D cube assemblies (Figure 1). The mental rotation task lasted about 4 minutes.

After a warm-up of 15 minutes, the participants performed a shuttle run for 2 minutes at one of the intensity levels corresponding to a percentage of their MAS (i.e., 60%, 80%, 100%, and 120%). A heart rate monitor (i.e., Polar time) was used to control the effort level and the percentage of MAS. Immediately afterward, they sat in front of a monitor at about 80 cm distance and performed the 3D cube mental rotation task. The next day, each participant performed the shuttle run at another intensity level followed by the 3D cube mental rotation task. To record a baseline cognitive performance on mental rotation, participant performed the 3D cube mental rotation task at rest on a different day. Which resulted in 5 experimentation days (Rest, 60%, 80%, 100%, and 120% of the MAS). The order of intensity levels was counterbalanced across the experimentation days and the participants.

Data are reported as mean ± standard deviation and confidence intervals at the 95% level (95% CI). Effect size (*dz*) was calculated using GPOWER software (Bonn FRG, Bonn University, Department of Psychology). The following scale was used to interpret *dz*: < 0.2, trivial; 0.2 – 0.6, small; 0.6 – 1.2, moderate; 1.2 – 2.0, large; and > 2.0, very large (Hopkins, 2002). The normality of distribution, estimated by the Shapiro-Wilk test, was acceptable for all variables. Therefore, a 2 (groups: gymnasts, and non-gymnasts) × 5 (exercise intensity level: rest, 60%, 80%, 100%, and 120% of MAS) ANOVA with repeated measures test was computed. For pairwise comparison, a post hoc / Bonferroni was established. The results were considered significantly different (significant) when the probability is less than or equal to 0.05% ($p \leq .05$). The statistical study was performed by SPSS® 20.0 software (SPSS Inc., Chicago, IL, USA).

## RESULTS

The ANOVA repeated measure showed a significant difference in the interaction between *Exercise Intensity* and *Groups*, and between *Gymnasts* and *No-gymnasts*, but between *Exercise Intensity* there is no significant difference (Table 1).

In the interaction between *Expertise* and *Exercise Intensity*, as shown in Figures 2, gymnasts had shorter RTs than non-gymnasts in 60% and 80% intensity conditions (i.e., $p < .05$ and $p < .001$ respectively) but not in the Rest, 100% and 120% condition ($p > .05$).

Table 1
*ANOVA Statistics.*

| Source | df | Mean Square | F | Sig. | Effect Size | Observed Power |
|---|---|---|---|---|---|---|
| Exercise Intensity | 4 | 9550.290 | 0.564 | 0.689 | 0.238[§] | 0.185 |
| Groups | 1 | 323704.61 | 5.576 | 0.023* | 0.756[#] | 0.634 |
| Exercise Intensity*Groups | 4 | 83845.085 | 4.948 | 0.001** | 0.714[#] | 0.957 |

*(*) significant at p<0.05; (**) significant at p<0.001; ([§]) small effect size; ([#]) moderate effect size.*

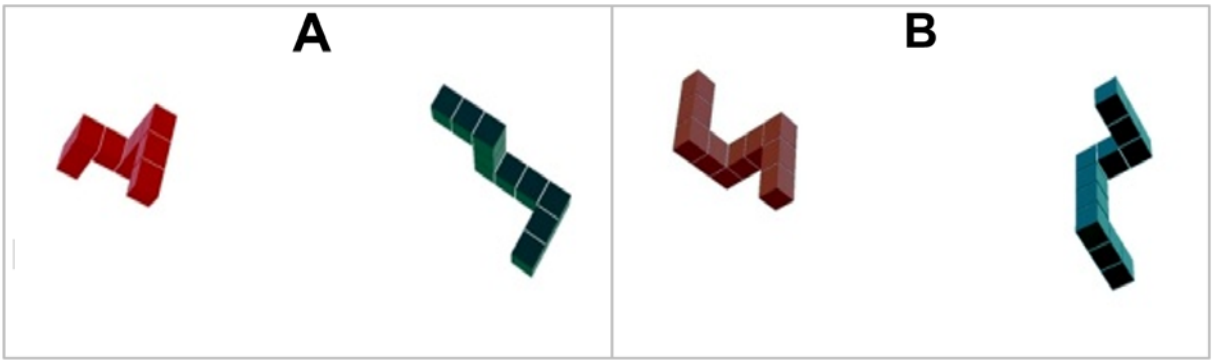


*Figure 1.* Examples of stimuli used in the 3D cube mental rotation task. A: a correct trial (correct response is "same"). B: a false trial (correct response "different").

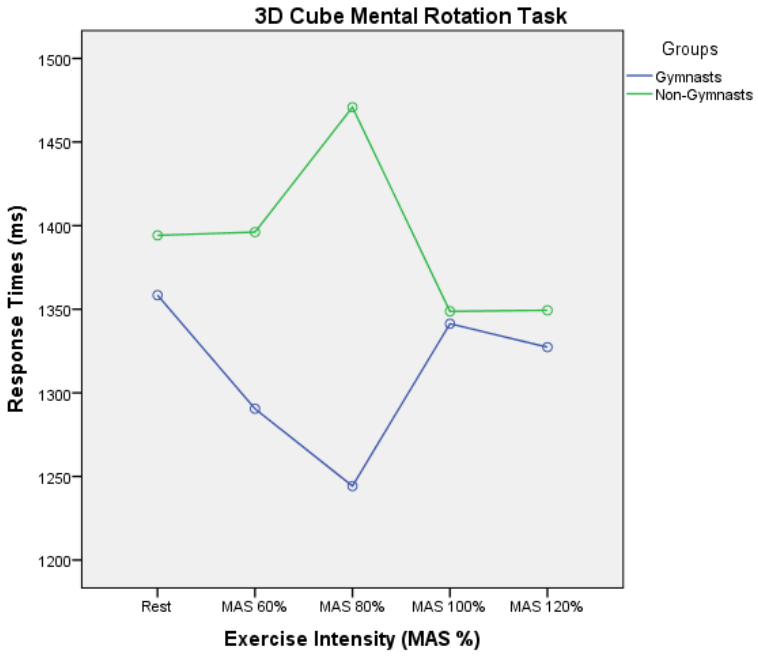


*Figure 2.* Response times according to different exercise intensities in 3D cube mental rotation task.

## DISCUSSION

The present study investigated the effect of exercise intensity on cognitive performance in gymnasts and non-gymnasts. The main aim was to verify whether gymnasts would be capable of maintaining their cognitive processing level and even enhance it after a short period of acute exercise when they perform a cognitive task involving mental rotation of 3D object. For this aim, we designed a 3D cube mental rotation task (Habacha et al., 2017; Jansen & Lehmann, 2013; Metzler & Shepard, 1974; Shepard & Metzler, 1971; Shepard & Metzler, 1988), and we compared the effect of preceding bouts of intense exercise on the mental rotation performances of gymnasts and non-gymnasts.

Our results showed that the gymnasts were able to maintain cognitive ability and even improve it after acute bouts of exercise (i.e., 60%, 80%, 100% and 102% of MAS). In addition, the gymnasts performed mental rotation significantly faster after undergoing a brief exercise at 60% and 80% of their maximal aerobic

speed (MAS). This is in accordance with the suggestion that an increase in arousal (i.e., neurophysiological activation) goes along with increasing exercise intensity (McMorris & Graydon, 2000). Likewise, our result agrees with McMorris and Graydon (2000), not only for submaximal exercise, but also for maximum exercise. This increase may be associated with increased cognitive processing in the central nervous system and consequently with an enhanced amount of attentional resources devoted to the cognitive task administered (Kamijo et al., 2004; Kamijo, Nishihira, Higashiura, & Kuroiwa, 2007). However, non-gymnasts performed mental rotation significantly slower after undergoing a brief exercise at 80% of their maximal aerobic speed (MAS). This result is in accordance with the study of Delignières, Brisswalter, and Legros (1994) which showed that when performing a cognitive task at different exercise intensities (i.e., Rest, 20%, 40%, 60% an 80% of MAS), non-athletes, unlike athletes, significantly increase their response times during submaximal effort (i.e., 80% of MAS). In addition, Naito (1994), Pietsch and Jansen (2012) and Ozel et al. (2002) tested athletes and non-athletes in an abstract object mental rotation task and showed shorter response times in athletes than non-athletes. These authors suggested that the regular practice of physical activity could be linked to the spatial abilities of the participants whose subjects present.

However, as demonstrated here, in non-gymnasts, 2 minutes of exercise at 60% of MAS seems to be insufficient to trigger an increase or decrease in cognitive processing. This result may suggest that when designing experiments on the effect of short bouts of exercise on cognitive ability in non-expert athletes, an intensity greater than 60% of the MAS could be necessary to generate an increase in arousal and thus cognitive processing. Alternatively, 2 minutes at 60% of the MAS could have been too short and a longer duration at the same intensity might be necessary. It should be noted that these results take into consideration the level of specific physical expertise.

Interestingly, the interaction between exercise intensity and expertise revealed that only the gymnasts benefited from an enhancement of cognitive processing (i.e., 60% and 80% of MAS). On the one hand, this result corroborates the assumption that cognitive processing is facilitated after bouts of acute exercise (Tomporowski, 2003). On the other hand, this finding specifies the effect of acute exercise by revealing that cognitive facilitation depends on tasks linked to well-learned and automatic skills (McMorris & Graydon, 2000). Additionally and more interestingly, this improvement (i.e., for gymnasts) of mental rotation performance is at 80% of MAS. This is in line with several research studies (Cox, Thomas, Hinton, & Donahue, 2004; Jouini, Mkaouer, & Chamari, 2017a, 2017b) that suggested 80% of MAS as a cut-point for enhancing cognitive performance.

The results of the present study reveal an enhancement of visual mental rotation after brief bouts of intense exercise only in gymnast. However, in a recently accepted study (Khalfallah, Mkaouer, Amara, Habacha, & Souissi, 2021), gymnasts, unlike non-gymnasts, were shown to benefit from the preceding bouts of exercise also with mental rotation based on egocentric motor strategies. Indeed, the same research protocol was carried out, but the mental rotation task included 3D human body images. The results showed that the gymnasts performed mental rotation significantly faster than non-gymnast after undergoing brief bouts of exercise at 80°, 100°, and 120° of their maximal aerobic speed (MAS). The authors suggested that non-gymnasts, faced with upside-down body positions that were not well-learned (as in gymnasts), could not benefit from the increased attention resources devoted to the task. Taken together, these findings

may suggest that preceding bouts of intense exercise enhance mental rotation performances in gymnasts and not in non-gymnasts, both in motor-based and visual-based mental rotation tasks. In fact, the mental emulations of a 3D rotated cube are quite familiar to the internal logic of artistic gymnastics, so gymnasts were able to fully benefit from the increase in arousal and enhanced amount of attentional resources to solve the task (Kamijo et al., 2004, 2007). This finding corroborates the selective physical expertise of gymnasts in mental rotations task (Habacha et al., 2017; Khalfallah et al., 2021; Steggemann et al., 2011).

## CONCLUSION

Our study is the first to show a decrease in response times in a 3D cube mental rotation task after acute bouts of exercise, but it could hardly explain the discrepancies in the literature about the influence of exercise on cognitive processing. The level of physical activity/expertise seems to be an important variable that may affect cognitive performance following intense exercise. Our study, based on egocentric motor strategy, highlights another variable: the task parameters linked to selective physical expertise of the participants. Further studies should take into account these two variables to better understand the influence of exercise on cognition and to avoid unwarranted generalizations.

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Article received: 4.5.2021
Article accepted: 18.8.2021

# BODY AND PERFORMANCE IN RHYTHMIC GYMNASTICS: SCIENCE OR BELIEF?

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*Original article* *DOI:10.52165/sgj.13.3.311-321*

***Abstract***

*This study aims to identify whether competitive rhythmic gymnasts feel body dissatisfaction and, if so, to analyze the factors related to its development and the implications for the gymnasts' health. We interviewed 28 female gymnasts, aged between 13 and 16 years, from three teams in one Brazilian state. Based on the thematic analysis, we present the following themes: "Body, Performance, and Misconceptions in Rhytmic Gymnastics (RG)" and "Body weight in RG: Belief vs. Science." Gymnasts' dissatisfaction with their bodies appears to be influenced by their coaches, judges, and other athletes, who reinforce the existence of an established "ideal" body type in this sport. The athletes seem to believe that this body ideal would help them in the movements execution in the judges' evaluation, and would, therefore, influence competitive performance. Their coaches used body mass measured on a set of scales as a reference for controlling and guiding weight loss. To lose weight at all costs, the gymnasts mentioned that they took laxatives and adhered to self-imposed calorie restriction. Excessive pressure to lose weight and obtain results could lead to or maintain body dissatisfaction and damage gymnasts' health. Thus, coaches must be careful when associating weight loss with better performance; they need to consider the individuality of gymnasts and should not generalize them. Moreover, professional monitoring should be adopted, as well as the use of reliable and justified body evaluation methods. Preventive measures and coach education should also be implemented, and official agencies should regulate and punish any excessive and abusive practices.*

***Keywords***: *young athletes, rhythmic gymnastics, body dissatisfaction.*

## INTRODUCTION

Back in the beginning, Rhythmic Gymnastics (RG) was named Modern Gymnastics, including the discipline, the body conditioning, and the aesthetics (Bobo & Sierra, 1998). Adult women with mature and curvilinear bodies practiced this sport, as portrayed in photographs and videos from that period.

Women Modern Gymnastics gained prominence in the sports world and became RG. In RG, women presented sensitive characteristics and body expressions, considered appropriate to a female sport (Wiltshire Viana & Mezzaroba, 2013). Over time, as a result of the sportivization process, the gymnasts'

movement became dynamic, trained, and extremely technical (Matias da Costa Pereira & Nascimento de Medeiros, 2016). Currently, in high performance RG, a lean body, long limbs, and low body weight represent the athletes' body ideal (Purenović-Ivanović, Popović, Bubanj, & Stanković, 2019; Batista, 2019). The relation of this ideal body shape to performance has become an issue increasingly present in the discipline (Santos, 2019). Moreover, most gymnasts are young and a high performance level is achieved at an early age, with the main national and international results achieved at between 15 and 19 years old (Antualpa, Moraes, Schiavon, De Arruda, & Moreira, 2015).

Generally in competitive RG, the coaches and athletes consider low body weight to be an essential requirement for performance (Kaur & Koley, 2019). Thus, RG athletes would be subject to early concerns about their appearance, about oscillation of weight, and, in particular, dietary habits for maintaining or losing weight (Amorim, 2019; Johns & Johns, 2000). This perception about gymnasts' body weight may also be distorted by their coaches, judges, media, and their parents, and consequently could lead to body dissatisfaction and be indicative of gymnasts' inadequate dietary behaviours (Kerr, Berman, & De Souza, 2006).

Other factors may also influence the RG athletes' body dissatisfaction. One of those factors is that they are children and young female practitioners (Kosmidou et al., 2015) and as such they tend to be more affected by body dissatisfaction and appearance (Conti, Frutuoso, & Gambardella, 2005). They may also be more subject to external evaluations regarding their physical appearance, such as by the media and society in general. Moreover, studies have reported that the higher the RG athletes competitive level, the greater is the prevalence of eating disorders and risky dietary behaviours (Francisco, Alarcão, & Narciso, 2012; Krentz & Warschburger, 2013; Mountjoy et al., 2018; Sundgot-Borgen, Garthe, & Meyer, 2013)

Body dissatisfaction and demands for a body ideal are facts in RG, directly and negatively affecting the athletes, at a physical and psychological level (Flament et al., 2012). Thus, it is necessary for coaches, judges, media, and society in general to listen to the athletes. This will hopefully trigger changes in the historically built habits, misconceived practices, perceptions of the ideal body type, and beliefs. It is necessary that the changes preferably occur vertically and top-down, in other words, they should start at the International Gymnastics Federation (FIG), which should regulate and monitor those involved with RG; trickle down to confederations and federations, and finally reach coaches, parents and gymnasts. The changes should be encouraged through reflection, discussion about the sport, and education for coaches, parents, and gymnasts.

In this context, this qualitative study aims to investigate whether adolescent athletes who practice competitive RG feel body dissatisfaction and, if so, to analyze the factors related to that process and the implications for the athletes' health.

## METHODS

This study is part of a larger qualitative research project, based on semi-structured interviews with female Brazilian gymnasts and RG coaches, entitled "Body dissatisfaction in Rhythmic Gymnastics".

The project obtained ethical approval from the Research Ethics Committee of the first author's university (CAAE: 13359219.3.0000.5659). All ethical criteria were met and all participants and their parents/tutors signed a consent form.

28 female Brazilian gymnasts aged between 13 and 16 years participated in this study. The participants average age (standard deviation) was 13.96 (± 1.1), and

the mean time of practice was 5.88 (± 2.1) years.

The gymnasts were from RG teams of three cities in the São Paulo state, in Brazil. They were all randomly given a number (G1 to G28) in order to maintain their anonymity. The gymnasts had to had more than three years of practice, in our opinion, as this would give clearer perceptions regarding RG practice and enough experience to be able to discuss the topic. In 2019, the teams of those interviewed participated in state and national RG competitions, both in individual and team categories.

To obtain data we conducted semi-structured interviews (Triviños, 1987) individually with each gymnast. The interviews were conducted by the first author of this article in the gym of each participant. As a former rhythmic gymnast at the same level as the participants, the first author was able to sustain a lively and frank interview and encourage the young participants to talk about their perceptions about RG practice. All interviews were recorded and transcribed verbatim. They lasted between 6 and 20 minutes and followed an interview schedule composed of 10 questions attached at the end of this document.

We used the six-phase model of thematic analysis for data treatment (Braun & Clarke, 2006). The method aimed to analyse and report patterns (themes) within data (Braun & Clarke, 2006). In doing so, it allowed us to "minimally organize and describe our data set in (rich) detail" (Braun & Clarke, 2006, p. 79).

Therefore, after listening to all interviews and re-reading the transcripts (Phase 1), we coded the material. We used data-driven codes (e.g., a decrease in carbohydrate intake, use of laxatives, refusal to eat) (phase 2). This process allowed for "coding the data without trying to fit it into a pre-existing coding frame, or the researcher's analytical preconceptions" (Braun & Clarke, 2006, p. 83). In phases 3 to 5, the different codes were organized into (initial) themes: for example, codes such as (Use of inappropriate methods to lose weight) were collated in the theme "The balance in RG: Belief vs. Science", and in the subtheme "Consequences of weight control in competitive RG". We also paid attention to the relationships between themes and subthemes (see the thematic "map" in Fig 1). Finally, our analytic narrative was structured and is presented in this article (phase 6).

Despite our data-driven approach, thematic analysis ascribes great importance to researchers' reflexive engagement in the analytic process (Braun et al., 2016; Braun & Clarke, 2019, 2020). Our group of researchers comprised two former rhythmic gymnasts, one former artistic gymnast and expert in gymnastics research, and one gymnastics researcher with no-background as gymnast. Thus, the personal perspectives of the researchers were important to the research formulation and discussions, especially, in the phase 6 of the thematic analysis model (Braun & Clarke, 2006). However, in an attempt to ensure the credibility and rid research of subjective bias we have invested in an interactive triangulation in the data analysis since the first drafts of this article (Tracy, 2010).

## RESULTS AND DISCUSION

***Theme 1: Body, Performance, and Misconceptions in RG***. There were gymnasts who reported that they were satisfied, while others showed dissatisfaction with their body. They mentioned an increase in body weight during adolescence as well as physical characteristics that displeased them, such as shortness and bulky parts of the body.

Elite gymnasts usually present a low percentage of body fat (Sundgot-Borgen et al., 2013). This may be explained by the high value placed on the body with long limbs and low weight that could be associated with better performance in the

sport (Donti, Bogdanis, Kritikou, Donti, & Theodorakou, 2016; Porpino, 2004). The reflection of this RG body ideal is observed in the biotype of gymnasts from countries that have a tradition in this sport and present most impressive international results, such as Eastern European countries (Bulgaria, Russia, Ukraine): *"My body is not the same as this or that gymnast's because we always compare ourselves with the Russians, Ukrainians, and they are so, like, lean, you know? They barely have a belly and we sometimes look at ourselves in the mirror and we aren't like that"* (G17); *"My body is not a gymnast's type. [...] They're all tall and thinner, you know? Long legs. […] And as if it was another world within RG, there's a certain type you need to be"* (G15).

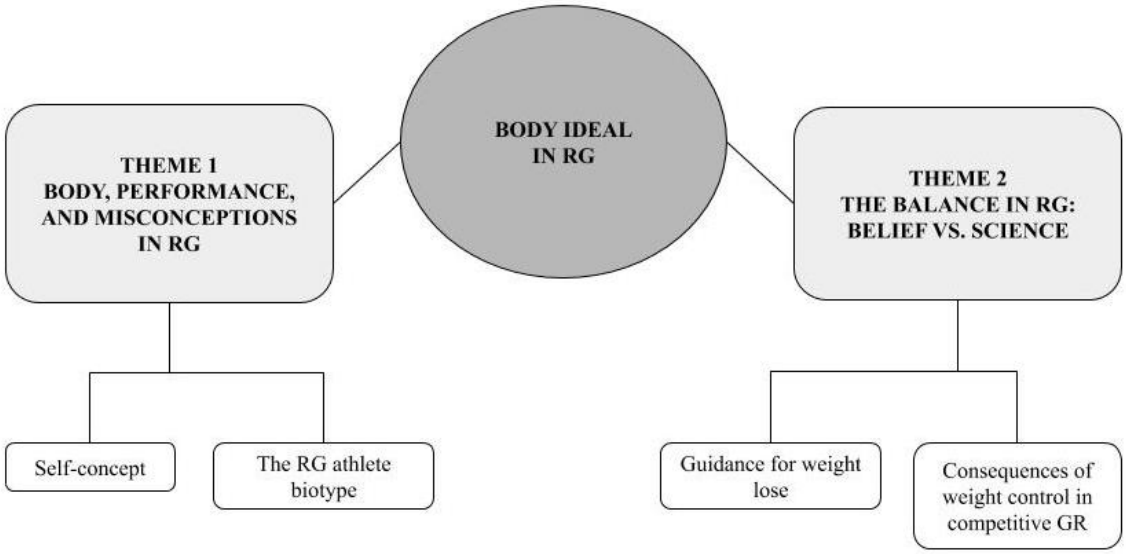


Figure 1. *Thematic analysis map.*

Body dissatisfaction was also shown in relation to the athletes' impressions at specific moments, such as in pre-competitive periods, for example, when the pressure to lose weight was intensified: *"When it's close to a competition I get paranoid, saying I need to lose weight, lose weight, lose weight, I get that in my head"* (G28).

In this sense, de Bruin, Oudejans, and Bakker (2007) highlight that gymnasts may be satisfied with their body image in their daily life; however, they believe that in the gymnastics context they need to be thinner to improve their abilities. Our respondents confirmed this as they held different perspectives regarding their bodies within the RG context and outside. *"I saw all the girls at school maturing physically, and I was still very thin [...] I had very low self-esteem regarding my body because of that. [...] I don't know why I give so much consideration to the gymnastics standard and the society standard. Because that society parameter is always thin, with huge thighs, big breasts and all; and in gymnastics it is the really thin girl, with no breasts, no butt, nothing"* (G17). The association of that "mature" body with performance is not presented nor discussed among the gymnasts. Small and almost infantile bodies are compared with the social body standards, which demand maturity, whereas the sport standards demand the thin ideal. However, these standards are forged within a foreign reality, which is not based on the Brazilian biotype, its descendants and their own characteristics.

The ideal body shape valued and desired by society is in sharp contrast with the RG standard. Except for those who give up the sport, gymnasts generally submit to what they believe to be necessary to achieve the sporting results they desire, and they submit themselves to unequal power in relationships with coaches, judges, and sports managers (Johns & Johns, 2000). How many reports, stories, and scenes have already been heard, seen, and reported (Boaventura, 2016) of gymnasts who were denied a place in a team or were even denied a position because they had a body outside the ideal type? Thus, the reasons athletes find to accept and internalize explanations that justify their attitudes are numerous (Johns & Johns, 2000).

Even though improved performance in RG is associated to biological and physical conditions, to the teaching-learning process, and to technical aspects, among other factors (Bobo-Arce & Méndez-Rial, 2013), the athletes mistakenly related it to the body ideal, believing that it would facilitate the execution of movements, would make them less prone to injuries and more harmonious, while also influencing the results in competitions: *"A thinner (body) would make the routine prettier, it would be easier to jump, and you get fewer injuries"* (G24); *"It has a lot to do with their [the coaches] impression, what they see, what they say about us being chubby. And also in relation to the other girls (from RG) who are thin"* (G4). This perspective is undoubtedly present due to the influence of coaches and the sport community, given the famous discourse around the association between the ideal body shape and performance.

According to some authors (Donti et al., 2016; Sundgot-Borgen & Garthe, 2011), a high percentage of body fat would be considered a disadvantage in RG, as it would reduce the efficiency of movement and, therefore, negatively affect the athlete's performance. However, from the athletes' reports, this may not be the reality: *"She [the coach] says that we are fat, but we don't think we're so fat"* (G21); *"Here we have to lose weight because the discipline demands thin girls, but I don't think I'm fat"* (G2). Boaventura (2016) presents various studies about relatively low body mass index in RG athletes compared with non-athlete girls of the same age, and she emphasizes the need to educate coaches and athletes, and to allow dietitians to monitor the situation. Amidst disinformation and assumptions without any adequate clinical evaluation, the body that RG coaches and athletes consider overweight for the sport is not always one with a high fat percentage, but one that does not appear to fit the ideal. Similarly, a so-called thin body is not necessarily one with a low-fat percentage, but a body that is visually lean.

Other factors that could cause body dissatisfaction, and that contribute to the athletes attributing importance to the RG ideal body are judges' comments regarding the gymnasts' bodies and their supposed evaluation of the biotype. Interviewees reported situations in which this occurred: *"I've already seen cases when a judge reduced a score because of the girl's body: 'Ah, but you're giving that score to that chubby girl?"* (G17).

Thompson and Trattner Sherman (1993) affirm that the the judges who emphasize thinness are essential in the etiology of eating disorders. That search for the ideal body for the practice is deeply linked to the propensity of the sport for eating disorders, especially bulimia, as gymnasts are not guided toward a healthy diet, but are encouraged above all to obtain a standardized body (Boaventura, 2016). Besides the possibility of being harmful to athletes' health (Kerr et al., 2006), the biotype evaluation is not in accordance with the RG Code of Points rules (FIG, 2020) since it does not specify a body profile of the athletes (Ávila-Carvalho, Klentrou, Palomero, & Lebre, 2012). Studies have analysed judges and the

evaluation process in RG (Fernandez-Villarino, Bobo-Arce, & Sierra-Palmeiro, 2013; Leandro, Ávila-Carvalho, Sierra-Palmeiro, & Bobo-Arce, 2017; Popovic, 2000; van Bokhorst et al., 2016). However, the results do not show clearly what impact the gymnasts' biotype has on their competition results.

Even though evaluation is regulated by the RG Code of Points (FIG, 2020), there is no scientific evidence that supports the body standard established by the sport. Rules and references are dominated by those countries that have achieved best results on the international stage, i.e., Russia, Bulgaria. This global influence may dictate guidelines regarding technical questions (exacerbated use of flexibility, body elements), artistic questions (choreographic dynamics, costumes), and also nutritional questions. Boaventura (2016) confirms the influence of these countries and mentions a case of a gymnast from the Brazilian RG team who said that drinking water was not allowed during training sessions due to probable weight gain. The author notes that girls that could not drink water during training sessions got chills and became dizzy as a consequence.

In addition, if there are no requirements in the Code of Points (FIG, 2020) regarding the gymnasts' biotype, it is be important to understand why the idea of the ideal body shape persists and to knowwho is creating this misconception.

***Theme 2: Body weight in RG: Belief vs. Science.*** In RG, the psychological pressure to lose weight has been associated with negative comments from coaches on the athletes' bodies and with regular control of the athletes' weight using only a set of scales (Francisco et al., 2012; Sundgot-Borgen & Garthe, 2011; Porpino, 2004): *"here, they've always said I'm fat, since I joined [...], and that we need to lose weight"* (G8); *"I felt pressured a lot, a lot, a lot, a lot! I think that I feel even fatter when I am weighed. [...] I started to get kind of desperate then I'd cry. [...] It was a lot of pressure, we weighed ourselves, and we didn't lose weight nor get fatter, it stayed the same. They [the coaches] were already angry because I had to lose weight"* (G2).

For gymnasts, the pressure to lose weight makes them more likely to believe in the need to be thin and this can trigger inadequate and sometimes extreme dietary behaviours (Rosen & Hough, 1988). G4's statement exemplifies the situation. Her teammate and herself used laxatives: *"They'd put on the pressure to lose weight, call us fat, it just got us down, so we took laxatives, to lose weight at all costs. [...] It was me and her, we shared that"* (G4).

Beside using laxatives, some participants reported self-imposed calories restriction. The use of inadequate methods to try to quickly lose weight appears to be very common among athletes in sports that associate thinness and low body weight with performance and are often accepted and reproduced practices in RG (Sundgot-Borgen & Garthe, 2011). In these environments, younger athletes may learn these inadequate methods from experienced mates and develop eating disorders (Francisco et al., 2012). There are various consequences of inappropriate weight loss methods, such as metabolic disorders, abnormal hormonal alterations, dehydration, and prolonged low and insufficient energy levels that prevents girls from meeting the demands of physical exercise and normal body functioning (Mountjoy et al., 2018).

It is observed that gymnasts concentrate their efforts and focus on the search for the ideal body instead of on improving their physical abilities and skills (Sundgot-Borgen et al., 2013). These misconceived practices in RG have been passed on from generation to generation and the athletes generally fail to recognize them as inappropriate when they are immersed in the sport (Kerr & Dacyshyn, 2000). They see them as the *"norm or normal"*: *"I think that they [the coaches] set the goal for you to achieve and be*

*thinner, so that when you reach that goal you have to achieve another one and you get thinner and thinner. To be able to achieve the body of a girl who will go to a world championship, who will go to the Pan American Games, those things [...] They just decide by looking at you: 'you will lose such and such weight"* (G22). This report reflects the daily routine of many teams where coaches assert control over body mass on a weekly and sometimes daily basis and monitor weight fluctuations. Further, action is taken to counter weight gain and combat excess body fat (Boaventura, 2016). *"You will lose certain amount of weight"* (G22) is a common demand in RG and needs to be discussed and reconsidered. What are the parameters for that "certain amount"? What are the indications that "certain amount" will be positively reflected in the technical performance of those gymnasts? What is the psychological and physiological impact on the gymnasts generated by weight control, as they try to meet the daily, weekly, monthly goals, and to achieve them, they control their diet in a misconceived way? (Boaventura, 2016).

In Brazil, RG is not a traditional sport like in Russia, Bulgaria, Belarus, and Ukraine. However, RG has been growing in Brazil and efforts have been made to further develop the discipline (Agostini & Aleksandrovna Novikova, 2015). Through initiatives by the Brazilian Gymnastics Confederation, courses, workshops, and training camps are organized aiming to improve coaches' performance and broadening the understanding of the sport. They are part of an effort to help Brazilian coaches gain higher international qualifications; however, these channels have also brought in RG traditions and European standards even when they are harmful to gymnasts' health.

It is highly desirable that countries share experience and knowledge; in particular, that countries with a long tradition in RG pass them on to those that are still developing the sport. However, more attention needs be paid to the training methods: they should no conflict with cultural characteristics; they have to be based on the gymnasts, the group and the objectives they want to achieve.

## CONCLUSION

Just like adoption of inadequate dietary behaviours (Kerr et al., 2006), body dissatisfaction among gymnasts appears to be often endorsed by coaches and the sports environment, explicitly or implicitly. Some competitive RG practices appear to contradict the science: for example, when sport performance is associated with the ideal body shape rather than physical and motor abilities. This is further worsened by unhealthy means of losing weight and without any proof from professionals that weight loss is really necessary.

Thus, it is paramount that RG in Brazil is based on scientific facts that consider gymnasts' health; the particularities and genetic factors of Brazilian gymnasts; a better reading and use of the RG Code of Points, and study and knowledge about sports training.

In this sense, it is essential to look at gymnast's health before performance and if professional guidance reveals that weight loss really is necessary, it should be monitored by professionals and agreed upon by athletes and those responsible for them. However, Sundgot-Borgen et al. (2013) propose that gymnasts' physical capacities and specific abilities for the sport should be improved first, along with maintaining a healthy diet and taking care of gymnast's health rather than demanding weight loss.

Therefore, coaches should master sport training and technical issues in RG, and it is essential for them to understand the RG Code of Points while being able to get the best out of each gymnast, in a strategic and conscious way, in order to identify and develop everyone's maximum potential.

Demanding from athletes that they fit an ideal body shape is unviable and practically impossible to achieve, as it ignores individual characteristics. Coaches must respect the Brazilian culture and genetic factors, especially since linear body measurements (i.e., height, lengths and diameters) tend to have a major genetic influence rather than circumferences, skinfolds, body mass, and body fat that can be impacted by training as a result of adaptive processes (Douda, Laparidis, & Tokmakidis, 2002).

The International Olympic Committee's Medical Commission (IOCMC) stresses the need to create specific prevention programs for each sports modality and to establish alarm-raising criteria (Sangenis et al., 2005).

In the case of RG, coaching education is essential and should prioritize guiding and raising awareness among sports professionals, parents, and athletes, and to demystify practices created in RG. In this sense, it is important that gymnasts are instructed since an early age what to expect from coaches and not to accept any inappropriate practices. It is indispensable that parents do not adhere to and support unhealthy practices.

It is also important for the institutions responsible for the sport, like FIG, national and state federations of gymnastics, to be aware and take measures against coaches who use inappropriate practices. Currently, this appears to be a great challenge for RG; however, until this occurs, the efforts for preventing disorders related to body dissatisfaction among athletes are bound to produce limited results and the gymnasts will continue being the ones most adversely affected.

## ACKNOWLEDGEMENT

The São Paulo Research Foundation (FAPESP) (grant numbers: 2019/04687-7) supported this research, and the Research Committee of School of Physical Education and Sport of Ribeirão Preto (EEFERP-USP) through Notice n. 01/2020 financed the translation of this article.

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## ANNEX

Interview Schedule

1. What does your body represent for you?
2. What does your body represent for RG?
3. How do you feel in relation to your body image?
4. Do you share these thoughts with anyone?
5. What do you think about your diet?
6. How do you feel during a training sessions?
7. What do you feel when you're being judged?
8. What would you say about the biotype of other gymnasts?
9. Do you perceive any change that has occurred in your body over the course of your journey within RG?
10. Should anything (or anyone) change in RG?

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Article received: 10.12.2020
Article accepted: 3.5.2021

# ARE THERE CONNECTIONS BETWEEN THE BODY FAT PERCENTAGE, COMPETITIVE RESULTS AND MOTIVATION IN WHEEL GYMNASTS?

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*Original article* *DOI:10.52165/sgj.13.3.323-336*

***Abstract***
*Motivation is a performance-limiting factor in sports. Thus, the relevance of motivation for performance in wheel gymnastics must be clarified. 203 German gymnasts were studied. Motivational differences were found between different disciplines and performance levels. Differences between performance levels were also present in groups grouped by discipline. Additionally, a connection was found between hope for success and body fat percentage as well as motivational factors and deductions to difficulty score. Several motivational aspects correlated with age. There were significant correlations between motivational factors and age at different performance levels. Results suggest that motivation might be relevant for the development of talent in wheel gymnastics*

***Keys words***: wheel gymnastics, body fat percentage, judges, competitive results, motivation.

## INTRODUCTION

Wheel gymnastics originated in Germany in 1925 when Otto Feick built a two-rimmed wheel in which a person can stand while the wheel itself is moving (Sebesta, 2002). In current wheel gymnastics, there are four different disciplines: vault, straight line with/ without music, spiral, and, more recently, cyr (Kauther, Rummel, Hussmann, Lendemans, Wedemeyer & Jaeger, 2015). In wheel gymnastics, points are given to the athlete for technical difficulty and composition of a routine but deducted from the execution value if the athlete performs a movement technically correctly but inaccurately (Deutscher Turner-Bund (DTB), 2008). According to literature, the disciplines demand strength, endurance, flexibility, as well as core, explosive and jumping strength, coordination of movement, concentration, emotional control, perception, stress resistance and self-esteem, as well as aesthetic expression (Hundrieser, 2012; Weyermann, 2016).

Sports performance is limited by physical aspects and psychological factors such as motivation: psychological factors in performance have, for example, been researched in volleyball (Mostafa & Mansour, 2016), netball (Grobbelaar & Eloff, 2011) and soccer (Hughes, Caudrelier, James, Redwood-Brown, Donnelly, Kirkbride et al., 2012). It should be researched whether motivation is also relevant to performance in wheel gymnastics. Hume, Hopkins, Robinson, Robinson & Hollings (1993) found that motivation correlates with attainment in gymnastics, while D'Arripe-Longueville, Hars, Debois & Calmels (2009, p.424)

showed that "the main psychological characteristics developed by all the participants pertained to achievement motivation, performance enhancement cognitive skills (e.g., focusing, imagery), and affective and psychosomatic skills (e.g., ability to deal with anxiety; relaxation)". It is claimed that a strong motivational driving force is essential to perform high level gymnastic exercises and maintain daily practice (Munkácsi, Kalmár, Hamar, Katona & Dancs, 2012).

When selecting gymnasts for wheel gymnastics, the current discussion regarding talent selection must be kept in mind. Samuelsen (2003) claims that anthropometric factors are irrelevant for performance in wheel gymnastics because the wheels come in different sizes. Rummel (2016), however, names BMI as relevant for wheel gymnastics and claims that it is comparable to that in ski-jumping (Muller, Groschl, Muller & Sudi, 2006). Female gymnasts show a lower BMI than males and female wheel gymnasts have the lowest percentage of body fat in the German population (Kromeyer-Hauschild, Wabitsch, Kunze, Geller, Geiß, Hesse et al, 2001). Some gymnasts' BMI is below the z-scores recommended by the World Health Organization (Onis, Onyango, Borghi, Syiam, Nishida & Siekmann, 2007). According to Rummel (2016), low BMI is mostly prevalent in amateur wheel gymnasts. Findlay & Ste-Marie (2004) state that in figure skating, expectations of judges can be reflected in the ratings. According to the authors, judges might, for example, associate low body fat percentage with a higher motivation for extensive practice and discipline and award marks accordingly, thus judging not the performance but the psychological characteristics supposedly displayed by the physical appearance of the gymnasts.

However, fitness and physical factors are viewed with reservations in talent selection (Gonçalves, Rama & Figueiredo, 2012); therefore, mental skills might be of better use (Baron-Thiene & Alfermann, 2015). According to Moesch, Hauge, Wikman & Elbe (2013), skills such as volition and probably motivation might be a better predictor than other performance factors in selecting for team sports. This might also be true for individual sports and thus for wheel gymnastics. However, only a few studies so far have researched the connection between motivation and performance in gymnastics and no studies in wheel gymnastics in particular. Koumpoula, Tsopani, Flessas and Chairopoulou (2011) found high motivation in rhythmic gymnasts. Additionally, motivation and training time can be seen as predictors of attainment in gymnastics (Hume, Hopkins, Robinson, Robinson & Hollings, 1993). In team handball, differences were found between male and female athletes (Kristjánsdóttir, Erlingsdóttir, Sveinsson & Saavedra, 2018).

Mies (1994) states that wheel gymnastics can be considered an aesthetic sport, where athletes are required to look slim (Potter, Lavery & Bell, 1996). In aesthetic sports, such as artistic and rhythmic gymnastics, performance is related to thinness (Avilla-Carvalho, Klentrou, Luz Palomero & Lebre, 2013; Falls & Humphrey, 2013; Bacciotti, Baxter-Jones, Gaya & Maia, 2017, amongst others). Athletes in aesthetic sports display lower body fat values than non-athletes or athletes from other sports (Georgopoulos, Markou, Theodoropoulou, Bernadot, Leglise & Vagenakis, 2002; Gomez-Landero, Vernetta & Bedoya, 2009; Parm, Saar, Pärna, Jürimäe, Maasalu, Neissaar & Jürimäae, 2011; Galetta, Franzoni, D'Alessandro, Piazza, Tocchini, Fallahi et al., 2015; San Mauro Martín, Cevallos, Pina Ordúñez & Garicano Vilar, 2016). Compared to other aesthetic sports, wheel gymnasts display a rather low percentage of body fat and earn lower scores from the judges for their performance (Weber, 2020). Thinness might be related to motivation.

These findings further suggest that an overrating of the aesthetic aspect of athletes could endanger the healthy development and motivation of young competitors and thus lead to an early drop-out. If overrating of aesthetic aspects takes place in wheel gymnastics, gymnasts and especially young gymnasts, should be protected. At the same time, psychological factors may be a better predictor of future success than physical aspects; therefore, selection and mental training should take place according to the actual motivational performance demands.

Therefore, this study aims to answer the following questions:

1. Are there significant differences in motivation between:

a) gymnasts at different performance levels;

b) female and male wheel gymnasts; and

c) gymnasts competing in different disciplines?

2. Is there a connection between motivation and performance during

a) training, and

b) competition

regarding overall merit, difficulty, composition, and execution?

3. Is there a connection between percentage of body fat and motivation?

4. Is there a connection between motivation and the difference between the planned and earned difficulty score?

5. Does motivation correlate with age?

## METHODS

Measurements included 203 voluntary participants (female: N = 183, % body fat average = 14.54 ± 3.4 and age average = 21.17 ± 11.91; male: N = 20, % body fat average = 8.00 ± 3.74 and age average = 16.84 ± 4.90) of the German Gymnastics Federation (Deutscher Turner-Bund/ DTB), section gym-wheel. The age ranged from 6 to 58 for female and from 7 to 27 for male gymnasts. Only gymnasts participating in a competition on the day of measurement were included. Informed consent was obtained from all participants.

Skin folds were recorded using a calliper (Slim Guide, Creative Health Products, Plymouth, Michigan). Competitive results, performance during training, evaluation of the current competition, gender, age and competitive level were obtained using a specially developed questionnaire. All values were recorded at major national competitions in 2018.

Body fat percentage was calculated using the method of Siri (1956) for calculating body fat, using three skin folds for female gymnasts (Jackson, Pollock & Ward, 1980). For male gymnasts, Siri (1956) and Jackson & Pollock (1978) were used to calculate the percentage of body fat using three skin folds and two circumferences. Due to different compositions of body tissue, female and male athletes require individual calculation methods (Jackson & Pollock, 1978; Jackson et al., 1980).

Percentage of body fat was calculated with $\%\_Bodyfat = (4.95 / Body\ density) - 4.5$ (Siri, 1956). Body density was calculated with $Body\ density = 1.096095 – 0.0006952 * sf\_tri + sf\_abd + sf\_sup + sf\_thigh) + 0.0000011 * (sf\_tri + sf\_abd + sf\_sup + sf\_thigh)^2 – 0.0000714 * age$ for female gymnasts (Jackson, Pollock & Ward, 1980), using age in years and four skinfolds, where sf = skinfold, tri = triceps, abd = abdominal, sup = suprailiacal and thigh = directly above the knee. Body density for male gymnasts was calculated with $Body\ density = 1.15737 – 0.02288 * ln(sf\_pect + sf\_abd + sf\_thigh) – 0.00019 * age – 0.0075 * c\_nav + 0.223 * c\_arm$ (Jackson & Pollock, 1978), using age in years, two skinfolds and two circumferences, where sf = skinfold, pect = pectoralis, abd = abdominal, c_nav = circumference at navel height and c_ arm = highest circumference of the lower arm.

Motivation was measured using the Achievement Motives Scale (AMS) by Elbe & Wenhold (2005), which consists of the following dimensions: hope of success; fear of failure; net hope (hope of success minus fear of failure), and total achievement motive (sum of hope of success and fear of failure). The questionnaire is in use in German talent selection in team sports up to the national level (Beckmann & Linz, 2009) and suitable for talent selection in several sports (Wenhold, Meier, Beckmann, Elbe & Ehrlenspiel, 2007). The scale consists of 30 questions with 0 to 3 points per question; there are 15 questions for hope of success (0 to 45 points) and 15 for fear of failure (0 to 45 points); on this basis, net hope is calculated as net hope = hope of success – fear of failure (-45 to 45 points) and the total achievement motive as total achievement motive = hope of success + fear of failure.

An additional questionnaire asked for age, gender, straight line difficulty (technical merit) achieved during training and straight line difficulty achieved at the last competition. The difficulty difference was calculated as the difference between the technical difficulty achieved during training minus the technical difficulty achieved during competition in the straight line discipline. In German competitive wheel gymnastics, gymnasts are required to hand in a difficulty chart before competition, stating what difficulty they were able to perform during training and therefore intend to perform in competition.

Oneway ANOVA was used to compare gymnasts at both performance levels (Bundesklasse/ Landesklasse) and within two disciplines (Straight line/ All-around), once for all gymnasts and once for female gymnasts only, as there was an insufficient number of male participants. The criterion level for significance was set at $p<0.05$ and the trend significance at $p<0.10$. Effect size was evaluated with $\eta^2$ (Eta partial squared), where $0.01<\eta^2<0.06$ constitutes a small effect, $0.06<\eta^2<0.14$ constitutes a medium effect and $\eta^2>0.14$ constitutes a large effect (Cohen, 1988). Correlations between performance and motivation were calculated via Pearson and Spearman`s Rho with correlation levels >0.1 (weak), >0.3 (moderate) and >0.5 (strong). Different types of correlation coefficients were used due to varying sample sizes as well as outliers and lack of homogeneity within subgroups (Malawi-Paper, David 1938). Statistical analysis was carried out in SPSS, version 25 (SPSS, Inc., Chicago, IL).

## RESULTS

While no difference in motivation was found between female and male gymnasts, significant differences occurred between gymnasts competing in different disciplines (Table 1) and at different performance levels (Table 2). Differences between performance levels were also present when gymnasts were grouped according to discipline (Table 2).

Table 1
*Differences in motivation between gymnasts competing in different disciplines at different performance levels (due to the small number of participants, male gymnasts were not considered separately).*

| Differences | N | $\bar{X} \pm SD$ | $p$ | $\eta^2$ |
|---|---|---|---|---|
| Both genders | | | | |
| Straight line vs. all-around | | | | |
| | *80 vs. 42* | | | |
| *Hope for success* | 78 vs. 42 | *33.43 ± 7.54 vs. 36.81 ± 4.90* | *0.010* | *0.055* |
| Overall performance motive | | 43.95 ± 9.27 vs. 47.57 ± 8.90 | 0.039 | 0.036 |
| BK*, straight line vs. all-around | | | | |
| Hope for success | 6 vs. 30 | 41.33 ± 4.80 vs. 36.93 ± 4.81 | 0.049 | 0.110 |
| Fear of failure | 6 vs. 30 | 4.50 ± 4.93 vs. 11.83 ± 8.82 | 0.058 | 0.101 |
| Net hope | 6 vs. 30 | 36.63 ± 9.63 vs. 27.06 ± 11.53 | 0.021 | 0.148 |
| LK**, straight line vs. All-around | | | | |
| Net hope | | | | |
| | 46 vs. 7 | 22.43 ± 11.31 vs. 30.43 ± 11.27 | 0.087 | 0.086 |
| Female gymnasts | | | | |
| Straight line vs. All-around | | | | |
| *Hope for success* | *73 vs. 35* | *33.56 ± 7.86 vs. 36.91 ± 5.20* | *0.021* | *0.049* |
| Overall performance motive | 72 vs. 35 | 43.56 ± 9.03 vs. 47.63 ± 9.42 | 0.033 | 0.042 |
| BK*, straight line vs. All-around | | | | |
| Hope for success | 6 vs. 25 | 41.33 ± 4.80 vs. 37.08 ± 5.16 | 0.077 | 0.104 |
| Fear of failure | 6 vs. 25 | 4.50 ± 4.93 vs. 11.88 ± 9.55 | 0.079 | 0-102 |
| Net hope | 6 vs. 25 | 36.83 ± 9.62 vs. 25.02 ± 11.87 | 0.034 | 0.146 |
| LK**, straight line vs. All-around | | | | |
| Net hope | | | | |
| | 41 vs. 6 | 22.76 ± 11.54 vs. 31.67 ± 11.81 | 0.085 | 0.065 |

*No homogeneity of variance* *BK = Bundesklasse **LK = Landesklasse

Table 2
*Differences in motivation and body fat percentage between gymnasts competing at different performance levels (due to the small number of participants, male gymnasts were not considered separately).*

| Differences | N | $\bar{X} \pm SD$ | $p$ | $\eta^2$ |
|---|---|---|---|---|
| Both genders | | | | |
| BK* vs. LK** | | | | |
| *Hope for success* | *37 vs. 57* | *37.51 ± 5.04 vs. 32.95 ± 7.09* | *0.001* | *0.111* |
| Overall performance motive | 37 vs. 55 | 47.92 ± 8.48 vs. 42.89 ± 9.81 | 0.013 | 0.067 |
| Straight line, BK* vs. LK** | | | | |
| Hope for success | 6 vs. 48 | 41.33 ± 4.80 vs. 42.60 ± 7.21 | 0.060 | 0.137 |
| Fear of failure | 6 vs. 46 | 4.50 ± 4.93 vs. 10.41 ± 7.95 | 0.083 | 0.059 |
| Net hope | 6 vs. 46 | 36.83 ± 9.62 vs. 22.43 ± 11.31 | 0.005 | 0.150 |
| Female gymnasts | | | | |
| BK* vs. LK** | | | | |
| Hope for success | 32 vs. 50 | 37.19 ± 5.32 vs. 33.02 ± 7.23 | 0.002 | 0.111 |
| Overall performance motive | 32 vs. 49 | 47.94 ± 9.00 vs. 42.51 ± 9.82 | 0.014 | 0.074 |
| Straight line, BK* vs. LK** | | | | |
| Hope for success | 6 vs. 42 | 41.33 ± 4.80 vs. 32.67 ± 7.31 | 0.007 | 0.146 |
| Net hope | 6 vs. 41 | 36.83 ± 9.62 vs. 22.76 ± 11.54 | 0.040 | 0.152 |
| Body fat percentage | 7 vs. 42 | 12.27 ± 3.24 vs. 15.54 ± 3.86 | 0.007 | 0.087 |
| All-around, BK* vs. LK** | | | | |
| Body fat percentage | 26 vs. 6 | 12.78 ± 2.52 vs. 17.14 ± 3.52 | 0.001 | 0.296 |

*No homogeneity of variance* *BK = Bundesklasse **LK = Landesklasse

Table 3

*Correlations between motivation, performance factors, body fat percentage and difference between planned and earned difficulty score.*

| | | All female gymnasts | | | | Female gymnasts Bundesklasse | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Hope for success | Fear of failure | Net hope | Overall performance motive | Hope for success | Fear of failure | Net hope | Overall performance motive |
| Body fat percentage | *r* | -0.201 | 0.078 | -0.136 | -0.013 | -0.220 | 0.141 | -0.204 | 0.014 |
| | *p* | 0.036 | 0.420 | 0.162 | 0.895 | 0.227 | 0.442 | 0.262 | 0.938 |
| | N | 109 | 108 | 108 | 108 | 32 | 32 | 32 | 32 |
| Difficulty (competition) | *r* | 0.086 | 0.211 | -0.054 | 0.265 | -0.327 | 0.044 | -0.170 | -0.141 |
| (Straight line) | *p* | 0.420 | 0.046 | 0.616 | 0.012 | 0.128 | 0.843 | 0.438 | 0.522 |
| | N | 91 | 90 | 90 | 90 | 23 | 23 | 23 | 23 |
| Difficulty (competition) | *r* | 0.050 | -0.117 | 0.179 | -0.075 | 0.050 | -0.456 | 0.396 | -0.409 |
| (Vault) | *p* | 0.803 | 0.561 | 0.371 | 0.708 | 0.820 | 0.029 | 0.062 | 0.053 |
| | N | 27 | 27 | 27 | 27 | 23 | 23 | 23 | 23 |
| Difficulty (competition) | *r* | 0.267 | 0.232 | 0.069 | 0.392 | 0.072 | -0.040 | 0.066 | 0.008 |
| (Spiral) | *p* | 0.153 | 0.217 | 0.718 | 0.032 | 0.739 | 0.854 | 0.760 | 0.970 |
| | N | 30 | 30 | 30 | 30 | 24 | 24 | 24 | 24 |
| Execution (competition) | *r* | 0.062 | -0.169 | 0.160 | -0.009 | 0.058 | -0.579 | 0.470 | -0.577 |
| (Straight line) | *p* | 0.580 | 0.131 | 0.155 | 0.935 | 0.792 | 0.004 | 0.024 | 0.004 |
| | N | 82 | 81 | 81 | 81 | 23 | 23 | 23 | 23 |
| Execution (competition) | *r* | -0.181 | 0.258 | -0.314 | 0.173 | -0.206 | 0.443 | -0.454 | 0.315 |
| (Vault) | *p* | 0.367 | 0.194 | 0.111 | 0.388 | 0.346 | 0.034 | 0.030 | 0.143 |
| | N | 27 | 27 | 27 | 27 | 23 | 23 | 23 | 23 |
| Execution (competition) | *r* | -0.243 | -0.047 | -0.102 | -0.225 | -0.369 | -0.073 | -0.133 | -0.309 |
| (Spiral) | *p* | 0.222 | 0.816 | 0.612 | 0.260 | 0.083 | 0.739 | 0.545 | 0.151 |
| | N | 27 | 27 | 27 | 27 | 23 | 23 | 23 | 23 |
| Composition (competition) | *r* | 0.043 | 0.255 | -0.124 | 0.228 | -0.155 | 0.243 | -0.251 | 0.168 |
| (Straight line) | *p* | 0.704 | 0.023 | 0.277 | 0.043 | 0.481 | 0.264 | 0.247 | 0.445 |
| | N | 80 | 79 | 79 | 79 | 23 | 23 | 23 | 23 |
| Difficulty difference | *r* | 0.005 | 0.083 | -0.090 | 0.012 | 0.005 | 0.592 | -0.457 | 0.639 |
| (Straight line) | *p* | 0.965 | 0.481 | 0.444 | 0.917 | 0.982 | 0.005 | 0.037 | 0.002 |
| | N | 75 | 74 | 74 | 74 | 21 | 21 | 21 | 21 |
| Difficulty difference | *r* | -0.157 | 0.312 | -0.342 | -0.028 | 0.071 | 0.425 | -0.312 | 0.455 |
| (Vault) | *p* | 0.464 | 0.138 | 0.102 | 0.895 | 0.759 | 0.055 | 0.169 | 0.038 |
| | N | 24 | 24 | 24 | 24 | 21 | 21 | 21 | 21 |
| Difficulty difference | *r* | 0.555 | -0.306 | 0.496 | 0.148 | 0.609 | -0.312 | 0.535 | 0.101 |
| (Spiral) | *p* | 0.005 | 0.146 | 0.014 | 0.491 | 0.004 | 0.181 | 0.015 | 0.673 |
| | N | 24 | 24 | 24 | 24 | 20 | 20 | 20 | 20 |
| Overall merit (training) | *r* | 0.089 | 0.126 | -0.004 | 0.231 | -0.194 | -0.141 | 0.027 | -0.259 |
| (Straight line) | *p* | 0.394 | 0.229 | 0.969 | 0.026 | 0.375 | 0.522 | 0.902 | 0.232 |
| | N | 94 | 93 | 93 | 93 | 23 | 23 | 23 | 23 |
| DDifficulty (training) | *r* | 0.055 | 0.203 | -0.095 | 0.225 | -0.304 | 0.507 | -0.449 | 0.094 |
| (Straight line) | *p* | 0.633 | 0.078 | 0.416 | 0.051 | 0.169 | 0.016 | 0.036 | 0.678 |
| | N | 77 | 76 | 76 | 76 | 22 | 22 | 22 | 22 |

Blue = strong correlation, pink = moderate correlation, orange = low correlation; yellow = significant, green = trend.

Table 4
*Correlation between motivation and age.*

| | | All female gymnasts | Female gymnasts Landesklasse | Female gymnasts Bundesklasse | All male gymnasts |
|---|---|---|---|---|---|
| Hope for success | *r* | -0,188 | -0,003 | -0,421 | 0,774 |
| | *p* | 0,048 | 0,983 | 0,016 | 0,002 |
| | N | 111 | 49 | 32 | 13 |
| Fear of failure | *r* | -0,054 | -0,263 | 0,415 | -0,296 |
| | *p* | 0,574 | 0,071 | 0,018 | 0,350 |
| | N | 110 | 48 | 32 | 12 |
| Net hope | *r* | -0,072 | 0,164 | -0,508 | 0,596 |
| | *p* | 0,454 | 0,266 | 0,003 | 0,041 |
| | N | 110 | 48 | 32 | 12 |
| Overall performance motive | *r* | -0,185 | -0,154 | 0,090 | 0,297 |
| | *p* | 0,052 | 0,296 | 0,625 | 0,348 |
| | N | 110 | 48 | 32 | 12 |

Connections were found between motivation and several performance factors (Table 3). Also, a connection was found between hope for success and body fat percentage (Table 3) as well as motivational factors and difference between planned and earned difficulty score (Table 3). Several motivational aspects correlated with age in both female and male gymnasts at different performance levels (Table 4).

When considering gymnasts at different performance levels, it is evident that when looking at both genders together, gymnasts need to display higher hopes for success and overall performance motive regardless of the discipline, if they want to perform at the Bundesklasse level. When considering only the straight line discipline, however, gymnasts in Landesklasse show higher hope for success. This could be due to the fact that gymnasts in Landesklasse predominantly perform in the straight line discipline and feel more confident than high-level gymnasts who very often perform in the all-around and have to prepare for several disciplines. A lower fear of failure and higher net hope is required for gymnasts of both genders in Bundesklasse. Most probably this helps them to get in a positive mental state prior to competition. For female gymnasts only, the difference between hope for success in Bundesklasse and Landesklasse in straight line is even greater, perhaps due to more intense competition. Other results do not vary much when male gymnasts are eliminated from the calculations.

Significant differences in motivation (hope for success, overall performance motive, see Table 3) were found in gymnasts of both genders, regardless of the performance level, who performed in straight line and all-around. Higher motivation seems to be required for gymnasts who compete in all-around. This might be due to the longer training period and higher intensity (training three disciplines in one session, no breaks) required when training three disciplines instead of only one. When considering female gymnasts at the Bundesklasse level, however, different motivational demands are demonstrated: higher hopes for success and overall performance motive together with a lower fear of failure are necessary when competing only in straight line. This

might be due to the fact that most gymnasts in Germany start their training in the straight line discipline; hence, this discipline has the highest level of competition and the highest difficulties are very frequently achieved. At the Landesklasse level, higher net hope is necessary for gymnasts who compete in the all-around. The all-around discipline has only recently been introduced at the Landesklasse level. Thus, gymnasts need to be very confident to even enter the competition, mostly competing only against small numbers of competitors in the all-around at their performance level. When considering female gymnasts only, the results are almost the same, as there were only a few male gymnasts participating in the study.

When considering the connection between motivation and performance during training, a correlation between the overall performance motive and the overall merit in straight line was found for all gymnasts. Most probably, high motivation is needed to maintain the drive to perform well during training at this level, even if there is no competitive pressure during training. Further, the difficulty value during training in straight line showed a tendency towards correlation with fear of failure and the overall performance motive. This suggests that a certain degree of avoidance of negative stimuli together with pressure created through high difficulty might be necessary to perform well when training for the straight line discipline for gymnasts at all levels. For gymnasts competing at the Bundesklasse level, there was also a positive correlation between fear of failure and difficulty during training in straight line. Further, gymnasts at this level showed a negative correlation between net hope and difficulty during training; this suggests an even stronger connection between negative motivational aspects and performance at this competitive level. Perhaps gymnasts want to secure high difficulty scores to compensate for a potentially flawed execution value.

There are connections between motivation and performance during competition in relation to the difficulty value in straight line and fear or failure as well as overall performance motive when considering gymnasts at all performance levels together. Also, gymnasts at all levels showed a correlation between the difficulty in the spiral discipline during competition and the overall performance motive. Perhaps high difficulty poses a challenge for gymnasts. It is still unusual for an athlete to compete in the spiral discipline at the Landesklasse level, therefore high motivation is probably required to do so. Also, there are positive correlations between the composition merit of the routine and fear of failure as well as overall performance motive. This could be an indication that gymnasts are trying to create a safety net, i.e., using the composition merit to prevent failure in competition. When considering the Bundesklasse gymnasts alone, a negative correlation can be observed between the difficulty in competition in the vault discipline and fear of failure. Additionally, there is a tendency for correlation between competitive difficulty in this discipline and net hope and for a negative correlation with the overall performance motive. This suggests that gymnasts need to have low fear of failure and, conversely, high-self confidence to be able to cope with the prospect of having to perform a high difficulty routine during competition. For the Bundesklasse gymnasts competing in straight line, there is a negative correlation between fear of failure as well as overall performance motive and execution value, along with a positive correlation with net hope, which suggests that fear of failure negatively influences accuracy of movement while high net hope is beneficial. When assessing correlations in Bundesklasse for the execution value during competition in the vault discipline, it is evident that high fear of failure and

low net hope is relevant to achieving high merit, which suggests avoidance motivated behaviour. When looking at the spiral discipline during competition, gymnasts in Bundesklasse show tendency towards displaying lower execution value when their hopes for success are higher. This could mean that gymnasts at this performance level tend to get careless when they are not challenged enough by a task.

When considering the difference between the planned and the achieved difficulty score, several correlations can be observed. The difficulty difference in spiral correlated with hope for success and net hope for all female gymnasts. This could mean that gymnasts might be overestimating their skill when they have high hopes for success, which may lead them to compose their routines with too high difficulty. At the Bundesklasse level, this connection is even more striking. In straight line, gymnasts at the Bundesklasse level showed positive correlations between the difficulty difference and hope for success as well as overall performance motive, but a negative correlation between the difficulty difference and net hope. This suggests that gymnasts suffer a kind of black-out and therefore underperform under pressure due to high fear of failure. A tendency towards the same mechanism can be seen for the vault discipline at the Bundesklasse level.

Although according to Findlay and Ste-Marie (2004) judges might expect this connection, motivational aspects did neither correlate with the body fat percentage nor any performance factors in Landesklasse. This leads to the conclusion that for Landesklasse, neither gymnasts' body fat percentage nor competitive or training performance are influenced by motivational aspects or vice versa. However, when considering all female gymnasts, hope for success correlated negatively with the body fat percentage. In both straight line and all-around, the body fat percentage of female gymnasts is lower in Bundesklasse than in Landesklasse. This is in line with the findings of Weber (2020) and indicates that gymnasts with a higher body fat percentage do not expect to receive good marks from the judges, regardless of the performance level. When considering Bundesklasse only, no correlations could be found between motivational factors and the body fat percentage. It should be noted that for female gymnasts the standard deviation for body fat percentage at the Bundesklasse level was only 3.24 in straight line and 2.52 in all-around compared to 3.86 and 3.52 in Landesklasse. Bundesklasse therefore displays a higher homogeneity for this factor, which means that correlations are not strong enough to be relevant to Bundesklasse alone.

Age correlated with all motivational factors except overall performance motive in Bundesklasse. Age only showed a tendency for correlation with fear of failure in Landesklasse. Female gymnasts at all levels not only showed a negative correlation between age and hope for success, but also a tendency towards negative correlation between age and overall performance motive, probably due fewer performances at higher age.

When comparing the current findings to results from other sports, it is evident that, as in the study of Wolko et al. (1993), wheel gymnasts could benefit from training self-regulation - and this could be of benefit to gymnasts from other disciplines as well. Additionally, achievement motivation and the ability to deal with anxiety seems to be as relevant in wheel gymnastics as in other types of gymnastics (D'Arripe-Longueville et al., 2009). Strong motivation is necessary to perform wheel gymnastics at a high level, which also applies to other gymnastic disciplines, especially when considering the ability to keep motivation up during training (Munkácsi et al., 2012). Motivation (and thus training time) can be seen as predictors of attainment in wheel gymnastics, which is in line with the

findings of Hume et al. (1993) for other gymnastic disciplines.

The small number of participants in general and especially the small number of male participants have to be considered the main limitation of the study. Additionally, it is necessary to repeat the study internationally. The current findings can only be applied to German wheel gymnasts.

## CONCLUSION

In summary, motivation has shown to be a performance limiting factor in wheel gymnastics in several ways. It can be concluded that motivation in wheel gymnastics is related to performance, as is in other gymnastic disciplines as shown by Munkácsi et al. (2012). Coaching and mental training and perhaps talent selection should be based on an approach that is tailored individually according to discipline, physical fitness, age and performance level.

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Article received: 9.2.2021
Article accepted: 23.7.2021

# THE SPORTING TRAJECTORY OF ELITE ATHLETES IN ARTISTIC GYMNASTICS: A SYSTEMATIC REVIEW

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*Review article* *DOI:10.52165/sgj.13.3.337-355*

***Abstract***

*Sporting success may be influenced by several factors, the magnitudes of which are revealed throughout the athletes' training process. This study sought to systematically review research that deals qualitatively with the sporting trajectory of elite athletes in artistic gymnastics (AG). The searches were conducted in the Web of Science and Scopus databases, contemplating studies published before July 2020. Data extraction was organized according to the focus and location of the study (context), participants, and methodology used, whereby we analyzed the variables associated with the athletes' trajectory. We located 318 articles and, after applying the inclusion and exclusion criteria, 15 original studies were selected for the review. The articles used semi-structured interviews with athletes, former athletes, coaches, referees, and managers. In two studies, the authors used methodological assumptions of oral history: one of them documental analysis, and the other ethnography. The systematic review revealed that parental support is essential for insertion and retention in the sport, both for logistical (financing, transportation, organization of school activities) and emotional reasons. Financial support and good training facilities are factors that positively influence success in AG. A healthy relationship between the coach and the athlete is essential, but this relationship is often reported as authoritarian. The post-career phase must be planned and guided so that the transition happens gradually and the athlete is able to seek a new identity.*

***Keywords***: *gymnastics, career, athletes, review.*

## INTRODUCTION

It may prove challenging to objectively detect the aspects that lead to success in elite sports. De Bosscher, Shibli, Westerbeek, and van Bottenbur (2015) have classified various factors that influence this success into three different levels: macro, meso, and micro level. At the first level are the social and cultural factors such as geography, politics, urbanization, demography, economy, and the national culture. At the second level are the factors that influence the political context, in this case, policies regulating talent detection, coach education, and fostering athletes. Finally, at the micro-level includes factors that influence athletes on an individual level, i.e. genetic predispositions, parental support, relationships with coaches, and engagement with colleagues (De Bosscher et al., 2015).

Several studies (Barreiros, Côté, & Fonseca, 2014; Diehl et al., 2014; Duffy, Lyons, Moran, Warrington, & MacManus,

2006; Hallmann, Breuer, Ilgner, Giel, & Rossi, 2018) have attempted to analyze sporting success based on other variables. Hallmann et al. (2018) emphasize the need to examine it from an individual's perspective, assuming that human capital, motivation, organizational characteristics, and socio-demographic data all play a role in sporting success.

Thus, it is clear that the sporting trajectory of elite athletes is a relevant topic of study; after all, they go through different stages of the formation process that will lead them to sporting success or otherwise (Peres & Lovisolo, 2006). Nevertheless, we are aware that there are differences between different sports that should not be overlooked. Considering such differences, we proceed to the analysis of a specific modality – artistic gymnastics (AG).

This Olympic sport has unique characteristics (Aleixio & Nunomura, 2018; Ferreira-Filho, Machado, Marques, & Nunomura, 2016; Lopes, Oliveira, Fátima, & Nunomura, 2016; Oliveira, Bortoleto, & Nunomura, 2018), namely, constant changes in the scoring code (Carrara, Amadio, Serrão, Irwin, & Mochizuki, 2016; Heorhiivna, Oleksandrivna, & Oleksandrovich, 2020; Nunomura, Kerr, Cervin, Schubring, & Barker-Ruchti, 2019; Rohleder & Vogt, 2019), early specialization (Nunomura, Carrara, & Tsukamoto, 2010; Pion, Lenoir, Vandorpe, & Segers, 2015), athletes' morphological characteristics (Atikovic, 2020; Barker-Ruchti, 2009; Carrara et al., 2016; Kaur & Koley, 2019; Silva, Silva, & Luemba, 2020), and the extensive training required to achieve high-level performance (Carrara et al., 2016; Ericsson, Krampe, & Tesch-Romer, 1993; Issurin, 2017).

However, up until 2021, no systematic review aiming to summarize the findings of different studies on the trajectory of AG athletes was available. Therefore, this study aims to systematically review studies that address the sporting trajectory of elite athletes in AG. For this purpose, we looked at the focus of each study, the characteristics of the participants, the methodology employed, and the results obtained. This is possible due to online databases of articles which have become a useful tool for reference, intervention, and further research (Park, Lavallee, & Tod, 2013; Vissoc, Caruzzo, Nascimento Junior, & Moreira, 2020).

## METHODS

To achieve our objective, we employed a qualitative systematic review method, that is, a rigorous summary and interpretation of research data relative to the study's objective (Gomes & De Oliveira Caminha, 2014; Vissoc et al., 2020). We will analyze the differences and similarities found in the literature, seeking to expand data interpretations and suggesting new readings about the topic. We took the following steps: 1) search of articles in the databases; 2) exclusion of duplicate articles; 3) analysis of titles, abstracts, and keywords; 4) exclusion of articles that did not satisfy the inclusion criteria; 5) description of the exclusion criteria; 6) full reading of selected articles; 7) analysis of eligibility criteria; 8) extraction and organization of research data, and 9) data interpretation.

We chose to search the *Web of Science* and *Scopus* databases due to the coverage and academic quality of the indexed articles (AlRyalat, Malkawi, & Momani, 2019; Harzing & Alakangas, 2016; Mongeon & Paul-Hus, 2016). We searched the titles, abstracts, and keywords for the English terms: "career", "talent", "support", "development", "performance", "coach", "financial" – each in combination with "artistic gymnastics", using the Boolean operator AND. Our research included all original articles, without filter, available up until July 2020, that deal with the sporting trajectory of mens's artistic gymnastics (MAG) amd/or women artistic gymnastics (WAG) elite athletes. We

excluded all review and opinion articles, as well as abstracts for scientific conferences.

As for the quality of the studies, we focused on those that could help answer the question of this review (Higgins & Thomas, 2019). Ultimately, we understand that quality evaluation criteria in qualitative studies are related to the congruence between the object of research, the methodology employed, the interpretation of results, and attention to ethical research criteria (Peters et al., 2020). Therefore, all articles analyzed met the criteria.

Following the research method, two independent researchers searched for the articles and applied the inclusion and exclusion criteria. Upon any divergence among the researchers, we consulted a third specialist. The data extraction from the articles was organized by the following items: the focus of the study (all articles analyzed met the criteria centered around men's artistic gymnastics (MAG) and/or women artistic gymnastics (WAG)), location of the study (context), participants, the methodology employed, and main results. In addition, we identified the variables associated with the sporting trajectory of AG athletes, the congruences and divergences between the studies, and possible interpretations of the proposed synthesis

## RESULTS

715 studies were found with the search criteria. Figure 1 illustrates the selection process of the articles included in this review.

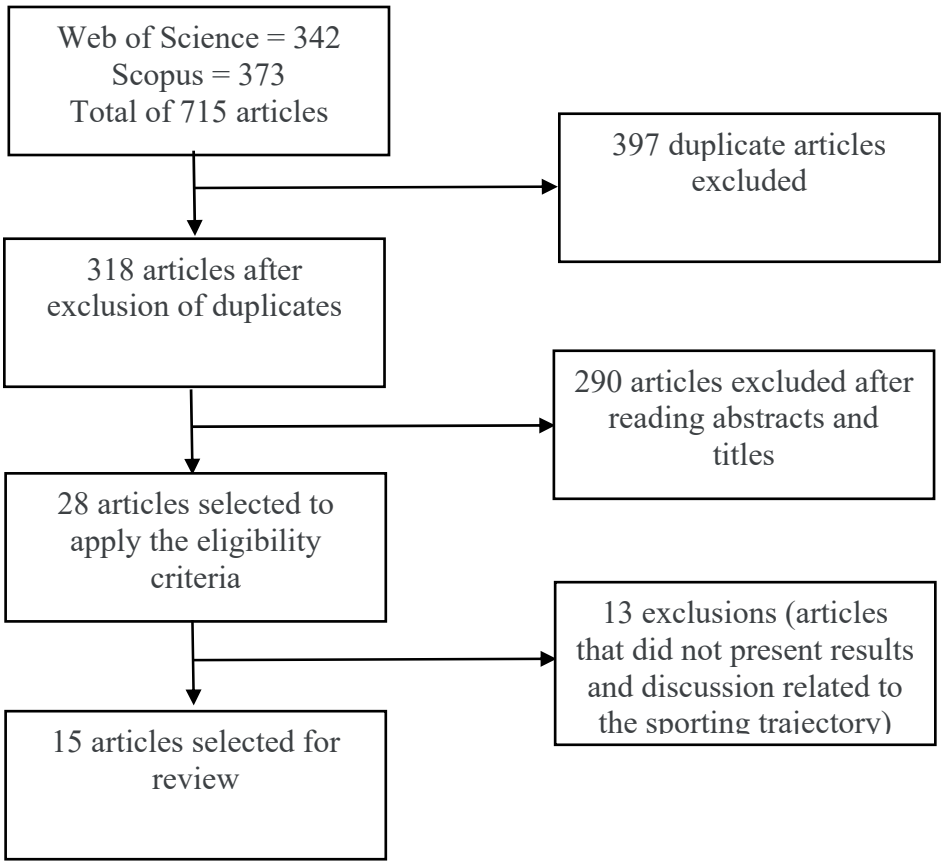


*Figure 1.* Flow diagram for the selection of studies included in the systematic review.

The first analysis excluded 397 duplicate studies. After reading the abstracts, titles, and keywords, 290 articles were excluded as they dealt with other topics, such as rhythmic or trampoline gymnastics, biomechanical analysis, instrument validation, experimental studies that measure the effects of training under different physical capacities, motor development, athletes' body composition or age, nutritional issues, as well as AG arbitration and support technologies. 28 studies were selected for full reading; however, 13 articles were excluded since they did not present results and discussion relevant to the topic of this review. Thus, we analyzed a total number of 15 articles. Among them, 13 were published in English and two in Portuguese, all of which used semi-structured interviews. In two studies, the authors used methodological assumptions of oral history: one of them documental analysis, and the other ethnography. As for the data analysis methodology, the articles were grouped into three categories: content analysis (Table 1), interpretive and phenomenological analysis (Table 2), and oral history and others (Table 3).

The studies interviewed athletes, former athletes, coaches, referees, and managers from different generations. They also addressed different contexts, namely the Brazilian (seven studies), Portuguese (two studies), Swedish, Slovenian, Australian, and English (one study each). Additionally, there was a comparative study between two nations – New Zealand and Australia (Kerr & Barker-Ruchti, 2015), as well as an international study with participants from different countries and continents (Barker-Ruchti, Kerr, Schubring, Cervin, & Nunomura, 2017). The combination of these diverse samples reveals the worldwide trend of sporting careers among nations that are seeking international representation. We say this because none of the countries mentioned were among the top three teams in the main international AG competitions (women's and men's) during the 2016-2020 Olympic cycle. Still, it must be emphasized that there are differences in how AG is dealt with in these contexts, though the purpose of this review is simply to present the results of research on the topic.

Among the selected articles, we also found a greater number (12) of studies dealing specifically with WAG. As a result, some unique aspects of the sporting trajectory of female gymnasts were highlighted, such as the early age of entry (Barker-Ruchti & Schubring, 2016; Zurc, 2017), the impact of puberty on the continuity of athletes in the sport (Aleixio & Nunomura, 2018; Barker-Ruchti et al., 2017), and abusive relationships with coaches (Cervin, Kerr, Barker-Ruchti, Schubring, & Nunomura, 2017; Pinheiro, Pimenta, Resende, & Malcolm, 2014).

Furthermore, in the articles' coverage of the sporting trajectory, we identified the following categories: infrastructure (Nunomura & Oliveira, 2012; Schiavon & Paes, 2012), financial support (Kerr & Barker-Ruchti, 2015; Oliveira & Bortoleto, 2012), parental support (Barker-Ruchti & Schubring, 2016; Duarte, Carbinatto, & Nunomura, 2015; Nunomura & Oliveira, 2013; Zurc, 2017), coach and athlete relationship (Barker-Ruchti, 2008; Barker-Ruchti & Schubring, 2016; Cervin et al., 2017; Duarte et al., 2015; Nunomura, Okade, & Carrara, 2012; Pinheiro et al., 2014; Stewart, Schiavon, & Bellotto, 2017), and adaptation for post-athletic career (Aleixio & Nunomura, 2018; Lavallee & Robinson, 2007). We will discuss these categories below.

Table 1
*Articles that used content analysis.*

| Authors and year of publication | Focus | Context | Participants | Method | Main results |
|---|---|---|---|---|---|
| Nunomura, M., Okade, Y., & Carrara, P. (2012) | Coach-athlete relationship and how coaches handle gymnasts' motivation. | Brazil | 46 participants from Brazil: 12 (MAG) and 34 (WAG) elite coaches from various categories. | Semi-structured interviews. Content analysis. | AG training requires a lot of motivation. Coaches use motivational strategies that are often inadequate. The authors observed that the infrastructure and funding may be detrimental to motivation in Brazilian gymnasts. |
| Nunomura, M., & Oliveira, M. S. (2012) | Gymnastics training center under a boarding school regime (infrastructure). | Brazil | 34 elite Brazilian coaches (WAG) from various categories. | Semi-structured interviews. Content analysis. | Positive aspects of the Training Center (TC): the Brazilian team improved their international results once the athletes got access to high-quality equipment, coaches with international experience, financial support, and a multidisciplinary staff. On the other hand, the centralization led to clubs downsizing, it devalued national coaches, and reduced the number of AG athletes in Brazil. |
| Nunomura, M., & Oliveira, M. S. (2013) | Parental support for WAG and MAG sporting careers. | Brazil | 163 participants from Brazil: 123 (WAG) and 40 elite athletes (MAG) from various categories. | Semi-structured interviews. Content analysis. | The results revealed different views on positive and negative parental support. Younger athletes appreciate parents' participation and interest in monitoring their sporting activity. The authors stress the need for a balanced amount of parental involvement, as the excess proved to be negative. |

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|---|---|---|---|---|---|
| Pinheiro, M. C., Pimenta, N., Resende, R., & Malcolm, D. (2014) | The abuses experienced by former gymnasts during their sporting careers. | Portugal | 6 former WAG athletes from Portugal who have competed internationally (OG, WC, and European Championship) | Semi-structured interviews. Content analysis. | Weight control, injuries, and punishments have been identified as part of gymnastics culture, and are seen as "normal" by those who practice them. Families seem to accept and follow the coaches' instructions. |
| Duarte, L. H., Carbinatto, M. V., & Nunomura, M. (2015) | Fear in artistic gymnastics (training). | Brazil | 16 athletes (WAG), between 9 and 10 years old, who participated in a regional competition. | Semi-structured interviews. Content analysis. | The main sources of fear were as follows: injuries, errors, the equipment, and the coaches. As the strategies to manage fear, the authors suggest: social support (friends and family), instructional support, attention and concentration, positive thinking and self-confidence, mental practice, and relaxation techniques. |
| Cervin, G., Kerr, R., Barker-Ruchti, N., Schubring, A., & Nunomura, M. (2017) | Coach-athlete relationship and financial support | Australia | 18 participants: 6 athletes, 5 former athletes, 2 referees, and 5 coaches (WAG) at an international level. | Semi-structured interviews. Content analysis. | The authors exposed a new relationship between gymnasts and their bodies in line with the new coaching policies, which focused on the athletes' health. The changes in the coach-athlete relationship prolonged sporting careers, though the gymnasts had to stand up for their rights as adults. Financial support ensured the continued participation of some athletes, while others were excluded due to economic discrimination. |

Table 2
*Articles that used interpretative phenomenological analysis or cultural perspective.*

| Authors and year of publication | Focus | Context | Participants | Method | Main results |
|---|---|---|---|---|---|
| Lavallee, D., & Robinson, H. K. (2007) | Identity formation and post-career. | England | 5 former WAG elite athletes from England. | Semi-structured interviews. Phenomenological interpretative analysis. | The participants reported that they had dedicated their lives to gymnastics, which caused them to question their identities in their post-athletic careers. It is suggested that there should be a pre-retirement transition period so that gymnasts can gradually find a new identity. |
| Barker-Ruchti, N., Kerr, R., Schubring, A., Cervin, G., & Nunomura, M. (2016) | Gymnasts' career extension. | Australia, Asia, Europe, and North American countries | 10 "older" high-level WAG athletes (20 years or older). | Semi-structured interviews. Analysis from a cultural perspective. | Puberty is a key stage for WAG. The coach-gymnast relationship, the content of the training, and performance goals can prolong the gymnast's successful career. |
| Zurc, J. (2017) | Gymnasts' opinion about the sporting career. | Slovenia | 41 participants from Slovenia - 26 WAG athletes, 11 former WAG athletes, and 4 elite coaches. | Semi-structured interviews. Phenomenological interpretative analysis. | Gymnasts have a specific lifestyle that demands that they start training at a very early age, and thus age is a determining factor in their careers. The authors indicate that regardless of the lifestyle they had to adopt and the consequences for their physical and mental health, the athletes claimed that they would do it again. |
| Aleixio, I. M., & Nunomura, M. (2018) | Gymnasts' career extension. | Portugal | 7 "older" high-level WAG athletes (20 years or older). | Semi-structured interviews. Analysis from a cultural perspective. | The experience of older gymnasts shown to be positive, opposing the myth that WAG is only for young gymnasts. |

Table 3
*Articles that used oral history and other analysis methods.*

| Authors and year of publication | Focus | Context | Participants | Method | Main results |
|---|---|---|---|---|---|
| Stewart, C., Schiavon, L. M., & Bellotto, M. L. (2017) | Development of the nutritional knowledge for gymnasts. | Brazil | 10 Brazilian WAG athletes that competed in the OG until 2004 (3 generations). | Semi-structured interviews. Oral History. | Coaches have been responsible for the nutritional knowledge of gymnasts and have held this control across all generations. Nutritionists have begun to play an important role as new approaches start to be implemented in the Brazilian gymnastics. |
| Barker-Ruchti, N., & Schubring, A. (2016) | The sporting life story of a former athlete. | Sweden | 1 former WAG athlete from Sweden. | Semi-structured interviews. Oral History. | The authors address the starting of a gymnastics career at an early age, moving to a new city, parental support, the relationship with coaches, and the adjustment to post-career life. |
| Schiavon, L. M., & Paes, R. R. (2012) | Conditions of high-performance TCs from the 1980s to 2008. | Brazil | 10 Brazilian WAF athletes that competed in the OG until 2004 (3 generations) | Semi-structured interviews. Oral History. | The authors pointed out that WAG has had two leaps of investment in equipment, in the early and late 1990s. However, the investments were focused on high-performance TCs, whereas in the basic TCs there were several infrastructure problems. |
| Kerr, R., & Barker-Ruchti, N. (2015) | Public policies on sports funding and their effects on AG clubs. | Australia and New Zealand | 1 WAG club from Australia and 4 WAG clubs from New Zealand. Players, coaches, referees, and managers were interviewed. | Two ethnographic surveys and semi-structured interviews. Analysis from a Foucauldian perspective. | In Australia, where the government provided funding for the sport and the gymnasts received scholarships, the pressure for results was higher. In New Zealand, where there was no government aid, it was the private clubs that invested in the gymnasts. As a result, the pressure was lower since the goal was to appeal to parents and gymnasts to remain in the club and continue paying monthly fees. |

| | | | | | |
|---|---|---|---|---|---|
| Oliveira, M. S., & Bortoleto, M. A. C. (2012) | The *Bolsa-Atleta* program and its implications for MAG. | Brazil | 9 Brazilian participants - 2 MAG athletes, 3 MAG coaches, 2 MAG judges, and 2 federal managers. | Documental and semi-structured interviews. Content analysis. | The authors highlight the importance of the *Bolsa-Atleta* Program, as the success of athletes relies on government support and the effectiveness of funding for the sport. Furthermore, they suggest improvements to the Program, such as a higher number of scholarships, reduction of bureaucracy, and transparency in the rendering of accounts. |

## DISCUSSION

***Infrastructure.*** De Bosscher et al. (2015) indicate that infrastructure is one of the pillars for a nation's sporting success. The authors highlight training centers (TCs) that offer training and housing facilities for athletes in the same place, as well as support services such as physicians and sports scientists. Some countries – like Spain – have chosen to distribute smaller TCs throughout the country; they are considered of great quality by athletes and coaches. On the other hand, countries like France and Australia have chosen a centralized approach, gathering athletes from various modalities in a single facility (De Bosscher et al., 2015).

In AG, particularly, the countries with the greatest tradition in the sport, such as Russia and Romania, offer boarding TCs specific to AG training. Athletes spend more than 250 days a year in these facilities, which comprise a gymnasium, rehabilitation area, sanitary facility, cafeteria, and dormitory (Nunomura & Oliveira, 2012).

Both articles that deal with infrastructure did so in the Brazilian context, focusing on the Center of Excellence in Gymnastics of Brazil, which was established in 1999 and shut down in 2008. The TC followed the permanent selection model, i.e, Brazilian gymnasts lived in the facilities (except for those who lived in the city where the TC was based) and trained daily with coaches from countries with a longer tradition in the sport (Nunomura & Oliveira, 2012; Schiavon & Paes, 2012).

The studies link the establishment of the TCs with the improvement in the international results of the Brazilian WAG team, since the facilities exclusively housed the women's gymnastics; although at the same time, the country also established a permanent selection of MAG. We identified several positive aspects of the TCs, including the gymnasts' technical improvement due to training on equipment that provided greater safety, along with the experience contributed by foreign coaches.

Schiavon and Paes (2012) have investigated the training infrastructure aspects of three generations of Brazilian WAG. The pioneer gymnasts reported that they lacked basic training infrastructure even when they were in preparations for the Olympics, which in a way justifies the unsatisfactory results at that time. The second-generation noted that there were improvements in the training conditions, albeit sporadic. Finally, the generation with the best results is the one that benefited from the gymnastics TC structure. Nonetheless, Nunomura and Oliveira (2012) also identified negative aspects of TCs from the perspective of 34 Brazilian coaches. These include: they are monopolized by the best gymnasts; the devaluation of the clubs and coaches that first trained the gymnasts; the lack of opportunity for Brazilian coaches to train with foreigners (limited to those who worked in the TCs); excessive training, and other related problems, as well as poor adaptation of some gymnasts to the distance from their families and the city's weather conditions.

In the Brazilian context, it is clear that athletes' training is club-based, which means that training facilities are mostly found in clubs. Because of this, gymnasts participating in the studies reiterated the need to move to cities so as to train with better equipment and better coaches. Furthermore, this training model was identified by Nunomura and Oliveira (2012) as one of the reasons for the end of the permanent selection and, consequently, the termination of the activities in the Brazilian Gymnastics TCs.

The training infrastructure also proved to be fundamental for AG in other studies, despite not being the main topic of these articles. For instance, Barker-Ruchti and Schubring (2016) emphasized the need for athletes to change cities in order to train in better conditions in the Swedish context. It is worth noting that, since the equipment is

fixed, AG requires exclusive infrastructure for training, namely: floor, pommel horse, rings, vault, parallel and uneven bars, horizontal bar, and balance beam (Caine, Russell, & Lim, 2013). Moreover, the equipment must be reliable and modern so that gymnasts can train safely and perform the complex movements that are characteristic of the sport. In this regard, Nunomura et al. (2012) revealed that poor infrastructure, as well as the need to move from one city to another to train in better facilities, may be one of the discouraging factors for the continuity of athletes in gymnastics. Therefore, it becomes relevant to discuss the investment/funding for the sport.

***Financial Support.*** Financial support is the key pillar, according to De Bosscher et al. (2015), for a country's sporting success. This means that, for the authors, financial support is crucial for the implementation of the other pillars (*Governance, organization and structure of (elite) sport policies; Sport participation; Talent identification and development; Athletic career and post-career support; Training facilities; Coach provision and coach development; National and international competition/events; Sport science support, scientific research and innovation in elite sport*). To do so, government funding for sport, lottery funds (a state-controlled service designed to complement funding for different areas, including sport), national Olympic Committee funding, and sponsorships are all indicators that contribute to the sporting success of different nations.

In this sense, Kerr and Barker-Ruchti (2015) compared the different kinds of financial incentives for gymnastics from the federal governments of Australia and New Zealand between 2004 and 2009. The authors found that the Australian government offered several benefits to athletes and teams; in return, the country demanded good results. This makes their training model quite rigid and excluding. Although in the ranking presented by De Bosscher et al. (2015) Australia occupies a prominent position in summer sports performance (2009-2012), the country's results in AG are still modest. For example, in the 2019 AG World Championship, the men's team finished in 22nd place and the women's team in 13th place. Individually, however, some athletes are beginning to stand out[1].

On the other hand, there is no specific funding program for AG in New Zealand, therefore the incentive/funding is provided by private clubs. Thus, the logic that prevails (at least in WAG, over the assessed period) is commercial. Kerr and Barker-Ruchti (2015) observed that training in this country is less rigid; it is common to switch clubs to seek personal satisfaction rather than better performance. Houlihan and Green (2007) claim that despite recent efforts (post-2002) to make the country relevant in the international sports context, AG is not among the ten most favored sports. This of course impacts the international results in the sport; in the last AG World Championship, New Zealand was only represented in the individual events.

Brazil was identified by De Bosscher et al. (2015) as one of the countries that progressively increased investment in elite sport, driven by the hosting of the 2016 Olympic Games in Rio de Janeiro. In this sense, the main funding policy for Brazilian athletes, the *Bolsa-Atleta* Program, was the focus of the study by Oliveira and Bortoleto (2012). When analyzing the Program between 2005-2009, the authors identified the importance of this incentive for MAG athletes in training, as it enabled full dedication to training and prevented early withdrawal from the sport. Thus, it is possible to associate the increased investment in sports by the Brazilian government with

[1] To learn more, see: https://www.gymnastics.sport/site/events/searchresults.php#filter

the rise of Brazilian gymnasts (Vargas & Capraro, 2020).

According to Oliveira and Bortoleto (2012), the amounts received by athletes through the *Bolsa-Atleta* Program are used to purchase world-class equipment, cover travel costs for training and competitions, and pay for the technical team. On the other hand, the interviewees in the study pointed out some of the Program's limitations, such as the need to increase the number of scholarships distributed and reduce the bureaucracy to obtain them. The interviewees also mentioned problems with the scholarship distribution criteria.

Given that in some countries the financial incentive programs are age-based and do not include young athletes, and that AG athletes enter the sport at an early age (Nunomura et al., 2010), there is a clear indication of the need for parental support during the specialization phase. Therefore, the relevance of parental support will be discussed in the next section.

***Parental Support.*** Parental support in the sporting trajectory was the central theme of one of the articles analyzed (Nunomura & Oliveira, 2013) and has surfaced in others. For De Bosscher et al. (2015), this support is one of the factors at the micro-level that influence athlete's success from the individual perspective. For the authors, parents can have both positive and negative psychological influences on the athlete's development, and this is directly linked to emotional factors.

Barker-Ruchti and Schubring (2016), when describing the sporting trajectory of gymnast Marie, highlight the relationship with her parents as an important source of support throughout her sporting career. In that specific case, the parents' role stood out when the gymnast had to move to another city to train with the national team. At the time, Marie regularly phoned her parents in tears, but she still hid much of her suffering from them because she believed they would take her back home if she revealed it all. Once she quit gymnastics, Marie's parents realized that she was not well psychologically and encouraged her to seek therapeutic help. This emotional support offered by parents was also a finding of Duarte, Carbinatto and Nunomura's (2015) research about young Brazilian gymnasts overcoming fear.

In the same sense, Zurc's (2017) study identified that it is common in AG for children/athletes to be "taken" from their families to seek more suitable training facilities. Also, their lives and that of their families are ultimately guided by gymnastics. Here, the authors highlight the positive influence of parents in the sporting trajectory of Slovenian gymnasts. Backer-Ruchti and Schubring (2016), Nunomura and Oliveira (2013), and Zurc (2017) agree that parents are primarily responsible for introducing their children to the sport environment; after all, they are the ones who enroll and take them to the gyms, although there may be contextual differences between the countries addressed in these studies. As children advance in gymnastics, parents strive to provide emotional support and opportunities for amenities such as transportation, nutrition, funding, and support in school tasks.

On the other hand, Nunomura and Oliveira (2013) also identified negative factors related to parental support, namely, discouragement to continue in the sport and pressure for results. It is known that excessive parental expectations can cause anxiety and excessive pressure on athletes (Harwood, Knight, Thrower, & Berrow, 2019; Knight, 2019; Knight, Berrow, & Harwood, 2017).

Therefore, when connecting the information present in the reviewed studies, parental support for AG athletes stands out as fundamental, especially regarding sports participation and aid during sports training. Parents are important sources of emotional support in overcoming fears and difficulties faced by athletes. Nevertheless, there is also the

possibility of a negative effect when the involvement of parents is perceived as a source of pressure by athletes. For this reason, Knight et al. (2017) reinforce that this relationship must take into account the young athletes' perception, since the parents' comments and reactions may be understood as either support or pressure. This leads us to another fundamental relationship, the one between athletes and coaches, which will be presented below.

***Coach-Athlete Relationship.*** Among the 15 articles selected for analysis, eight dealt with the coach-athlete relationship at some level. This topic is widely discussed among researchers in the field as AG is known for its authoritarianism and troubled interactions between coaches and gymnasts (Kerr, Barker-Ruchti, Schubring, Cervin, & Nunomura, 2019). However, this training system has been undergoing several updates and modifications (Bortoleto & Schiavon, 2016). The reviewed studies suggest that the interaction with coaches may be positive or negative for the athlete's career, based on how it is managed. This is because both the professional skills and teaching pedagogy of coaches may affect their relationship with the athletes. Regarding the first aspect, Nunomura and Oliveira (2012) state that after the arrival of Russian coaches, Brazilian gymnasts began to achieve better results in competitions. Regarding the second aspect, it was identified that coaches who pursue a closer relationship with their athletes through positive interactions also achieve better results (Barker-Ruchti & Schubring, 2016).

Having a good relationship with coaches encourages gymnasts to remain in the sport (Barker-Ruchti & Schubring, 2016), and motivates them to improve (Nunomura et al., 2012) and achieve better results. In other words, coaches must strive to build trust with their athletes (Cervin et al., 2017). For this, Barker-Ruchti et al. (2016) believe that coaches should not be so rigorous in their training hours.

Coaches should use those approaches: "have regular communication with athletes` parents, as they can be very informative; evaluate athletes' levels of satisfaction as a source of information regarding athletes` interests and needs, their reasons to participate, and objectives in the sport. Coaches and parental support are essential to maintain high levels of motivation and to avoid further emotional disturbances due to possible negative experiences as a result of a gap in interests" (Nunomura et al., 2012, p. 34).

Abuse is often mentioned as a type of negative interaction (Barker-Ruchti & Schubring, 2016; Cervin et al., 2017; Pinheiro et al., 2014; Zurc, 2017). This abuse may come in a "variety of forms of exploitation or abuse that can range from extreme diets and weight control, to verbal and emotional abuse, overtraining, corporal punishment, over-use injuries, and training and competing while in pain or injured" (Pinheiro et al., 2014, p. 436). Duarte et al. (2015) state that this relationship can generate fear in athletes. In the study, the authors identified the psychological and physical abuses that the participants experienced. According to the reports, the coaches would pull their hair and hit them whenever they made a mistake. In addition, yelling and cursing were common in training. As a result, the athletes experienced fear when performing the movements, especially in competitions (Duarte et al., 2015). Assuming that emotional control is an important skill for sporting success, the authors propose that coaches minimize gymnasts' fears and build mutual trust from a holistic and singular view of the athlete. Duarte et al. (2015) suggest that this feeling can be minimized with supportive and encouraging words instead of violent and authoritarian posturing.

In addition, such an authoritarian relationship can lead to eating disorders in athletes (Pinheiro et al., 2014; Stewart et

al., 2017). Stewart et al. (2017) state that coaches often do not have the necessary knowledge in nutrition and only focus on weight loss, jeopardizing the athletes' performance. Thus, the authors emphasize the importance of specialized nutritional support that gives necessary advice to gymnasts and coaches.

It is clear, thus, that the coach-athlete interaction is one of the main focuses of qualitative studies in AG. Furthermore, coaches' abusive behaviors are still a reality, and they have been questioned by researchers, parents, and sports entities. This is especially important because the results of the coach-athlete relationship can negatively interfere with the gymnasts' post-career, which will be discussed next.

***Preparation for Post-Athletic Career.*** The post-career of high-performance athletes has been increasingly discussed in the literature. Lavallee and Robinson (2007) point out that great caution is needed in this transition phase, and for many authors transition to retirement is reported as a bad and often traumatic experience (Alfermann, Stambulova, & Zemaityte, 2004; Stambulova, Alfermann, Statler, & Côté, 2009). For this reason, some athletes seek other professional paths while still active in their professional sports careers in order to have a smoother transition to the post-athletic period. (Torregrosa, Ramis, Pallarés, Azócar, & Selva, 2015). This tends to get complicated since the formation of one's identity takes place during adolescence, i.e., the athletes' identity is built around the sport (Lavallee & Robinson, 2007).

This claim was confirmed by Lavallee and Robinson (2007) in a study that addresses the post-athletic career. The authors observed that, in England, as gymnastics requires early entry, the athletes felt lost in regards to their identities and plans for the future once they quit the sport. It is normal for them to go through a difficult period after this transition. For the respondents, this phase lasted over five months. The gymnasts reported that they were left without any assistance after dedicating their entire lives to the sport, which led them to move away from the past to find a new identity beyond sport. To ensure that this process is not traumatic, it is advisable to reduce participation in training and competitions in a gradual manner. The authors emphasized the importance planning for retirement to minimize the impact of the transition. Corroborating with the authors, Martin, Fogarty e Albion (2014) state that a planned transition to retirement (not due to injury or involuntary reasons) facilitates this process. Thus, it is paramount to have a continuous and multidisciplinary approach so that high-performance athletes can be financially, physically, and psychologically prepared for this transition phase. Accordingly, it is essential to create public policies to support athletes in this process.

## CONCLUSION

This systematic review of articles that addressed the trajectory of AG athletes selected 15 studies, all of which compiled their data through semi-structured interviews; among them, two studies used the methodological assumptions of oral history: one used documentary analysis and the other ethnography. Through various methods, the authors dealt with the necessary infrastructure for the development of AG. In this respect, we were able to identify that the development of AG requires a unique structure with high-quality equipment. It is often necessary for athletes to move from one city to another to find places that offer the best conditions (TCs). Financial support is also covered in the articles, focusing on public policies designed to support and encourage participation in sport. In our view, such incentives are essential for athletes to remain fully dedicated to sport. On the other hand, in countries where there

is no such incentive, the sport is organized based on a commercial logic to the detriment of the development of high-level athletes. Parental support is highlighted as essential for the entry and permanence of athletes in the sport, as they are the ones who provide the initial contact with the sport and who organize the logistics of transportation and nutrition. They also provide emotional support, even from afar (in cases where the gymnast lives in another city), helping the athletes overcome their fears, including of coaches. The coach-athlete relationship was one of the most debated topics in the articles, as it is essential not only for the development of high-level athletes but also for their personal development. In some cases, authoritarian conduct of coaches towards athletes was observed. Additionally, the transition to retirement has been identified as a phase that should be planned and oriented. After all, the athletes are faced with a break in their routine and have to seek a new identity.

At the end of the study, we note that there is scarce scientific research on the sporting trajectory of athletes in AG, especially in men's gymnastics. Another important aspect is the regionality of the reviewed studies. Brazil, Portugal, Sweden, Slovenia, England, New Zealand, and Australia are all developing countries in AG, but are still lagging behind countries like the United States, China, and Russia. However, studies of athletes from these nations were not included in this review. The choice of databases (Scopus and Web of Science) and the use of descriptors in English may have limited the search for Russian and Chinese studies. This indicates the need for new studies to include databases from these countries, especially by researchers who speak the language(s). We also noticed the absence of studies produced in the United States of America, despite it being one of the world leaders in the sport. This may indicate a lack of interest by North American researchers. In addition to alerting coaches, gymnasts, and gymnasts' parents to important issues within AG, this study may aid national governments in the development of public policies as it points out the areas that need investment in order to successfully develop the sport. Nevertheless, we reiterate the need to expand the investigations about the sporting trajectory in AG from different perspectives and targeting different contexts, given the complexity surrounding the development of AG elite athletes and their needs.

## ACKNOWLEDGEMENT

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001".

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Article received: 13.1.2021
Article accepted: 3.5.2021

# COMPUTERISED GYMNASTICS JUDGING SCORING SYSTEM IMPLEMENTATION – AN EXPLORATION OF STAKEHOLDERS' PERCEPTIONS

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*Original article* *DOI:10.52165/sgj.13.3.357-370*

***Abstract***

*Gymnastics is one of the original Olympic sports, subjectively judged by humans. Judging errors and bias can occur, resulting in medals being incorrectly awarded. The International Gymnastics Federation (FIG) with Fujitsu are introducing a computerised gymnastics judging support system (CGJSS), a technology aimed to enhance fairness and accuracy but there is very little literature evaluating this technology and perceptions. This project aimed to explore stakeholders' reactions at this critical time. Therefore, interviews were conducted with coaches, judges, media, former and current international gymnasts. The findings concurred with the literature review of judging problems with the current system, including bias and subjectivity. New findings show, among other things, that gymnasts' scores can differ depending on which round they compete in. The findings also suggest that the CGJSS would be a great innovation for gymnastics to improve credibility by removing bias and helping to make the sport more objective. However, the majority of the participants believed it could not judge the artistry element of the sport. Close monitoring of the effectiveness of the CGJSS is therefore required to identify enhancement and to ensure the investment produces fairer, more reliable and credible results. Successful implementation of the CGJSS could also allow it to be introduced into other subjectively judged sports.*

***Keywords***: *gymnastics, judging, bias, technology, sport.*

## INTRODUCTION

Gymnastics has been a part of the modern Olympic programme since its introduction in 1896 (Leskosek et al., 2012) and has always been scored by qualified judges. The standard composition of a typical judging panel for artistic gymnastics is seven judges: five evaluating the execution of the routine (E-Score) (Mercier & Heiniger, 2017) and two evaluating the difficulty of the routines (D-score) (Leskosek et al., 2012). This is a significant change compared to only one judge when the sport began (Leskosek et al., 2010). Judges are marking in accordance with the Code of Points that, since 1949, have been put in place by the Fédération Internationale de Gymnastique (FIG) (Atikovic et al., 2011).

Many processes have been put in place to ensure objectivity of subjectively judged sports, such as gymnastics, but unfortunately injustices still occur. For example, at the Athens 2004 Olympic Games, Paul Hamm was awarded the gold medal after the silver medallist Yang Tae-young was incorrectly deducted marks

(Kelso, 2004). Alexi Nemov found himself in the middle of a controversy during the high-bar final at the same Olympic Games. The competition came to a complete standstill for 10 minutes when the audience booed his mark. After much deliberation, the score was increased, promoting Nemov to the third position (Reuters, 2004). In response to the problems in the Athens 2004 Olympic Games, a new scoring system was put in place in 2006 with an open-ended scoring system for the D score (Turner, 2014). Nevertheless, Green and Allen (1984, p. 47) suggest that "where there is a judged sport, there is always controversy".

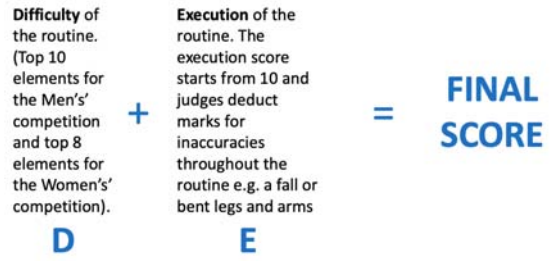


*Figure 1.* How the gymnast's score is calculated.

Controversy can arise for many reasons including the order in which the gymnasts perform, corruption and the relationship between the gymnast and the judge, or different judges' interpretations of the same information (Plessner, 1999). All sports must have integrity and credibility in ensuring results are fair; the errors and controversies that occurred during the Athens 2004 Olympic Games mean that people will question the sport and its integrity (Kelso, 2004). Also, competitions can be exceedingly long. A former president of the FIG commented: "A judge must work for eight hours per day – does that allow the mental capacity to remain coherent? It's not possible to maintain a coherent mind of criteria. Only the computer does" (Logothetis, 2017, para. 5). Perederji (2013) & Leskosek et al. (2010) both found judge fatigue had an effect on the score produced for the gymnast.

Gymnasts and coaches can appeal their score but only the difficulty score and not the execution score. The inquiry process was only introduced in 2004, following the judging problems during the Olympic Games (Zaccardi, 2012). During the men's team final at the London 2012 Olympic Games, an inquiry was put in for Japan for their last routine which created a delay to the official announcement of the results. The inquiry was upheld: as a result, Ukraine was pushed out of the medals and Japan moved to the second place, having been fourth prior to the inquiry (Zaccardi, 2012).

There has been considerable research conducted by various authors, including Ste-Marie, Leskosek et al. and Ansorge, to understand the effectiveness and quality of judging in gymnastics dating back to the 1970s (Bucar et al., 2012). Research, including the studies by Ansorge and Scheer (1988) and Leskosek et al. (2012), indicates that there are problems with the judging system in gymnastics.

These problems can include bias that can take many different forms, including a judge favouring a gymnast from their own nation as indicated by Ansorge & Scheer (1988), Ste-Marie (1996) & Popovic (2000). Studies by Ste-Marie & Lee (1991) & Ste-Marie and Valiquette (1996) highlighted bias occurring due to previous exposure of the gymnast and Scheer &Ansorge (1975), Ansorge et al. (1978) & Scheer and Ansorge (1979) found that bias could occur depending on the place a gymnast has within his or her team. The final bias found in research by Leskosek et al. (2010) & Leskosek et al. (2012) is bias that expresses itself in over- or under-scoring gymnasts in competitions. For instance, stress can have an impact on the score, as concluded by Duda et al. (1996). Similarly, a number of studies, including those by Dallas & Kirialanis (2010), Bard et al. (1980), Ste-Marie (1999) & Ste-Marie (2000), indicate that the extent of

experience a judge has, can impact the score that a gymnast receives.

To provide a solution to the judging problems, the FIG and Fujitsu began a collaboration in 2017 with the aim of setting up a real-time judging support system that is fair and accurate (IT News Online, 2019). The computerised gymnastics judging support system (CGJSS) was initially implemented during the 2019 World Championships in Germany and is planned for the Tokyo Olympic Games (Fujitsu, 2018).

The new system utilises artificial intelligence in order to support the judges on the vault during these competitions. Gymnastics skill level is ever increasing, and it can be very difficult for the naked eye to keep up with the number and complexity of manoeuvres that the gymnasts are performing. The new system collects information using 3D sensors and compares the information to the FIG standards to provide a score. "It offers a three-dimensional digital view of the performed elements, with a variety of selections for angle measurements, all of which helps to deliver a fair and accurate judgement" (Fujitsu Sys-Con Media, 2019, para 7). The FIG president Morinari Watanabe says, "Once gymnasts see it (CGJSS) they will like the technology and that is a great thing" (Logothetis, 2017).

There is very little literature about the CGJSS in the public domain currently due to the fact it is so new to the market. Watanabe is supporting the implementation of the CGJSS and mentions that it is for gymnasts that they are making this change to ensure all their hard work and dedication is rewarded fairly and not misjudged by human error. He suggests it is "a big step towards the future" (Fujitsu, 2019, para. 6).

Although the rules as set out by the Code of Points are objectively specified, this does not prevent intentional or unintentional human error (Leskosek et al., 2010). Various studies have been conducted over the years to reinforce this.

It is clear that there are numerous errors and biases present in gymnastics judging, whether conscious or unconscious, affecting gymnasts' results and medals awarded. This can potentially have a negative effect, including on bonuses and rewards. The literature confirms that further intervention is needed to reduce human error and bias in gymnastics and make it more objective to provide more accurate results. This research therefore fills the gap in understanding stakeholders' perceptions of this new scoring technology.

## METHODS

Our study aims to create further understanding about this new intervention from the perspective of stakeholders by asking the question: does gymnastics need the introduction of the CGJSS? In doing so, the following interview questions were posed in Table 1.

Semi-structured interviews, which create structure but also flexibility to gain new insights (Wilson, 2014), with nine key stakeholders were conducted during this project to gain insight into the research questions. The interviews were conducted face-to-face or via Skype. Skype interviews were used when it was impossible to conduct face-to-face interviews due to different time zones and geographical barriers. Participants included judges, coaches, gymnasts and the media. Table 2 indicates the roles of the participants. Roles were anonymised in line with the ethical approval process at the University of Salford.

A sample size of nine was chosen following Mears' (2009) suggestion that depth rather than breadth of information is the goal, that is, to use between 6 and 9 participants. Once the participants start highlighting the same points, the study has reached saturation point. Fusch and Ness (2015, p. 1408) proposed that saturation is met when there is "enough information to replicate the study". All information

collected remained anonymous and collected data kept confidential to ensure that participants' individual identities were protected and could not be identified publicly (Polit & Beck, 2006).

Participants' responses were transcribed verbatim and the responses for each question were then labeled and ordered into categories and sub-categories to create meanings (See Table 3). A deductive thematic analysis of all codes was then conducted to generate overall themes arising from the interviews (Braun and Clarke, 2006). Two members of the research team independently analysed the data and inductively co-created initial codes that were then discussed and developed into themes in order to ensure consistency. There were no disagreements; however, the process of coding was checked and agreed upon by all authors. Following data reduction, three main themes were identified, described and refined as: (1) bias and subjectivity in judging, (2) benefits to gymnastics, and (3) negative impact on gymnastics. All answers were transcribed. Table 3 presents the grouping of these answers around problems which are then discussed in the results.

Table 1
*Questions used during the semi-structured interviews.*

| | |
|---|---|
| 1 | Why is the FIG looking at the CGJSS? |
| 2 | What concerns, if any, do you have with the current judging system in gymnastics? |
| 3 | How could the CGJSS move gymnastics forwards or backwards? |
| 4 | How could the CGJSS change the way gymnasts train or coaches coach? |
| 5 | What concerns, if any, are there with the CGJSS? |
| 6 | Why do you believe or not that the CGJSS will be good value for money in either short- or long-term? |

Table 2
*Participants in the study and their Participant (P) number.*

| Participant ID | Participants' current and previous roles in gymnastics |
|---|---|
| P1 | Team leader of Youth Olympics |
| P2 | Former international gymnast, coach and commentator |
| P3 | Former international gymnast |
| P4 | Press relations manager |
| P5 | Coach to international gymnasts and former Olympians |
| P6 | International gymnast |
| P7 | International gymnast |
| P8 | Coach to international gymnasts and FIG judge |
| P9 | FIG judge, coach and former gymnast |

Table 3
*A summary of the findings to the sub-questions from the primary data collection.*

| Question | Answer from the primary research |
|---|---|
| Why are FIG looking at the CGJSS? | • To make the sport more understandable<br>• Removing the subjectivity from the sport<br>• To make the judging more valid and reliable<br>• To remove judging bias<br>• To create a level playing field<br>• The skills within the sport are evolving so quickly, it is becoming increasingly more difficult to see things with the naked eye |
| What problems if any do you see with the current judging system in gymnastics? | • Bias judging of performing in later rounds of the competition<br>• Unconscious bias of having seen a gymnast perform previously<br>• International bias of judges from the same nationality<br>• Bias due to federations who are friendly with each other and gymnasts/federations with a well-known name<br>• Bias due to the place within the team<br>• Fatigue due to long days of competition<br>• The judging is subjective<br>• Skill level is rapidly increasing |
| How could the CGJSS move gymnastics forwards or backwards ? | • Positive - Make the sport more marketable<br>• Positive - Make the results more reliable and valid<br>• Positive – The sport becomes more objective<br>• Positive – The sport would evolve with time<br>• Negative – It can't judge all aspects of the sport including artistry<br>• Negative – Potential loss of judges<br>• Negative – Potential loss of traditions of the sport |
| How could the CGJSS system change the way gymnasts train or coaches coach? | • Most participants did not feel it would change the way gymnasts train or coaches coach<br>• Positive - The system could be used as an analytic tool<br>• Negative – It would have to be readily available to all nations if it was available outside of competitions to ensure there is no disparity between the rich and the poor countries |
| What concerns if any are there with the CGJSS? | • Gymnasts could lose their flair and become robots<br>• The accuracy of the system<br>• Stakeholders adopting the system<br>• The CGJSS is only able to judge certain aspects of the sport<br>• Which variation of the skill the gymnasts will have their skill compared to<br>• The CGJSS crashing during competitions<br>• Potential loss of traditions of the sport<br>• Needs to be readily available to all countries if it is available outside of competitions<br>• Potential loss of judges |
| Do you believe CGJSS will be good value for money in the short term or long term? | • Most participants think it is worth the investment both short-term and long-term to ensure a level playing field is created, and that the sport becomes more accurate so that the most deserving gymnasts stand on the podium. |

## RESULTS

***Bias and subjectivity in judging.*** Concerns over bias and subjectivity in judging were one of the issues that surfaced in the interviews. P4 suggested: "It's [bias] something that gymnasts just accept; it's part of the sport and it shouldn't really be like that." Different types of bias were highlighted including gymnasts performing in later rounds; unconscious bias from previous exposure, and international bias of judges judging gymnasts of the same nationality.

Biased judging of gymnasts of the same nationality as the judges or federations that are friendly with each other were also pointed out. P1 commented that "bias is a big one as judges tend to know the athletes and coaches of the federations they are judging, so personal relationships develop". P3 backed this up: "It does depend a lot on what federations are friendly with what other federations".

Bias from previous exposure, whether via competitions, training or online videos, came up as another potential problem. P3 felt this can influence the score: "Unconscious bias from what they may have seen previously; they may make deductions automatically without actually seeing them". The two judges in our group disagreed with this and felt that seeing a gymnast previously perform was only helping them to prepare for a competition. P8 said: "I have always said it's my job to warm up in the way that gymnasts do, and that's what I am doing; and of course someone could say that I am doing something different but I can say, hand on heart, that when I go in, I am prepared not to miss anything".

Gymnasts performing in later rounds were mentioned in a number of interviews. P5 commented: "Depends on what round you are judging. It's not necessarily intentional, but scores do tend to rise a little bit". P4 and P6 also felt this and commented, respectively: "I think gymnasts feel that in qualifying there might be a difference between whether you are on in the afternoon or in the morning," and "People always say it's better to perform later in the day". P2 and P3 mentioned that from their own previous experience the place in which a gymnast performs in a team can be a factor for team tactics. The use of the CGJSS, "would make that hypothesis irrelevant", said P3 since the computer would not be able to identify who it is judging.

Long days and fatigue were mentioned as factors that can have an impact on this higher scoring later in the day. P3 mentions: "Actually judges, when they are doing a World Championships, they are judging from the crack of dawn until late at night with minimal breaks in between and when that sort of tiredness level kicks in, is there going to be human error? Absolutely".

P8 commented:

"At world championships, you start at 6 in the morning when the day starts and then you have to give consideration and concentration all the way through to 10 o'clock at night and do that for 2 days in a row; no matter how hard we try…there has got to be an effect on some of your decision making."

P9 reinforced this by saying:

"We will have a degree of accuracy when we first arrive … to ask us to be just as accurate 14 hours later… I think that might be asking a bit much of us … you are not going to be 100% accurate from the start of a competition until its end."

The time that the judges are expected to concentrate for over two days is considered to be too long in some cases and the participants felt that it could have a negative effect on the consistency of scoring.

Creating a level playing field and the need for fairness were seen as an important consideration. P5 commented on the need for such a scoring system "so that it is totally fair", and P4 suggested "to take away the mistakes and the bias and creating a sport that is very exact".

Building on this, P3, P4 and P6 all suggested that the CGJSS would create more valid and reliable results. P3 said "that it will make it as objective as possible and it's a valid and reliable measure…. that will make it a lot easier to justify scores to athletes, to coaches". P6 suggested the current scoring system "seems to sort of fluctuate quite a lot…it's hard to compare scores from one competition to another". P8 commented: "The emphasis is on what can we do to make the sport as objective as possible," and P9 states: "There is a lot that is asked of us…the more that we can use AI (Artificial Intelligence) to evaluate the objective part, the more accurate scores and deductions the athletes will be awarded." The participants want to ensure that the scores are fully justified and reliable.

P1, P2, P4, P8 and P9 all mentioned that gymnastics is progressing so fast that it is becoming much more difficult to see the gymnasts' skills with the naked eye, or to accurately observe the mistakes, or even note what skill is being performed. P2 mentioned the 2019 European Championships when it was unclear whether a gymnast had gone out of bounds on the floor. This impacted the decision on who became the European Champion:

"We were also at the last Europeans …we thought she might have just bounced her heels out; and we know as gymnasts, performers, you can't land back in full straight on your toes, so the heels must have gone down, but it happened so quickly."

P2 commented: "I think what's really cool about this [the CGJSS] is to protect the medal winners to make sure you have the right people on the podium". P8 mentioned how the skills are advancing and the judges need to see the skill to know exactly what was performed. "10 years ago people weren't doing quadruple twists on the floor… If I know someone is performing a quadruple twist, I bet every MAG judge is in the hall to make sure they see the quad." Participants were of the opinion that the CGJSS would really help identify the harder skills and make sure that mistakes are not missed, ensuring the results are fair.

Nearly all of the participants felt they had seen or experienced an injustice during competition. P4 mentioned "it happens all the time". A press relations manager who sees the gymnasts immediately after their performance, confirmed that they often say that they were not given a fair score. He admitted that "part of that is emotion because they have just finished competing but there is also frustration". The results suggest that there are still problems with the current judging system, including bias, subjectivity and fatigue, which can result in medals being awarded to the wrong gymnasts; hence, the FIG are looking at implementing the CGJSS.

Additionally, expert judges P8 and P9 observed that the skill levels have improved very much, whereas they are expected to recognise and evaluate skills exactly the same as 10 years ago. As P8 mentioned: "10 years ago people weren't doing quadruple twists on floor".

P9 stated:

"We are asked to make very accurate evaluations in terms of angles of completion within 1 degree … we are asked to look at not only the execution at an angle but also the body itself and the shapes of the body."

They mentioned that the number of elements that the judges are required to judge is becoming too high, including the level of skill and the degree of accuracy of execution.

***Benefits to gymnastics.*** Throughout the interviews, a number of reasons why the FIG would be considering the CGJSS became apparent. One of the main reasons appeared to be to make the sport more understandable. P2, P3, P4 and P8 all mentioned this as a reason. As noted by P2: "So that it becomes a bit easier for the

general public to understand; I assume the driver behind this is to have more people viewing gymnastics".

P4 added:

"I think that anything that can help demystify gymnastics is helpful, because it is an exceptionally complicated sport. We all know it is a complicated sport to explain in terms of the scoring process; the way things are in the modern world, the consumer - the audience - want to know why things happen."

The participants agreed that making the scoring easier to understand would make the audience understand the results better and as a result more people would watch it. P2 and P3 felt that the sport would become more marketable to sponsors and easier to understand for the general public. P3 stated that creating World Records would mean that "sponsors would want to get on board with it and it would also help athletes get personal sponsors". As a result of being more marketable, P2 and P3 suggested it would create bigger audiences. P8 believes that "it may help educate people and if they use this to improve their knowledge, then this is a good thing." With a system which would allow competitions and results to be comparable, the sport would be able to have World Records which is currently not possible.

P3 and P4 suggested it would create a more valid and reliable sport, the audience would believe the scores and the judges would be able to justify their scores and remove the subjectivity from the sport. P4 thought: "It is to increase the accuracy of the judging and take away mistakes" and P3 asked: "Is it reliable? Is it valid? Is it objective? These can only be positives". P4 suggests it would make the sport better: "If it makes the judging better, then that's a benefit; if it gives gymnast and coaches more confidence in the scores, then that's a benefit, … and if it means that gymnastics is more accessible to more people then it is definitely worth it".

It seemed important to a couple of participants that the stakeholders believed in the new system. P1 stated: "Obviously, the athletes have to adopt the system and believe that it is accurate". P3 has concerns about hesitancy to try the CGJSS: "For the more traditional older coaches, I can see a few challenges there."

***Negative impacts on gymnastics.*** There was some negativity associated with the CGJSS. The participants were concerned that the sport would lose judges if the system became fully integrated. Interviewees expressed doubts over whether it could judge all aspects of gymnastics. P5 challenged: "How does a computer judge artistry?" and "They [judges] put a lot of work and hours in this and it's not fair that they don't get their Olympic Games".

Moreover, over half of the participants were worried that the CGJSS would only be able to judge certain aspects of gymnastics and not the artistry element. P2 stated that he didn't "think a computer system is good enough yet to interpret performances as well as a judge" and P5 commented that "it's ok for the elements, but when it comes to artistry, how does a computer judge the artistry?" P6 commented: "I don't know about the artistry, I don't know how the system would do that on the floor and the beam". P8 stated: "The AI side of things is purely theoretical, it goes by the book. There is nothing else but mathematics - but that's not our sport," and P9 feels that AI is a great evaluation tool but does not have the capacity to evaluate the emotional side of gymnastics: "I am not sure if any type of AI is going to be able to recognise that".

As gymnastics is a traditional sport, the participants were worried that the tradition would be lost. Over half of the participants think gymnasts would lose the individual flair as they would work towards what the CGJSS wants rather than their own interpretation of the skill. P1 suggests: "It might happen that you train

the athlete to execute a move in a certain way, because the computer picks it up

better". P2 said: "As a gymnast and a coach I can say that the way you learn skills and the way you perform them can vary a lot. I think it is like someone's fingerprint, it is unique to that person and that's why gymnastics is quite a unique sport". P4 suggests: "Are you taking out creativity, artistry, individuality, and are you then trying to create robots that are doing everything perfectly?"

One participant was concerned that AI may take over the sport with P9 commenting:

"Right now, we will use AI to evaluate things, but what happens in the future if technology advances so much …The sport is about trying to evoke a reaction with judges and audience and I don't want to see that ever get lost for the sake of coming up with something that is technically perfectly accurate."

P3 and P7 feel that gymnasts and coaches would be able to use the GGJSS to work out risks versus execution. P3 indicated:

"The gymnast can check if the skill is getting credited. It is giving you an insight into what score you can realistically expect to get if you use it and then you can use this to your advantage as it becomes a bit easier to weigh up the risk-to-reward factor."

P7 felt "if you are debating whether to put a new skill in or an extra turn in a spin…it is going to tell you if you are going to get it awarded or not". P9 commented that "if it will be practical for people to have in their gyms, then it can be used in a really positive way".

Some participants thought the sport will evolve as a result of the use of technology. P8 thinks that "evolving is a good thing, but we need to keep an eye on the bigger picture the whole time." P9 has seen change throughout his time in the sport and stated that "change always causes different feelings in different people. There will always be questions and sometimes controversy until people get used to the idea."

Although participants did not think that GGJSS would change the way that gymnasts train or coaches coach, there were concerns that if the GGJSS were available outside of competitions it would have to be accessible to everybody to ensure equality. P4 stated: "It doesn't matter whether you are a rich country or a poor country or whatever, it has to be a really level playing field … otherwise it will just add to the disparity." P9 is worried: "To be current, it costs lots of money. How are we going to ensure that everyone from the beginner competitor through to the top athlete will have access to all these systems?"

Table 4
*Concerns highlighted by the participants during the interviews.*

| Concern raised | Participant that mentioned the concern |
|---|---|
| Loses the flair of individual gymnasts and their personalities and creates robots | P1, P2, P4, P8, P9 |
| The accuracy of the system | P1, P2 |
| Stakeholders adopting the new technology | P1, P3, P4 |
| Computers are only able to judge certain aspects of the sport | P2, P4, P5, P6, P8, P9 |
| Which variation of the skill should it be compared to, potential bias | P2 |
| Software crashing at competitions | P2, P6, P7, P8, P9 |
| Lose the tradition of the sport | P2, P3, P5 |
| If available outside of competitions, it needs to be available to everyone | P3, P4 |
| Lose judges | P3, P4, P5, P8, P9 |

Finally, some participants raised concerns about technological aspects and the system crashing, "I know I wouldn't be happy if it crashed at the beginning of my floor routine," stated P7. P9 felt the system would have to have "a lot of safeguards, otherwise it would turn out to be a nightmare. If you have got rid of all of your human judges and rely on AI, when it goes down, so does the competition". In addition to the these opinions, other respondents had similar concerns. Table 4 summarises them.

## DISCUSSION

Our findings support those of scholars, such as Bucar et al. (2012) and Leskosek et al. (2012), as we identified that there are a number of areas where potential bias can be an issue in gymnastics scoring. However, whereas biases due to the position within the team and judges favouring gymnasts of the same nationality have been previously reported, we can add bias due to familiarity as another area in judging. Bias and subjectivity are seen as an 'accepted' part of the sport but one that causes consternation for gymnasts. It was primarily for this reason that the introduction of the CGJSS has been welcomed.

However, participants were worried that its introduction would result in a reduction of artistic flair that they saw as a key element of gymnastics. It is worth noting that with increased professionalisation and commercialisation of elite sports, success has become more important, and this corresponds with a lower freedom of expression and joy that is often part of sport participation at grassroots and youth levels (Cashmore, 2010). It would not be surprising to see gymnastics evolve in this direction, since the introduction of technology has seen a number of sports change over time (Collins & Evans, 2011; Vera-Rivera et al, 2019).

This change may be needed for two reasons. Firstly, the judges among our interviewees noted that as the skill level of gymnasts has increased, it has become harder for them to keep track of complex routines; therefore, technology was needed to ensure accurate scoring. Secondly, there was a view that less subjectivity in scoring would make the sport more appealing for sponsors and easier for the wider public to understand and engage with. These commercial drivers are important considerations if the sport is to continue to grow in an increasingly competitive sporting landscape (Clarkson et al., 2020).

Interestingly, fairness was mentioned by our interviewees who were concerned that the technology may only be available to gymnasts from more affluent nations. Indeed, one of the great myths of sport is that it is equitable. Success in Summer Olympic sports has been shown to be dependent on the GDP per capita and the population size (Trivedi & Zimmer, 2014). Therefore, further research would be required to evaluate whether the introduction of this technology further widens the gap between the more and the less affluent nations.

In summary, there is a common theme that the participants are positive and excited about the move forward to use the CJGSS technology in gymnastics, but they have some reservations about it. The participants feel that the technology would be helpful if it can help remove subjectivity and bias and result in fairer and more reliable scores to ensure that the most deserving gymnasts stand on the podium. They would not, however, want to see judges completely removed from the sport, especially as they are worried whether the CGJSS is capable of judging all aspects of the sport, with artistry as the main element of concern.

## CONCLUSIONS

The aims of this research were to explore how stakeholders felt about the introduction of a computerised gymnastics judging scoring system (CGJSS) and why gymnastics needed a CGJSS. The use of this technology in gymnastics is currently evolving and this shows how important this research is. There is currently no published data to evaluate the investment needed to implement the CGJSS or the concerns associated with its implementation. Stakeholders' perceptions and the literature review in this study found that CGJSS needs to be introduced into gymnastics for certain aspects of judging to help remove subjectivity and create a valid, reliable scoring system to ensure the best gymnasts on the day win the medals.

The relevant literature confirms that there is a range of problems with the current judging system and the findings from this project concurred with the literature. They include biases in judging due to previous exposure to gymnasts, preferential assessment of gymnasts from their own country, and due to the time of the day gymnasts compete. Fatigue of the judges and advancement in the skills were also mentioned as factors affecting gymnasts' scores. All these factors meant that nearly all participants felt that they had witnessed an injustice due to judging. Nearly all participants thought that by introducing the CGJSS some of subjectivity could be removed from the sport and most participants felt that the investment was worthwhile to ensure a fairer and more reliable scoring system for gymnastics competitions.

An additional, novel finding from this study is that the inherent subjectivity and complexity of gymnastics were seen as a barrier to the sport becoming more popular and marketable. Our participants believe that the popularity of the sport is to some extent based on transparency and integrity. Moreover, there is a sense that for a sport to be popular it needs to be relatively simple and easy to understand – something that gymnastics and its scoring system are not. Nevertheless, over half of the participants were concerned that the CGJSS could not judge all aspects of gymnastics. Fujitsu acknowledging this limitation. However, most of the participants feel that with further development, the CGJSS could move the sport forward in the future.

Throughout the literature and in our study, the CGJSS is referred to as a support system. This means that it is only to be used as an aid and not a replacement for judges. Just under half of the participants had concerns about losing judges altogether from the sport, even though this is unlikely. In other sports where technology has been introduced to remove human error in judging/officiating (such as the Video Assistant Referee in association football or the Decision Review System in cricket), the match officials remain an integral part of the game. However, we should also note that the introduction of technology has not removed human error from these sports. Future research should focus on the implementation of AI in judging of other sports. This may also include global and team sports such as football where VAR implementation still suffers from some of the issues raised in this paper. Nevertheless, AI has the potential to address issues such as bias, subjectivity and fatigue, and therefore provides rich opportunities for further research.

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Article received: 29.3.2021
Article accepted: 23.7.2021

# ENERGY EXPENDITURE IN PRESCHOOL CHILDREN DEPENDING ON VARIOUS TEACHING METHODS WHEN PRACTICING THE ABC GYMNASTICS PROGRAMME

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*Original article* *DOI:10.52165/sgj.13.3.371-384*

***Abstract***

*The aim of the study was to determine whether obstacle course and circuit training are efficient teaching methods as forms of exercise in terms of their intensity, monitored by using energy expenditure measuring devices. The key differences in energy expenditure between the two teaching methods were examined. The BodyMedia SenseWear equipment for measuring energy expenditure was used to acquire data from two practice sessions. A sample of participants included 24 five-year-old children from one kindergarten in Ljubljana, although complete data from both afternoon practice sessions was obtained only from 12 children. The study has shown that obstacle course and circuit training are adequate teaching methods, as moderate to vigorous intensity was achieved with both methods when practicing the ABCs of gymnastics. The average energy expenditure has exceeded 7 MET in the main part of two practice sessions for both obstacle course and circuit training. The results showed no statistically significant differences in energy expenditure between genders or the specific teaching method used.*

***Keywords***: *preschool children, ABC gymnastics, energy expenditure, exercise intensity, obstacle course*

## INTRODUCTION

Regular physical activity is an important indicator of a person´s healthy lifestyle, as it has a positive impact on the physical and motor development of children and adolescents (Goldfield, Harvey, Grattan, & Adamo, 2012) and contributes significantly to the reduction of diseases and mortality in adulthood (Hadžić et al., 2014; Carson et al., 2017). At the same time, regular physical activity has a positive impact on other developmental areas in children – cognitive, emotional, and social (Aalizadeh, Mohamadzadeh, & Hosseini, 2014). These areas are interrelated, especially in the preschool years when changes in one area influence changes in others (Rostami & Ghaedi, 2016).

Any physical activity that is caused by skeletal muscles and results in energy expenditure above resting levels is defined as physical activity (Hollis et al., 2017). Physical activity of younger children differs in many ways from that of other age groups (e.g., youth or adults). Preschool children enjoy playtime and particularly activities requiring locomotion of the entire body and natural forms of movement

(Škof, 2016; Trevlas, Matsouka & Zachopoulou, 2003). Natural movement develops motor and functional abilities in children and represents the foundation for learning various sports skills (Lubans, Morgan, Cliff, Barnett, & Okely, 2010), among others also gymnastic abilities. Artistic gymnastics as an elite sport is not considered an activity with an emphatically playful character, yet its implementation in the classroom can be simple, natural, and fun. Indirect preparation for learning gymnastic skills can be implemented with the help of gymnastic exercises and content included in obstacle courses (Novak, Kovač, & Čuk, 2008).

Gymnastic contents offer a great range of locomotor and stability movements. Their implementation and content can have a positive impact on children´s development (cognitive, affective and social) (Baumgarten & Pagnano-Richardson, 2010).

In the ABC gymnastics programme children learn to use and perform natural movement forms (running, jumping, hopping, climbing, rolling, swinging, etc.) efficiently. They are performing movements through play while trying to complete a variety of motor tasks. This greatly influences children's movement to gradually become relaxed and efficient (Lovrić, Jelaska, & Bilić, 2015). The ABCs of gymnastics most commonly includes obstacle course and circuit training as teaching methods. In the former, children perform motor tasks through stepwise continuous movement over a prepared course while overcoming various obstacles (Culjak et al., 2014). In the latter, children are divided into several groups at different practice stations; these are logically positioned in the room so that children can perform the set motor tasks and then in groups change places in an orderly sequence after a set time. Both teaching methods help improve children's motor skills (Lovrić et al., 2015).

The implementation of the ABCs of gymnastics or other similar sport programs for preschool children has a positive influence on the children's physical and motor as well as emotional, social and cognitive development (Culjak, Delas Kalinski, Kezic & Miletic, 2011). Therefore, it is important to measure, monitor, assess and manage their biological growth and all developmental aspects (Culjak, Miletic, Delas Kalinski, Kezi, & Zuvela, 2014). Motor activity represents a complex process; therefore, its measurement is also complex. Several aspects of physical activity can be assessed: the type, content, duration, and intensity (Rowlands & Eston, 2007). The intensity of physical activity can broadly be defined as light, moderate or vigorous, based on the difference in energy expenditure during exercise and rest; this is defined as a metabolic equivalent of the task or MET (Hadžić et al., 2014), which is expressed as the resting energy expenditure multiplication rate.

Bates (2006) divides various methods of measuring energy expenditure during different physical activities into subjective and objective. In the former methods, study participants (or their parents) describe participation in recent physical activities using questionnaires, diaries, or reports. This method has some shortcomings related to the accuracy of individuals´ perceptions (Oliver, Schofield, & Kolt, 2007). Subjective methods are therefore mostly used with adults, while they are less reliable with children under 10 years of age (Bates, 2006) when parents report on their children´s physical activity (Colley et al., 2012). Objective methods, on the other hand, assess physical activity using various devices that measure the duration, intensity, and type of physical activity. These methods use objective indicators that are not subject to human influence; such data are much more reliable than data obtained through subjective assessment (Cliff, Reilly, & Okely, 2009).

Recent studies in the field of children´s physical activity is increasingly using devices to measure energy expenditure, which allows for more precise and empirical processing and presentation of results (Bedenk, Karpljuk, & Videmšek, 2019; Cliff et al., 2009). Nowadays, data collection is carried out by various equipment, such as Fitbit, Garmin Fitness Band, Nike+ FuelBand, BodyMedia SenseWear, ActiGraph, ActivPal, GeneActive and all sorts of other measuring apparatus (Hills, Mokhtar, & Byrne, 2014; Stålesen, Vik, Hansen, & Berntsen, 2016).

The World Health Organisation (2020) as well as the Slovenian guidelines for physical activity of children and youth (Bratina et al., 2011) recommend that the content of physical activity for children should be designed in such way that it has a positive impact on cardiovascular and muscular performance and bone health. Children and adolescents should engage in more than 60-minutes of moderate to vigorous (MVPA) intensity physical activity every day of the week (Fulton, Garg, Galuska, Rattay, & Caspersen, 2004; Strong et al., 2005). In children, running, jumping, leaping, climbing, etc., are considered as moderate to vigorous intensity activity (Cliff, & Janssen, 2019).

Gymnastic contents offer a great range of locomotor, stability, and body control movements. Consequently, their implementation and the content can positively impact on children´s development. In organising the exercise classes, various teaching methods. can be used. The purpose of this study was to determine whether obstacle courses and circuit training are efficient teaching methods of exercise for preschool children in relation to their intensity, which was monitored using energy expenditure measuring devices. In addition, the study examined differences in energy expenditure between males and females.

## METHODS

This study included 24 five-year-old children from Oton Zupančič Ljubljana kindergarten. The children practiced the ABCs of gymnastics in two sessions; however, acceptable measurement data for both sessions were acquired only for 12 children – 5 boys and 7 girls. The children did not participate in gymnastics or any other organized physical activity programme.

Measurements were carried out during two practice sessions at the Faculty of Sport, University of Ljubljana. The children's parents were informed about the purpose and procedures of data collection and written consent for the children's participation in the study was obtained. Prior to the first measurement session, children's body height and weight were measured for better accuracy of data. The equipment used were digital scales Sanitas (model SBF 70, Sanitas, Madrid, Spain) and a wall-mounted height measuring tape. Average body weight of participants was 22.3 kg and average height 117.6 cm. No statistically significant differences were found between the genders ($p<0.05$).

Physical activity was measured with a multisensory equipment Bodymedia SenseWear Fit Core (SWA; BodyMedia Inc., Pittsburgh, USA). The functioning of the SWA measuring equipment is based on recognition of energy expenditure patterns and the estimation of physical activity. Several non-invasive biometric sensors are used for measuring various physical indicators (heat current, galvanic skin response, skin temperature, air temperature near participant's skin and physical activity measured by dual axis accelerometer). The measuring device uses algorithms to calculate data collected from several sensors, whilst at the same time considering gender, age, height and weight in order to calculate energy expenditure. The SWA measuring equipment has often been used in the past to estimate energy expenditure in children and youth (Sorić et

al., 2015) and has been shown to be a reliable measuring device both in adults (St-Onge, Mignault, Allison, & Rabasa-Lhoret, 2007; Berntsen et al., 2010) as well as in children (Arvidsson, Slinde, Larsson, & Hulthén, 2009; Calabró, Welk & Eisenmann, 2009; Dorminy, Choi, Akohouse, Chen & Buchowski, 2008). Children wore the measuring equipment on the triceps of the right arm and only data from children who wore it continuously throughout the entire session were included in our analysis.

The practice session was divided in three parts: the warm-up period with a running game, the main part, and the cool-down period with relaxation. The first session included obstacle course, whereas a week later, circuit training was used in the main part of the session. Both teaching methods used were very similar contents – natural forms of movement, such as fast walking, running, jumping (straight, pike, tuck, straddle, split, half turn), crawling, climbing, gymnastic elements, such as: rolling (forward, backward, log rolls, on left and right), cartwheel, walking on balance beam (on toes and hills), swinging on gymnastic rings (frontwards and backwards), support on horizontal bars, arm hang, walking on all fours (forward, backward, to side), arms support (donkey kicks), etc.

Both practice sessions were 45 minutes long and the measurements were carried out during the entire sessions (45 minutes). In order to examine the differences between the teaching methods, the main part of each session (obstacle course or circuit training) was analysed separately.

Data on physical activity was analysed with the use of the Bodymedia SenseWear Professional 8.1. programme package (Bodymedia SenseWear Pro Armband; BodyMedia Inc., Pittsburgh, USA). Energy expenditure was expressed in kilojoules (kJ), whilst MVPA was defined as a physical activity that exceeded metabolic rate of 3 MET. Collected data were analysed with the use of the IBM SPSS 25.0 statistical package (IBM Inc. Armonk, USA). Simple descriptive statistics and the normality of data distribution were calculated. In order to compare the differences in energy expenditure between the two practice sessions and specifically between the two teaching methods, the t-test for dependent samples was used. On the other hand, the t-test for independent samples was also used to compare the differences between energy expenditure in girls and boys. Statistically significant differences between the variables were accepted at 5% risk level ($p \leq 0.05$).

## RESULTS

The results of the study are presented below.

Table 1 shows the difference in energy expenditure (kJ), number of steps and MET between the two chosen teaching methods (obstacle course, circuit training). Our results did not reveal statistically significant differences in any of the observed variables. Insignificant tendency of differences was shown in the number of steps ($t = 2.060$, $p = 0.064$), as it was revealed that children performed 184 steps more in obstacle course than in circuit training. Nevertheless, the observed differences were not sufficiently expressed to reach statistical significance.

Table 2 presents the differences between the boys and the girls in energy expenditure, number of steps and metabolic equivalent (MET) for obstacle course and circuit training respectively. The results did not reveal statistically significant differences between boys and girls in any of the observed variables. In circuit training, insignificant difference in the value of metabolic equivalent was revealed between the genders ($t = 2.027$, $p = 0.070$) as boys had on average 1.27 units higher energy expenditure than girls.

Table 1
*Comparison of energy expenditure, number of steps and MET between obstacle course and circuit training.*

| Variable | *μ* | N | *SD* | *t* | *p* |
|---|---|---|---|---|---|
| Energy expenditure (kJ) – obstacle course | 274.92 | 12 | 33.64 | –1.263 | 0.233 |
| Energy expenditure (kJ) – circuit training | 300.67 | 12 | 75.11 | | |
| Number of steps – obstacle course | 1161.75 | 12 | 361.58 | 2.060 | 0.064 |
| Number of steps – circuit training | 977.17 | 12 | 399.47 | | |
| MET – obstacle course | 7.12 | 12 | 0.95 | –0.984 | 0.346 |
| MET – circuit training | 7.64 | 12 | 1.21 | | |

*Key: μ* – average; *SD* – standard deviation; *t* – test statistics; *p* – statistical significance

Table 2
*Comparison between boys and girls in energy expenditure according to energy expenditure, number of steps and MET depending on the chosen teaching methods.*

| Variable | Gender | N | *μ* | *SD* | *t* | *p* |
|---|---|---|---|---|---|---|
| Energy expenditure (kJ) - obstacle course | Boys | 7 | 280,43 | 36.05 | 0.654 | 0.528 |
| | Girls | 5 | 267.20 | 32.17 | | |
| Energy expenditure (kJ) - circuit training | Boys | 7 | 330.00 | 68.02 | 1.743 | 0.112 |
| | Girls | 5 | 259.60 | 70.42 | | |
| Number of steps - obstacle course | Boys | 7 | 1182.57 | 383.10 | 0.226 | 0.826 |
| | Girls | 5 | 1132.60 | 370.88 | | |
| Number of steps - circuit training | Boys | 7 | 965.29 | 423.58 | –0.116 | 0.910 |
| | Girls | 5 | 993.80 | 411.25 | | |
| MET - obstacle course | Boys | 7 | 7.03 | 0.89 | –0.365 | 0.723 |
| | Girls | 5 | 7.24 | 1.13 | | |
| MET - circuit training | Boys | 7 | 8.17 | 0.96 | 2.027 | 0.070 |
| | Girls | 5 | 6.90 | 1.22 | | |

*Key: μ* – average; *SD* – standard deviation; *t* – test statistics; *p* – statistical significance

Table 3
*Comparison of energy expenditure, number of steps and MET for the entire duration of training sessions.*

| Variable | *μ* | N | *SD* | *t* | *p* |
|---|---|---|---|---|---|
| Energy expenditure (kJ) during the entire session (obstacle course) | 486.50 | 12 | 65.51 | –2.161 | 0.054 |
| Energy expenditure (kJ) during the entire session (circuit training) | 553.33 | 12 | 123.81 | | |
| Number of steps during the entire session (obstacle course) | 1652.58 | 12 | 441.16 | –1.414 | 0.185 |
| Number of steps during the entire session (circuit training) | 1819.42 | 12 | 619.89 | | |
| MET during the entire session (obstacle course) | 7.27 | 12 | 0.84 | 0.212 | 0.836 |
| MET during the entire session (circuit training) | 7.18 | 12 | 1.10 | | |

*Key: μ* – average; *SD* – standard deviation; *t* – test statistics; *p* – statistical significance

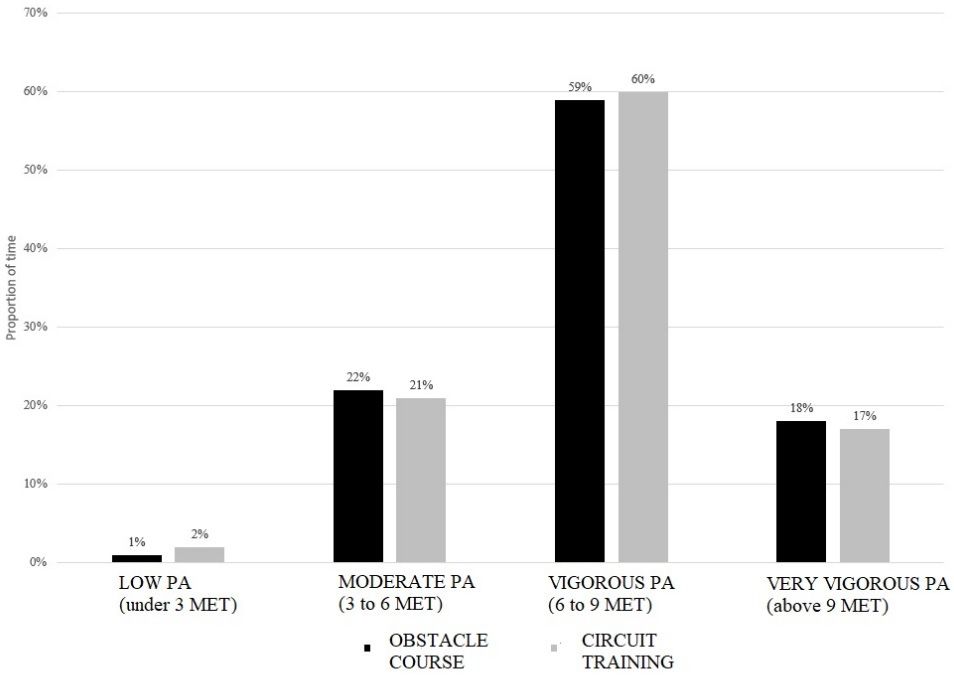


*Figure 1.* Comparison of intensity between practice sessions.

The study also compared energy expenditure during the entire practice sessions, where the ABC gymnastics programme was implemented using either obstacle course or circuit training teaching method. In both sessions, the warm-up part of the session consisted of two running games and gymnastic exercises, whereas a relaxation game was used in the cool-down part of the session.

The results have shown no statistically significant differences in any of the observed variables. Nevertheless, a strong tendency for the appearance of significant differences was noticed in variable energy expenditure for the entire duration of training sessions (t = -2.161,; p = 0.054). This variable was larger by 66.83 kJ when the main part of the session included circuit training. Similarly, the variable

number of steps when the main part was circuit training was higher by 167 steps for the entire session then when the main part included obstacle course.

A comparison between boys and girls was carried out for variables energy expenditure, number of steps and the value of metabolic equivalent. The results did not reveal any statistically significant differences between the genders in any of the observed variables.

Furthermore, the aim of the study was also to find out the degree of intensity when practicing the ABC gymnastics programme, when the main part of the session included obstacle course or circuit training teaching method respectively.

The results have revealed very similar intensity of practice sessions, regardless of the type of teaching method used. For the most part of both practice sessions children performed physical activities of vigorous intensity, as their level of metabolic equivalent was between 6 to 9 MET (Figure 1).

## DISCUSSION

As kindergarten curriculum does not specify the amount of physical activities and due to research findings showing that only a few kindergartens have daily organised physical activity (Videmšek et al., 2014), afternoon hours with organised practice sessions are very important. One of such practices was examined in the present study, namely the ABC gymnastics programme, which incorporates natural forms of movement (walking, running, jumping, crawling, climbing, rolling etc.) to a great extent and presents a joy and challenge to children. It represents an important developmental encouragement, as it influences all areas of child's development (Culjak et al., 2014). Additionally, it strengthens and safeguards health, it forms habits and behavioural patterns, which are crucial for ensuring healthy lifestyle in all age periods.

The sample of measured subjects in the present study included 5-year-old children, whose bodies and particularly central nervous system are in the period of early childhood that is extremely susceptible to environmental effects (Sheridan, Konopasky, Kirkwood & Defeyter, 2016). As development in this period is dynamic and holistic, physical activity plays a key role in this process. The study has shown that preschool children when practicing the ABC gymnastics programme reach and even exceed the recommendations for physical activity of children and youth (Cliff & Janssen, 2019; Hadžić et al., 2014; Strong et al., 2005), both when obstacle course or circuit training teaching methods are used. Out of two 45minutesessions, 27 minutes of activity were practiced in a state of vigorous intensity, 10 minutes in moderate and 8 minutes in very vigorous intensity.

When comparing energy expenditure for the entire duration of practice sessions, it has been revealed that the choice of the teaching method (obstacle course or circuit training) did not produce any differences in energy expenditure or intensity of exercising. In both cases the value of metabolic equivalent (MET) was above 7, meaning that on average the activity was performed in a state of vigorous intensity. It has also been found that in both practice sessions of ABC gymnastics programme no significant differences were noticed between boys and girls.

One of the important goals of the study was to find out whether obstacle course and circuit training are efficient teaching methods to teach the ABCs of gymnastics to preschool children and provide enough intense activity. Thus, the expenditure of energy in children in the main part of each session was compared and similar results were revealed for both teaching methods. The main parts of each session also revealed a metabolic equivalent above 7 (vigorous intensity activity). In addition, it has been found that there were no significant differences in any

of the observed variables. A tendency for the appearance of significant differences was noticed only in the variable number of steps, as it was revealed that children performed on average 184 steps more when obstacle course was used. Similarly, the only noticeable difference between the genders was revealed in the MET value, where boys showed a slight tendency toward significant differences in the activity intensity.

The expenditure of energy in children and youth at rest is higher than in adults; it is usually also higher in boys than in girls (Bitar, Fellmann, Vernet, Coudert, & Vermorel, 1999). Presumably there are several reasons for this; on one hand, they are undoubtedly related to the high energy consuming growth and maturation processes. On the other hand, children have a different proportion of inner organs, shorter legs and lower muscle mass, all of which is manifested in larger differences between energy expenditure at rest and when being active compared to adults. During adolescence, the expenditure of energy at rest starts to decrease and becomes similar to that of adults (Roemich et al., 2000).

According to several authors (Pate, O´Neill, & Mitchell, 2006; Ridley, Ainsworth, & Olds, 2008), the bottom level of moderate intensity activity is set too low; as such, it had to be increased so that in children the value of metabolic equivalent for light intensity activity should be set at 4 MET or less, for moderate intensity between 4 and 7 MET, for vigorous intensity between 7 and 9 MET and for very vigorous intensity activity above 9 MET (Van Loo et al., 2018; Cliff and Janssen, 2019). Even when considering this recommendation, the ABC gymnastic practice sessions, examined in the present study, fulfilled the recommendations set for sports sessions, where children should engage at least 50% of their sports time in activities of moderate to vigorous intensity (US Department of Health and Human Services, 2008). The study by Puyau et al. (2016) revealed the highest value of measured metabolic equivalent in 3- to 5-year-old children at 6.8 MET and the highest heart rate at 250 bpm (beats per minute). Younger children reach higher frequency of heart rate than adults and at the same time they also reach it in shorter time; thus, the borderline value of heart rate frequency in sedentary and moderate intensity activity is around 110 bpm, between light and moderate intensity around 140 bpm and between moderate and vigorous intensity around 160 beats per minute (Butte et al., 2014).

Similar study, although carried out on a sample of 6- to 10-year-old school children, was carried out by Plut (2017), who evaluated the amount and intensity of motor activity of children during two physical education sessions of the same content but using two different teaching methods (obstacle course and circuit training). The study also found that participating children met the minimal recommendations, namely, more than 50% of practice session was carried out at an activity level of moderate to vigorous intensity. Children have manifested higher intensity and larger amount of work in practice session with circuit training, whilst there were no key differences in energy expenditure between genders.

Numerous research studies show that children do not meet the recommendations during their physical education lessons (Fairclough & Stratton, 2006; Hollis et al., 2016) and that they are for the better part of these lessons physically inactive (Volmut, 2014). The reasons for children's inactivity could be various: the choice of teaching methods; provision of PE lessons by regular classroom teacher rather than specialist physical education teacher, teacher’s inexperience, etc. (Volmut, 2014; Fairclough & Stratton, 2006; McKenzie et al., 1996).

The present study has found that boys and girls do not differ in energy expenditure during practice. Similar

findings have been shown also by Puketa (2015) on a sample of 1- to 5-year-old children; by Žerjal (2016) and Vorwerg, Petroff, Kiess, and Blüher (2013) on a sample of 3- to 6-year-old children; Plut (2017) on a sample of 6- to 10-year-old children, and Baron (2016) on a sample of 11-year-old children. In contrast, the results of some other Slovenian and foreign researchers revealed that boys were more active than girls in all age periods (Brasholt et al., 2013; Klasson Heggebø & Anderssen, 2003). The reasons for the differences between the genders in the amount and intensity of sports activity can be found in the interconnected combination of biological, physiological, social and environmental factors (Timmons, Naylor, & Pfeiffer, 2007).

The organisation of a practice session is very important to provide adequate motor efficiency when exercising. In planning and implementation of practice sessions, various teaching methods can be used (Culjak et al., 2014); selecting the most appropriate one leads to a safe, intensive and interesting implementation of sports exercise. When considering the energy expenditure aspect, tt has been found that both obstacle course and circuit training are very efficient methods in realisation of the ABC gymnastics programme for preschool children.

The study has proven that children in the ABCs of gymnastics use a lot of energy, regardless of whether obstacle course or circuit training are used as a teaching method. Due to the complexity of the motor tasks involved, children also develop motor abilities important for gymnastics, mainly motor coordination, flexibility and strength. In the Slovenian guidelines for physical activity of children and youth, it has been emphasised that children should participate 2- to 3-times per week in strength sessions, as these additionally and importantly improve the efficiency of aerobic exercising (Hadžić et al., 2014).

Success or efficiency of exercising rests undoubtedly with teachers, who should adequately plan and implement practice sessions that are adapted to the children's developmental level. As professionally carried out sports activities of preschool children that include basic elements of different sports disciplines are becoming progressively more popular, the requirement for their quality is also increasing. As such, it is recommended that the ABCs of gymnastics are adapted to the interests, developmental levels and needs of children, as only in this way the optimal development and positive influence on health of children will be facilitated.

When carrying out the measurement part of the present study, some difficulties arose that were previously noticed by Bedenk et al. (2019) who also measured the expenditure of energy in preschool children. Particularly disrupting was the fact that the measuring equipment is not adapted to the developmental level of preschool children. Occasionally, the measuring device slipped off the upper arm, resulting in incorrect data collection, which consequently led to the exclusion of such participants from the study. Furthermore, some children at first refused to wear the measuring devices as they did not understand their purpose. Other children were occasionally distracted by the device itself and transferred their attention from practice to the sound or flashing light emitted by the operating device. Some children were not present at both practice sessions. Consequently, the study initially included 24 children, yet only data from 12 children was correctly recorded in both sessions. Due to the abovementioned specific research difficulties, only a small sample of 7 boys and 5 girls was finally included in the data analysis. As a result, the authors recommend that a study on a larger, more representative sample is conducted in the future. However, there are also some other well-known limitations regarding the

measuring procedure: 1) children were aware that they were being measured and monitored, which might have resulted in changes in their habitual PA patterns; 2) biomechanical and physical factors could affect the results as higher mass gives lower acceleration and increased height of children produces longer pendulum; 3) the validity of the measuring device has not been verified on preschool children; 4) the sample size was too small and consequently is not representative; 5) the arm worn device is more sensitive to the arm movement, therefore the results could be overrated (Quante et al., 2015).

## CONCLUSION

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The present study demonstrated and confirmed that both obstacle course and circuit training are appropriate teaching exercise methods to achieve suitable intensity in the ABC gymnastics programme. In both practice sessions, children were active for more than half of the time at a level of moderate to vigorous intensity - that met and exceeded the minimum recommendations for exercise. Nevertheless, such exercise represents only a portion of the physical activity in children who should be physically active at least 60 minutes every day on a level of moderate to vigorous intensity.

Due to the listed positive effects of physical activity in children, it is a desire of the authors that all children would meet the recommended daily activity in the future. The authors believe that questionnaires used for the acquisition of qualitative data about the type and form of physical activity in children should be simultaneously supplemented with objective measures of children´s physical activity. Consequently, further research should be conducted with the use of devices specifically adapted to the developmental level of children to measure their energy expenditure. As the present study only included complete results for 12 children, they cannot be generalised, although they do open up various professional and research questions for the future.

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Article received: 12.11.2020
Article accepted: 3.5.2021

# PAIRED-CONNECTED DEVELOPMENT OF MOTOR QUALITIES IN AESTHETIC GYMNASTICS

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*Original article* *DOI:10.52165/sgj.13.3.385-397*

***Abstract***

*Intensification of training and competitive activity in sports creates the need to search and develop new training methods. This study was conducted with the aim to study the influence of the author's methodology of paired-connected development (PCD) of physical qualities on the level of technical readiness and performing skills in aesthetic gymnastics (AG). For 13 girls - gymnasts (12±1.2 years old), training according to the standard method (control group), and 12 gymnasts of the same age and qualifications, using PSD in the training cycle (main group), the level of development of flexibility, strength, speed, coordination, endurance, technical readiness and success of competitive activity was studied. It was shown that the use of PCD improves the flexibility in the hip joints by 4.24% and 2.28% for the right and left legs, respectively, and the flexibility of the spine by 7.04%. Coordination indicators improved by 32.66-41.25%, strength by 10.02%. The increase in speed indicators was 18.71-21.09%, the indicators of special endurance increased by 11.13-25.16%. For balance, the marks increased by 25.75%, for turns by 19.38%, for jumps by 24.58% and for the flexibility movements they increased by 15.47%. The average scores for the technical value of the composition increased from 4.5±0.07 to 5.45±0.06 points (21.1%), and the average indicators of the final competitive scores increased from 14.49±0.04 to 15.73±0.08 (8.56%). As a result of the experiment, the positive influence of the developed PCD methodology on the level of physical and technical readiness of female gymnasts, as well as on the final competitive result, was confirmed.*

***Keywords***: *aesthetic gymnastics, coupled method, flexibility, strength, speed, coordination, endurance.*

## INTRODUCTION

Today in AG there is a steady increase in the number of competitions during the year, which leads to a longer competitive period and a shorter preparatory period in the annual training cycle, the main task of which is to increase the technical readiness of female athletes (Tsepelevich, 2007). In this regard, coaches, athletes, and specialists are in constant search for new means and methods of special physical training (SPP) of athletes, that would, on one hand, have a complex effect on the physical qualities and technique of performing competitive elements, while on the other, it would not contradict the

principles of sports training (Tarabrina, 2018).

Karpenko and Rumba (2010) suggested that in AG the motor qualities do not appear separately, they are closely interconnected with each other and are manifested in different forms. Vishnyakova (2011) confirmed that in the situation of shorter time for the preparation of competitive compositions, it is necessary to include complex impact exercises in the SPP program that include elements of acrobatics, choreography, and, to a greater extent, competitive exercises.

Sports science introduced into practice the so-called method of connected impact (Dyachkov, 1960), based on the principles of redundancy, connection and advanced development. This means that while performing special exercises that develop any physical abilities, coordination is simultaneously developed and this forms the basis of a competitive exercise. In this way, it is possible to significantly increase the effectiveness of the training process (Tsepelevich, 2007). Simmons (2000) has proven the effectiveness of PCD in strength training for powerlifters and Epov (2018) has shown its positive effect on the development of leg strength in highly skilled taekwondo athletes. There are very few studies that experimentally prove the effectiveness of PCD of motor qualities in AG.

The aim of this research was to study the influence of the author's methodology of PCD on the level of technical readiness and performing skills in AG.

## METHODS

The study involved 25 girls aged 12±1.2 years, engaged in AG in the team of "Vestalia" in Simferopol, with the experience of sports training from 5 to 7 years. Informed parental consent was obtained for the participation of children in the experiment. All sportswomen, according to the Unified Sports Classification System (Federal law of the Russian Federation, 2007; Unified Sports Classification System, 2017) had the same sports qualification (sports category I); therefore, the difference in sports experience was not considered in the statistical analysis. They were divided into two groups: the first (control – CG) group consisted of 12 female gymnasts (10 girls (83.3%) had 7 years of sports experience and 2 (16.7%) had 6) and trained according to the standard method. The second (main – MG) group consisted of 13 gymnasts (11 girls (84.6%) with 7 years of sports experience, 1 with 6 and 1 with 5 (7.7%)) who, for four months in the preparatory period of the training cycle, performed a set of exercises developed at the Department of Medical and Biological Foundations of Physical Culture and Sports of V.I. Vernadsky Crimean Federal University (Tarabrina, Chernaya, 2018). This set was used in the general and special preparatory stages. The effectiveness of the developed sets was studied by looking at the following indicators:

- level of development of motor qualities according to the results of pedagogical testing;
- level of technical readiness based on the results of expert assessment for the performance of competitive elements by gymnasts;
- results of competitive activity at control competitions: regional stage: October, 2017; municipal stage: March, 2018.

In total, seven SPP sets of combined orientation were developed: three sets aimed at developing balance and flexibility (abbreviated in Table 1, Figure 1, Figure 2 and Figure 3, respectively), three sets to develop jumping ability (leg muscle strength and jumping special endurance) (J.1, J.2, J.3, respectively), as well as a set of

acrobatic exercises which include competitive elements of increased complexity (A).

Each set of exercises provides three levels of dosage, which varies by 10-30% depending on the microcycle and is designated by letters a, d, c (respectively). The sets are distributed in the preparatory period of the training process by days of the week (Table 1).

The entire program of the experiment was conditionally divided into four mesocycles (Table 1). In the retraction, basic and control mesocycles and Set F were performed, aiming to develop flexibility and balance, as well as Set J that aimed to develop the jumping ability, jumping special endurance and strength of the leg muscles. Set A was performed in the grinding mesocycle. The sets were included in microcycles as follows: on Monday, Wednesday and Friday, at the end of the preparatory part of the training, the athletes performed Set F; on Tuesday, Thursday and Saturday at the end of the main part of the training, the gymnasts performed Set J.

In the grinding mesocycle of a special preparatory stage, which is aimed at eliminating shortcomings, improving the technique of competitive elements, and correcting mistakes, MG gymnasts were offered Set A three times a week, characterized by increased intensity.

Exercises (A) have a conjugate character and include technically complex competitive elements, repeated several times in a series (up to eight movements in a series), and represent preset combinations connected by acrobatic elements. In the future, gymnasts can use combinations from the acrobatic set as a part of their competitive program. To perform these exercises, gymnasts must simultaneously show such physical qualities as flexibility, strength, special endurance and coordination.

Children's flexibility was assessed using an indirect, scientifically proven method, (Kamaev & Osadchyieva, 2018) which involves linear measurement of the distance between segments or to an external object. Thus, to assess the flexibility of the spine in the frontal plane, we used the following test: "bend-forward-from-a-standing-position". The gymnast stands on the edge of a bench with legs together and straight knees. How much the fingers extend below the edge of the bench is noted. If the fingers do not reach the edge, the distance is recorded using the "-" sign (Romanenko, 1999).

To assess the flexibility of the shoulder joints, the test "twist-back-with-a-grip-for-a-centimeter-tape" was used. The subject transfers straight arms over the head from the front to the back position; the grip width is fixed (Romanenko, 1999).

The mobility of the hip joints was assessed by measuring the distance to the floor while performing the split. In this case, a gymnastic bench 60cm high was used (Kamaev & Osadchyieva, 2018).

To assess the mobility of the spine, a test exercise "box" was used: from the initial position, lying on the stomach, it is necessary to grab the legs with the hands, while measuring the distance from the feet to the floor (Romanenko, 1999).

Coordination abilities were assessed using the Romberg test (Galán-Mercant & Cuesta-Vargas, 2014). The subject stands in such a way that her legs are on the same line while the heel of one leg touches the other leg, eyes closed, arms extended forward and fingers spread. The indicators of Romberg test in children depend on their age (Table 2) (Galán-Mercant, Cuesta-Vargas, 2014).

The Firileva test, confirmed by scientific and experimental data (Firileva, 1981), was used to assess the ability to coordinate movements. Under

the test conditions, the subjects learn control exercises for 2-5 minutes. They include multidirectional movements of the legs, the arms, and the head. When performing these exercises, it is necessary to take into account the quality (score in points) and the execution time (s). Further, by dividing the indicators of the time spent on the exercise by the mark (between 1 and 5), a coefficient is derived, which is an indicator of the level of development of the ability to coordinate movements. Thus, the shorter the time and the higher the score, the lower the coefficient of the level of coordination development.

The results are interpreted as follows:

- "excellent": 0.1–2.0, conventional unit;
- "good": 2.1–4.0, conventional unit;
- "satisfactory": 4.1-6.0, conventional unit;
- "unsatisfactory": 6.1 and higher, conventional unit.

We used coordination Set 1: initial position - normal stand position (n.s.p.); 1 - left leg back to toe, left arm bent at the elbow joint, elbows at shoulder height, wrist to shoulder, right arm up, head to the left; 2 - n.s.p.; 3 - repeat 1; 4 - n.s.p.; 5 - turn right; 6 - n.s.p.; 7 - half-squat, arms forward; 8 - n.s.p.. The combination must be repeated four times for the best score and for the best mark (Firileva, 1981).

To measure the gymnasts' strength of the muscles in the hands and the back of the wrist, dynamometers (hand-held flat-spring dynamometers, DRP-90, Russia) were used.

Strength indicators were determined for the muscles of the arms and shoulder girdle using the test exercise "flexion-and-extension-of-the arms-in-the-lying-position". In this case, the maximum number of repetitions of the test exercise, performed technically correctly, was counted: lying position, arms shoulder-width apart, angle at the elbow joint of at least 90° and straight arms to full extension (Romanenko, 1999).

The "angle" test was used to determine the strength of the trunk muscles: initial position - sitting on the floor, holding the legs at an angle of 135°, holding time is measured; boat test - from the initial position lying on the stomach, raised arms and legs up and hold the position, the holding time is recorded (Romanenko, 1999).

Strength indicators of the muscles of the lower extremities were assessed by using the "lifting-and-holding-the-pelvis-in-a-split" test (Romanenko, 1999).

To determine the speed and stability of the motor-sensory response, we measured the parameters of the time of a simple sensorimotor response using light and sound stimuli from the BioMouse software package (NeuroLab, Russia) (Kulakov, 2020).

The "fifteen-second-squat" test was used to assess the frequency of movements; the number of squats performed technically correctly is recorded (the legs should be shoulder-width apart, the angle at the knee joints is 90°, the heels do not come off the floor) (Tarabrina & Chernaya, 2018).

Special speed abilities were assessed using the "jumping-with-double-rope-rotation" test. The number of speed jumps in 10 seconds was assessed (Romanenko, 1999).

The level of high-speed special endurance was judged by the indicators of the number of jumps on the rope with alternating legs (running) for 1 minute and by the indicators of the maximum number of double jumps in the rope performed in a row (Romanenko, 1999) (Kamaev & Osadchyieva, 2018).

To determine the level of technical readiness of the female gymnasts, the method to expertly assess the fulfillment of competitive elements in all structural

groups of the exercise was used in the stage of in-depth training (IFAGG, 2020).

Competitive elements were performed by gymnasts in the main part of the training session and were assessed by three experts, coaches of the Federation of Aesthetic Gymnastics of the Republic of Crimea and "Vestalia" teams, and judges: one top category judge and two category II judges.

Twenty basic elements from the current competition rules were selected.

The following compulsory elements were evaluated: balance, turns, jumps and flexibility movements. The gymnasts were asked to perform the elements, and the experts were asked to give marks for the technique of each performed element. For this, the evaluation criteria presented in Table 3 have been developed. The final result was the average score from the sum of the marks for the performed elements in each structural group of the exercise.

The success of the competitive activity of gymnasts (SCAG) was assessed by adding together three assessments: for the technical value of the composition, for the artistic value, and for the performance (IFAGG, 2020).

The marks in each group are displayed as the arithmetic mean with or without dropping the highest and lowest marks, depending on the number of judges.

The maximum score for the technical value of the composition is 5.9+0.1 points - bonus increase; for the artistic value 3.9+0.1 points - bonus increase; for performance 9.8+0.2 points - bonus increase (Klyuchinskaya, 2012; IFAGG, 2020).

SCAG was judged on the basis of the results from two competitions: October 8-10, 2017 (Championship of Crimea in AG, Alushta) and March 11, 2018 (Championship of Simferopol in AG, Simferopol).

Thus, it was possible to compare the results of the competitive activity of gymnasts before and after the introduction of the sets.

The calculations and graphic design of the data obtained in the work were carried out using the Microsoft Excel program and the STATISTICA - 10.0 software package. The choice of the criterion for testing statistical hypotheses and measures of central tendencies that serve to describe the data was carried out depending on the results of the distribution test, which was carried out using the Shapiro-Wilk test. Pairwise comparison of groups was performed using the parametric Student's test. In this case, the arithmetic mean (M) was used as a measure of the central tendency, and the standard error of the arithmetic mean (m) was used as a scattering measure.

Table 1
*Distribution of sets of conjugate exercises in the preparatory stage of gymnasts' training.*

| | General preparatory stage | | | | | | Special preparatory stage | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Retracting mesocycle | | | Base mesocycle | | | Control mesocycle | | | Grinding mesocycle | | |
| | Microcycle | | | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Monday | F.1a | F.1b | F.1c | F.2a | F.2b | F.2c | F.3a | F.3b | F.3c | A.a | A.b | A.c |
| Tuesday | J.1a | J.1b | J.1c | J.2a | J.2b | J.2c | J.3a | J.3b | J.3c | | | |
| Wednesday | F.1a | F.1b | F.1c | F.2a | F.2b | F.2c | F.3a | F.3b | F.3c | A.a | A.b | A.c |
| Thursday | J.1a | J.1b | J.1c | J.2a | J.2b | J.2c | J.3a | J.3b | J.3c | | | |
| Friday | F.1a | F.1b | F.1c | F.2a | F.2b | F.2c | F.3a | F.3b | F.3c | A.a | A.b | A.c |
| Saturday | J.1a | J.1b | J.1c | J.2a | J.2b | J.2c | J.3a | J.3b | J.3c | | | |
| Sunday | Day of rest | | | Day of rest | | | Day of rest | | | Day of rest | | |

Table 2
*Average time of stability (s) in the Romberg position for children, adolescents and young men (according to A.F. Sinyakov).*

| Age (years) | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stability time (s) | 13 | 16 | 21 | 24 | 28 | 30 | 36 | 44 | 48 | 50 | 52 | 51 | 53 |

Table 3
*Criteria for assessing the technical readiness of gymnasts.*

| Assessment (score) | Description |
|---|---|
| 1.0 | element executed without errors |
| 0.9 | item executed with one minor error |
| 0.8 | average error in the technique of performing an element or two small errors while maintaining the amplitude of movement |
| 0.7 | slight decrease in the range of motion and minor error in the technique of performing the element |
| 0.6 | preservation of the shape of the element with the assumption of average error in technique |
| 0.5 | element made with significant technical error; in a competitive combination it cannot be scored |
| 0.4 | broken shape of the element, insufficient range of motion |
| 0.3 | the required form of the element is missing with several minor errors in the basic movement technique |
| 0.2 | gross error in the basic technique of performed movement |
| 0.1 | crash on element execution |
| 0 | refusal to execute an element |

## RESULTS

Figure 1 shows that in CG, the increase in flexibility indicators is insignificant, and in MG, improvement is observed only in such indicators as "split on the right leg", "split on the left leg" and "box" (4.24%, 2.28% and 7.04% ($p<0.05$), respectively). In gymnasts, the most developed of all physical qualities are passive and active flexibility in joints and the spine. Before the start of the study, these indicators in athletes of both groups were at a high level, therefore, the sets could only slightly affect their change. Coordination tests improved in CG (21.33-25.21%) ($p<0.05$-$0.01$) and in MG (32.66-41.25%) ($p<0.01$-$0.001$). The most striking changes were observed in Romberg test: 41.25% ($p<0.001$) (Figure 2).

As a result of training according to the standard method, the strength indicators of CG gymnasts did not change significantly, and the strength of the muscles of the upper shoulder girdle decreased by 2.5%. In MG, the strength of the back muscles increased between 8.74% to 10.02% ($p<0.01$). The greatest results were achieved in the development of the strength in the adductor muscle group which lift and hold the body and pelvis from a position sitting on a split. This indicator increased by 31.38% ($p<0.01$) (Figure 3).

Indicators of a simple sensorimotor reaction where light and sound signals were used as stimuli did not change significantly. The number of squats and double rope jumping in 10 seconds in MG improved by 18.71% ($p<0.05$) and 21.09% ($p<0.01$), respectively (Figure 4). Special working capacity was significantly improved only in MG gymnasts (Figure 5). Double and alternate rope jumping increased by 11.11-11.13% ($p<0.05$-$0.01$), respectively. At the same time, the expert assessments for the performance of the competitive elements of the gymnasts in both groups changed after the experiment. A statistically significant ($p<0.05$) increase is observed in the assessments of CG gymnasts for turns (9.66%), for jumping performance (9.49%), and for flexibility elements (3.48%). In MG gymnasts, the increase in the score for the fulfillment of balances was 25.75% ($p<0.05$), for the performance of turns 19.38% ($p<0.01$), for jumping 24.58% ($p<0.05$), and movements for flexibility: 18.71% ($p<0.05$) (Figure 6).

The average scores for the technical value of the composition of CG gymnasts increased by 4.35%, while in the MG these indicators increased by 21.1% ($p<0.05$). The final competitive result for the exercise performance of CG athletes remained practically unchanged and was 14.74±0.02 points (increased by 2.01%) after the experiment. In the MG, the increase occurred from 14.49±0.04 points before the experiment to 15.73±0.08 points after (increased by 8.56% ($p<0.05$)).

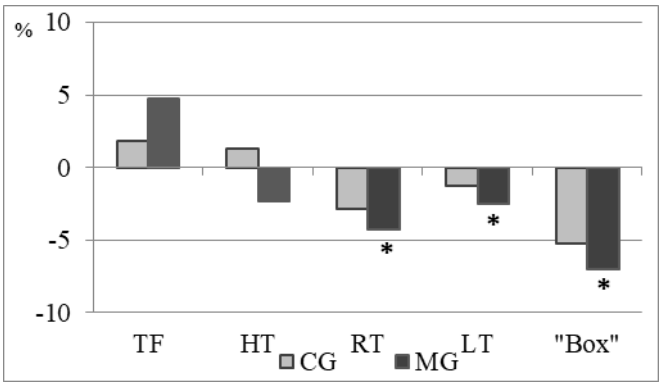


*Figure 1.* Changes in indicators of flexibility development in gymnasts of the control (n=12) and the main (n=13) group (%). Here and further: statistically significant differences at 0.05 level between the two groups at each assessment are denoted by asterisks: * – p<0,05; ** – p<0,01; *** – p<0,001; T is the Student criterion. TF is Tilt Forward, HT is Hands Twist, RT are Right Splits, LT are Left Splits.

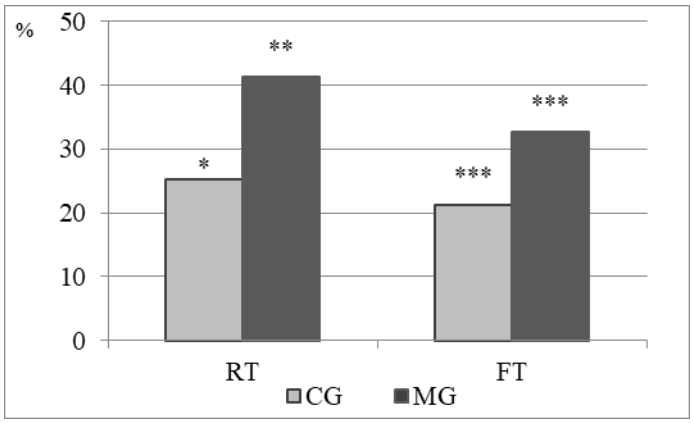


*Figure 2.* Changes in the indices of the coordination development in gymnasts of the control (n=12) and the main (n = 13) groups (%). RT is Romberg Test, FT is Firileva Test.

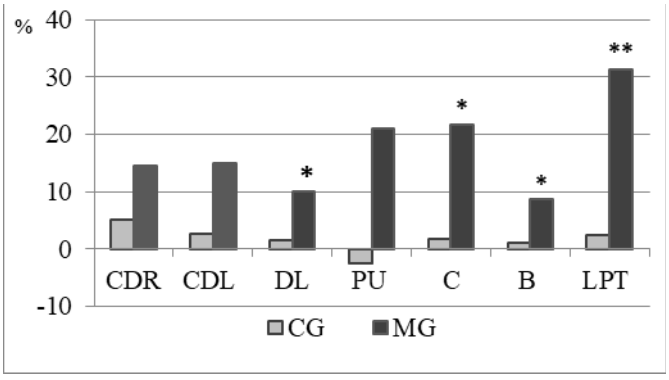


*Figure 3.* Changes in the strength indicators of gymnasts in the control (n=12) and the main (n=13) group (%). CDR is carpal dynamometry of the right hand, CDL is carpal dynamometry of the left hand, DL is deadlift, PU are push-ups, C is “Conner”, B is “Boat”, LPT is Lifting the pelvis in the twine.

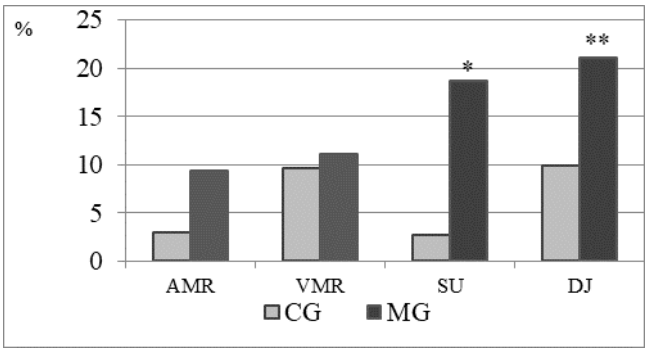


*Figure 4.* Changes in indicators of speed development in gymnasts of the control (n=12) and the main (n=13) group (%). AMR is audio-motor response, VMR is Visio-Motor Response, SU are Sit-Ups, DSR is Double Skipping Rope.

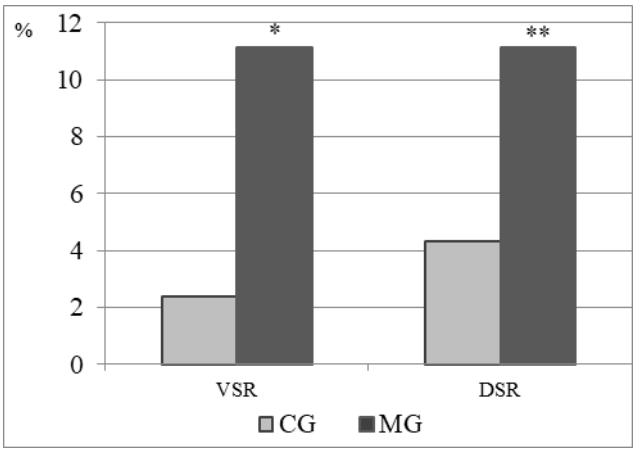


*Figure 5.* Changes in indicators of special endurance development in gymnasts of the control (n=12) and the main (n=13) group (%). VSR is variable skipping rope, DSR is double skipping rope.

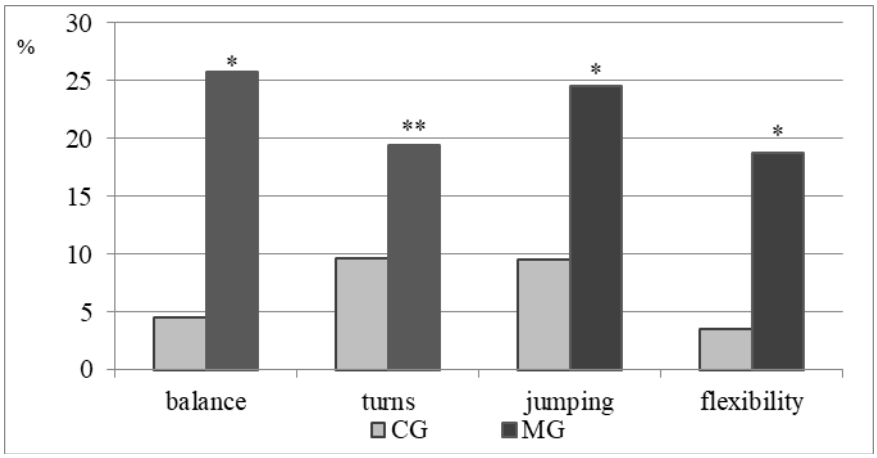


*Figure 6.* Changes in indicators of expert evaluations for the implementation of elements of gymnasts in the control (n=12) and the main (n=13) group (%).

## DISCUSSION

In the system of sports training, there are various approaches to improving the technical skills of gymnasts. According to the authors, this can be realized by combining or conjugating various types of training: physical, technical, functional and theoretical. This pairing, especially of physical and technical training, in the general concept of integral training, has been successfully used for more than ten years at the national level in AG. The main provisions of the methodology were laid down in the concept of in-depth training for young gymnasts. In AG, this stage corresponds to the age of 12 years, when the athletes master and perform the program of the first sports category. The data presented here indicates its effectiveness.

The results obtained show that the indicators for coordination, speed, endurance, and strength statistically improved. However, the level of flexibility has not changed significantly. Tsepelevich (2007) believes that flexibility in gymnastics is the most developed and significant physical quality. This is confirmed by our data: the athletes participating in the study had a high level of flexibility before the introduction of the sets. This insignificant increase is explained by the Wilder-Leites rule or the “law of the initial level”, i.e., that the relative or absolute increase in the value of indicator is inversely related to its initial level (Plekhanov, Vasiliev, Kozlova, 1989). To improve the level of development of passive and active flexibility, it is recommended, in addition to the developed sets, to perform daily passive-static exercises (sitting in twine on a gymnastic bench), as well as active-dynamic (springing, swinging, jerking) exercises that can be performed with weights, shock absorbers or other resistance objects, or without them. It is important that the RCD sets, along with exercises for the development of flexibility, include exercises aimed at developing muscle strength. This helps to avoid injury to gymnasts and to achieve the best results (Tarabrina, Kraev & Tikhonov, 2020).

The greatest results were achieved in the development of the strength in the adductor muscle group (short and long adductor, square femoris, sartorius and comb muscles), gluteal muscles (large, middle and small), piriformis muscles, all of which are involved in lifting and holding the trunk and pelvis from a sitting position on a split. This indicator increased by 31.38% ($p<0.01$).

It was shown that due to the developed sets, the speed-power qualities of the gymnasts in general improved; however, the indicators of a simple sensorimotor reaction, where light and sound signals were used as stimuli, did not change significantly. The speed capabilities of a person (reflected in this indicator), especially in their motor part, are mostly natural and hardly changeable under the influence of sports training, which at the same time weaken with age (starting from adulthood) (Gardner & Moore, 2006). An increase in rope jumping with double rotation by 21.09% ($p<0.01$) testifies to the improvement of intermuscular coordination and coordination of movements, speed and high accuracy of the movement, as well as the efficiency of work.

The effectiveness of the developed methodology is confirmed by the competitive results of gymnasts. In the MG, not only the final results increased (by 8.56% ($p<0.05$)), but also indicators of the technical value of the compositions by 21.1% ($p<0.05$).

It should be noted that in the CG, the increase in the competitive result was not due to more difficult, technically valuable elements, but due to the higher-quality performance of the

elements, the technical value of which, according to the rules of the competition, is small: up to 0.5 points. This was achieved mainly by correcting minor errors and inaccuracies in technical details rather than by exercising physical ability. The results of MG gymnasts improved mainly due to the high-quality fulfillment of technically complex elements with a value of 0.6 points and more; their fulfillment requires a high degree of physical abilities that manifest in a specific complex motor action.

## CONCLUSION

The theoretical analysis of scientific and methodological literature showed the need to search for directions to improve technical skills in gymnastic sports at all stages of training. This is associated with increased requirements for technical complexity and competitiveness at the international level. It is believed that ensuring a sufficiently high level of sportsmanship, as a necessary condition for achieving the highest results, is carried out as a result of fundamental, comprehensive and purposeful technical training. In this regard, it became necessary to develop the author's methodology of paired-conjugate development of motor qualities in 12-year-old female athletes engaged in AG at the stage of in-depth specialization in accordance with the methodological and didactic principles of sports training.

The author's methodology of paired-conjugate development of motor qualities was introduced into the educational-training process of a two-cycle annual training. It brought along the following improvements: use of methods and means of a practical and applied nature; development of seven sets for special physical training of a combined orientation: three sets of exercises mainly aimed at developing flexibility and balance; three sets mainly aimed at developing the jumping ability, leg muscle strength and jumping endurance, and a set that develops acrobatic exercises that include competitive elements of increased complexity. Each set of exercises provides three levels of dosage which varies by 10-30%, depending on the microcycle.

The analysis of the results obtained after the introduction of the author's method confirms the improvement of mobility in the hip joints by 4.24% and 2.28% for the right and left legs, respectively, and the flexibility of the spine by 7.04%. Coordination indicators improved by 32.66-41.25% ($p<0.001$), and strength indicators from 8.74% ($p<0.01$) to 10.77% ($p<0.05$). The increase in speed indicators was 18.71-21.09%, the indicators of special endurance increased from 11.13 ($p<0.01$) to 25.16% ($p<0.05$). The scores for balance increased by 25.75% ($p <0.05$), for the performance of turns - 19.38% ($p <0.01$), jumping - 24.58% ($p <0.05$), movements on flexibility - 18.71% ($p <0.05$). The average scores for the technical value of the composition increased from $4.5 \pm 0.07$ to $5.45 \pm 0.06$ points (21.1%) ($p <0.05$), and the average indicators of the final competitive scores increased from $14.49 \pm 0.04$ to $15.73 \pm 0.08$ points (8.56%) ($p <0.05$).

Thus, this study confirms our hypothesis and shows that in-depth training in AG as a method of PCD for motor qualities proved its effectiveness by making a difference to the physical and technical readiness of young gymnasts as well as their performing skills. This technique can be useful for both athletes and practicing trainers in AG. Some of its components can be used at different stages of sports training.

## ACKNOWLEDGEMENT

We express our special gratitude to the President of the Federation of AG of the Republic of Crimea, A. K. Mogiley, and to the head coach of "Vestalia" team, D. L. Mogiley, for help in conducting the experimental part of the research.

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Article received: 25.11.2020
Article accepted: 23.7.2021

# THE EFFECT OF 10-WEEK ISOKINETIC TRAINING ON MUSCLE STRENGTH AND GYMNASTIC PERFORMANCE IN PREADOLESCENT FEMALE GYMNAST

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*Original article* *DOI:10.52165/sgj.13.3.399-409*

***Abstract***

*The purpose of this study was to investigate the effect of isokinetic training on muscle strength and gymnastic performance when added to traditional gymnastic training on handspring vault in preadolescent female gymnasts. Twenty female gymnasts with a mean age of 10.50 ± 1.19 years, height 125.50 ± 4.52cm, and body mass 27.30 ± 2.58 kg volunteered to participate in this study. A Cybex II Isokinetic dynamometer was used to measure the peak torque of the knee joint in extension at angular velocities of 60°/sec and 300°/ sec. A Casio EX-F1 (Tokyo, Japan) high speed video camera was placed perpendicular to the optical axis of springboard and vaulting horse. The subjects participated in 10-weeks training for three non-consecutive days per week, 2 hours per day, and separated into two equal groups. The experimental group (EG) followed a specialized training program (technical preparation and muscle strength via Cybex II), whereas the control group (CG) followed the traditional training program (technical preparation and muscle strength). Results showed no significant interaction was found for gymnastic score; however, a significant main effect was found for the time. No significant interaction effect among the three independent variables (group, time, side) was found for the knee extension at 60°/sec. However, the EG had a significantly higher mean values compared to the CG in the post-test. The interaction among the three independent variables with respect to the knee flexion at 300°/sec was not significant. However, the interaction between sides by group was significant. The 10-week isokinetic training added to the traditional training improved the knee strength, which consequently improved aspects of the vault, but did not affect other technical aspects of the handspring performance. Furthermore, results of our study support the claim that optimal performance is the result of a complex interaction of several factors.*

***Keywords***: *isokinetic, handspring, vaulting, score, muscular strength, gymnastics.*

## INTRODUCTION

Artistic gymnastics is one of the most popular and rapidly growing sports for young girls and there has been a definite trend toward younger gymnasts performing more difficult exercises (Cote, Salmela, and Russel, 1995). Many authors agree that a high level of strength is needed for a correct learning of technical movements and a low level of strength has negative influence on the development of technical skills (Brown, Wells, Schade, Smith, and Fehling, 2007). The term muscular

strength refers to a measure describing an individual's ability to exert maximum muscular force statically or dynamically and defined as the peak force or torque developed during a maximal voluntary effort. Girls' ability to perform increases until the age of 13 or 14 years with little subsequent improvement (Malina, and Bouchard, 1991). Muscular strength in boys increases fairly linearly with chronological age, from early childhood until approximately 13 or 14 years of age (mid-puberty). In girls, strength improves linearly up until about 15 years of age, but there is no clear evidence of an adolescent spurt (Erlandson, Sherar, Mirwald, Maffulli, Baxter-Jones, 2008). The Position Statement on Youth Resistance Training published by the National Strength & Conditioning Association in the US upheld the more recent belief that properly supervised and well-planned resistance training can be effective and safe to improve the strength of preadolescent and adolescent populations (Naughton, Farpour-Lambert, Carlson, Bradney, and Van Praagh, 2000). Despite the old notion that prepubescents could not increase their strength due to insufficient levels of circulating androgens, other studies have reported significant improvements in strength following several weeks of strength training (American College of Sports Medicine, 1998; 2000; Faigenbaum, Kraemer, Cahill, Chandler, Dziados, Elfrink, et al, 1996; Faigenbaum, LaRosa Loud, O'Connell, Glover, O'Connell, and Westcott, 2001; Faigenbaum, Kraemer, Blimkie, Jeffreys, Micheli, Nitka, et al, 2009; Isaacs, Pohlman, and Craig, 1994; Ramsay, Blimkie, Smith, Garner, MacDougall, and Sale, 1990). Previous data demonstrated that children as young as 6 can improve muscle strength and power in order to achieve their maximal potential and complete the required skills when following age-specific resistance training guidelines (Bencke, Damsgaard, Saekmose, Jørgensen, Jørgensen, and Klausen, 2002; Falk, and Mor, 1996). Further, according to Seger and Thorstenson (2000), strength adaptation is sport-specific and athlete's specialization and training determine the muscle groups where the adaptations occur.

One type of strength movement is isokinetic; it has been shown to be relatively safe since once the movement is stopped the resistance is removed. This is an aspect that is extremely important when working with children (De Ste Croix, Deighan, Ratel, and Armstrong, 2009).

Isokinetic training allows maximal loading of a muscle throughout the full range of motion rather than at a specific angle as in an isotonic exercise, and the application of a specific isokinetic training program can efficiently restore imbalances in knee muscle strength (Gioftsidou, Ispirlidis, Pafis, Malliou, Bikos, and Godolias, 2008). Isokinetic training allows for maximal strength improvements and is usually combined with other types of strength training. Selecting low strength speed ($60°\cdot s_{-1}$), medium fast speed ($180°\cdot s_{-1}$) and high endurance speed ($300°\cdot s_{-1}$), isokinetic testing speeds are essential for optimal strength evaluation (Baltzopoulos, and Brodie, 1989).

Blimkie and Sale suggested that many girls might peak in strength before or during peak height velocity, with the magnitude of the strength gain being consistently greater in boys than in girls (Blimkie, and Sale, 1998). Additionally, the determination of the knee joint muscles activation in young gymnasts can provide useful information for better understanding of the mechanisms involved in strength production in athletic populations during developmental ages. Previous data indicated that isokinetic elbow and knee extensor and flexor develop in the same manner in boys and girls until the age of 10-11 (Gilliam, Villanacci, Freedson, and Sady, 1979). In another study Cools et al. (2007) compared the isokinetic muscle performance of the scapular muscles between elite adolescent gymnasts and

nonathletic adolescents to identify differences in strength, endurance, and muscle balance based on high-level sport participation and found that elite gymnasts demonstrated higher values for the protraction peak force/body mass than the control group.

There are limited intervention studies on artistic gymnasts. Previous findings suggested that gymnastics intervention program improved strength of lower limbs in pre-adolescent athletes (Douda, Tokmakidis, and Tsiggilis, 1997; Pienaar, and Van der Walt, 1988). Bassa and his colleagues (2002) described the isometric and isokinetic knee torque in pre-pubescent male gymnasts six months after the beginning of the annual training period and concluded that long term gymnastics training is associated with increased torque in knee extensors but not knee flexors. Further, Golik-Peric, Drapsin, Obradovic, and Drid (2011) examined the effects of two different training protocols, isokinetic training and isotonic training, on registered initial thigh muscles strength asymmetry after 4 weeks of training in 38 athletes in various sports and found that the implemented training protocols significantly enhanced the strength of thigh muscles measured isokinetically and decreased the degree of muscle strength asymmetry. Study of Deley et al. (2011) examined the effects of a 6-week combined electromyostimulation (EMS) and gymnastics training program on muscle strength and vertical jump performance in 16 prepubescent gymnasts and found that improvement was found after three weeks of EMS training in the maximal voluntary torque (MVT). However, after the three-week point, no further increase was demonstrated. There was no significant MVT change in the control group. The lack of change in the control group following this study demonstrates that the significant improvement is a result of the training intervention and not regular growth in the population (Deley et al, 2011). Findings of Tabaković et al. (2016) showed that isokinetic training of knee extensors and flexor muscles increases functional correlation between speed and strength leading to improved performance of acrobatic elements in floor exercises.

The handspring vault is a technical gymnastic skill which demands considerable force and power output and is of paramount importance for a gymnast's vaulting development (Takei, 1998). In a recent study, Hall et al. (2016) examined the effect of plyometric training when added to habitual gymnastic training on handspring vault performance variables on twenty youth female competitive gymnasts and found significant improvements for run-up velocity, take-off velocity, hurdle to board distance, board contact time, table contact time and post-flight time. However, there were no significant improvements on pre-flight time, shoulder angle or hip angle on the vault for the plyometric training group. To the best of our knowledge, there are no other studies that examined the effect of isokinetic training on muscle strength and gymnastic performance in preadolescent female gymnast. Hence, the purpose of this study was to investigate torque-generating capabilities of pre-adolescent female gymnasts for the knee extensor-flexors muscles in relationship to the performance of handspring vault. It is hoped that this study will focus attention upon this important aspect of performance and stimulate interest in future scientific investigations in this area. Our working hypothesis was that biomechanical parameters, augmented by training techniques, influence the performance of female pre-adolescent gymnasts.

## METHODS

Twenty female gymnasts with a mean age of 10.50 ± 1.19 years, height 129.50 ± 4.52cm, and body mass 27.30 ± 2.58 kg volunteered to participate in this study. They were engaged in gymnastics for at

least 3 years at competition level and the study was carried out during the preparation period. Further, they must have participated in official competitions at least once and had no previous training experience with an isokinetic device. There were additional exclusion criteria such as: any lower limb injury in the previous 6 months or not being able to perform the handspring vault. Both the children and their parents were informed extensively about the experimental procedures and the possible risks or benefits of the project, and parental written consent was obtained before participation. All procedures were in accordance with the ethics of the Institutional Ethics Board of the University of Athens. The total group was separated randomly into two equal groups. The experimental group (EG) followed a specialized training program (technical preparation and muscle strength via Cybex II), whereas the control group (CG) followed the traditional training program (technical preparation and muscle strength). The physical characteristics of the subjects are presented in Table 1. There were no statistical differences in age, height, and body weight between the two groups or in their strength parameters.

Table 1
*Physical characteristics and mean changes (±SE) of the subjects.*

| (n=20) | Pre | | Post | |
|---|---|---|---|---|
| | EG (n=10) | | CG (n=10) | |
| | Pre | Post | Pre | Post |
| Age | 10.20 ± 1.03 | | 10.80 ± 1.32 | |
| Weight (kg) | 26.80 ± 2.53 | 27.60 ± 2.99 | 27.80 ± 2.66 | 28.30 ± 2.98 |
| Height (cm) | 128.90 ± 5.02 | 129.60 ± 5.14 | 130.10 ± 4.15 | 130.70 ± 3.89 |

A Cybex II Isokinetic dynamometer was used to measure the peak torque of the knee joint. The knee extension and flexion were measured at angular velocities of 60°/sec and 300°/ sec. The latter velocity was selected because cine analysis of the take-off phase on springboard showed an angular velocity in excess of 300° per second. In addition, this velocity was chosen so that the participants could apply the strength in conditions similar to those encountered during the take-off phase of the springboard.

A Casio EX-F1 (Tokyo, Japan) high speed video camera was placed perpendicular to the optical axis of springboard and vaulting horse. The camera was set at 100fr/sec and placed on the right-hand side at 6.5m from the above materials to minimize the parallax error. The wall behind the vault area had horizontal and vertical reference axis. An electronic counter that establishes the true frame rate was used. The height of the vault was at 1.10 m and a Jansen-Fritzen springboard was used. Flat markers (spherical markers of 0.02-m diameter attached to the skin using a black double adhesive tape [creating also a white-on-black contrast]) were applied on the right side of the subject to locate the joints centers of ankle, knee, and hip. The measurements were obtained from two phases: a) from the last stride (hurdle step) to upward spring, b) from the strike of the horse until lift in the opposite direction upwards. A video camera was used to demonstrate the whole movement, from the start of the run-up phase to the completion of handspring vault during landing.

The EG followed a technical preparation and muscular activity that was obtained via isokinetic training program.

The CG followed the same technical program and traditional program for muscular activity containing lower limb strengthening exercises, such as jumping with both feet, squat jumps and generally exercises traditionally used. The subjects participated in a 10-week-training program for three non-consecutive days per week, 2 hours per day. Previous investigations have clearly demonstrated that resistance training twice per week is sufficient to enhance the muscle strength and local muscle endurance in children (Faigenbaum, Kraemer, Cahill, Chandler, Dziados, Elfrink, et al, 1996).

The typical training session consisted of a warm-up and all-around training. The strength testing was performed between 6 – 9pm with the same investigators performing each test. Gymnasts concentrated on the handspring vault technique to achieve better technical performance. After the typical training, the gymnasts performed two trials of the handspring vault and those with the higher score were analyzed for further statistical analysis. The performance of each subject on handspring vault was evaluated according to the Code of Point by two international judges (FIG, 2016) and the mean score was the final score for the handspring vault.

Each subject was given a familiarization period before testing to learn the correct exercise technique on the testing equipment, to reduce the influence of any learning effects, and to become familiar with general strength-training guidelines on the Cybex-II, followed by a pre-test performance. The subject was positioned and stabilized for the knee extension/ flexion test. Back "spacer" pads were used, if necessary, to establish a trunk angle of 90". The input shaft of the dynamometer was aligned with the axis of rotation of the subject's knee. The shin pad attachment was placed one to two centimeters proximal to the subject's lateral malleolus. Stabilization straps were secured about the shin, thigh, pelvis, and upper torso to prevent extraneous joint movements. Subjects were instructed to fold their arms comfortably across their chest to further isolate knee joint flexion and extension movements. During each testing session, subjects were allowed sufficient practice at each speed to ensure forceful, coordinated movements. A minimum of three submaximal extension/flexion cycles were required of each subject at each velocity to ensure execution of the full range of motion for each movement. Further, all subjects performed 10 minutes of stretching exercises before all testing and training procedures. All testing procedures were closely supervised, and uniform encouragement was offered to all subjects. The test protocol required the subjects to perform fifteen repetitions (3 sets of 5 repetitions for each velocity with a five-minute break between sets with full range of motion) in knee extension/flexion movement pattern at 60° $sec^{-1}$ and it was repeated at 300° $sec^{-1}$, with both tests then performed on the contralateral limb. In the extension-flexion phase of the movement, the data collected relates to quadriceps and hamstring muscle activity respectively. The knee testing tables were used for testing the extension-flexion movement pattern at the knee joint. Subjects were given standardized instructions verbally and all were equally motivated by the tester to encourage maximum effort throughout the entire range of motion. Adequate test periods of five minutes were given between tests to ensure that the subjects' initial performance on each test was not affected by muscle fatigue.

The Statistical Package for the Social Sciences (SPSS) (Norusis, 1993), with repeated measures ANOVA, and t-parameter estimates as post hoc analysis were used (Grimm, 1993; Tabachnick, and Fiddell, 1996). Specifically, a 2 x 2 x 2 ANOVA examined the interaction effect of group (independent groups factor, with experimental and control groups), time (repeated measures factor, with pre and

post test), and side (repeated measures factor, with left and right), with respect to the knee extension at 60°/sec and 300°/sec. Further, partial eta squared was computed as a measure of effect size. Significance was tested at the .05 level.

## RESULTS

The interaction between group (EG vs CG) and time (pre-post test) with respect to the gymnastic score on handspring vault was examined. No significant interaction was found ($F = .032$, $p = .859$, $n^2 = .002$) and no significant effect for the group factor ($F = 1.889$, $p = .185$, $n^2 = .095$). Significant main effect was found for the time ($F = 7.310$, $p = .015$, $n^2 = 2.89$) and examination of the mean score revealed that the participants had a significantly higher mean score in post-test compared to pre-test. The performance score of the two groups in regards to the vaulting techniques were 6.73 ± 0.46 and 6.98 ± 0.43 in pre-test, and 6.80 ± 0.40 and 7.06 ± 0.37 in post-test for the experimental and the control group, respectively. The temporal parameters of the handspring vault are presented in Table 2.

Table 2
*Temporal parameters on handspring vault.*

| | PRE | | POST | |
|---|---|---|---|---|
| | EG | CG | EG | CG |
| Board support | 0.13 ± 0.01 | 0.13 ± 0.01 | 0.13 ± 0.01 | 0.13 ± 0.01 |
| 1st flight phase | 0.32 ± 0.03 | 0.33 ± 0.02 | 0.31 ± 0.02 | 0.33 ± 0.03 |
| Hand support | 0.36 ± 0.03 | 0.37 ± 0.02 | 0.35 ± 0.03 | 0.36 ± 0.03 |
| 2nd flight phase | 0.47 ± 0.02 | 0.46 ± 0.01 | 0.48 ± 0.03 | 0.45 ± 0.03 |

Table 3
*Descriptive data on peak torque of knee joint (Nm) (Standard deviation are presented in parentheses).*

| | | Flexion | | | | Extension | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 60º | | 300º | | 60º | | 300º | |
| | | Pre | Post | Pre | Post | Pre | Post | Pre | Post |
| EG | RF | 28.30 | 32.20 | 15.90 | 19.30 | 40.80 | 48.30 | 11.40 | 12.10 |
| | | (4.54) | (3.96) | (2.37) | (3.05) | (3.61) | (3.30) | (1.83) | (1.52) |
| | LF | 26.20 | 29.20 | 13.60 | 16.00 | 38.90 | 45.50 | 12.78 | 13.00 |
| | | (5.05) | (4.30) | (2.36) | (2.53) | (4.30) | (4.62) | (2.78) | (2.86) |
| CG | RF | 28.60 | 32.60 | 15.20 | 12.60 | 37.70 | 40.80 | 10.90 | 11.60 |
| | | (9.51) | (12.17) | (4.75) | (3.71) | (11.28) | (8.27) | (4.94) | (1.83) |
| | LF | 26.70 | 21.80 | 13.70 | 12.10 | 40.10 | 42.90 | 11.10 | 12.30 |
| | | (7.49) | (4.87) | (6.25) | (2.46) | (11.73) | (4.97) | (3.57) | (2.11) |

EG: Experimental group; CG: Control group; RF: Right foot; LF: Left foot

The interaction effect among group (EG - CG), time (pre - post), and side (left-right) with respect to the knee extension at 60°/sec was examined. No significant interaction effect among the three independent variables was found (F = .013, p = .912, $n^2$ = .001). The interaction effect of side by group (F = 2.209, p = .155, $n^2$ = .109) and time by side (F = .050, p = .825, $n^2$ = .003) were not significant either. However, the interaction effect of time by group approached significance (F = 3.893, p = .064, $n^2$ = .178), and the t-parameter estimates were examined accordingly as a post hoc analysis. For pre-test, no significant differences were found between the two groups (t =. -827, p = .419, $n^2$ = .037). In post-test, however, the results were significant (t = -2.663, p = .016, $n^2$ = .283) and examination of the mean values revealed that the EG had a significantly higher mean values compared to the CG in the post-test (Table 3).

The interaction among time (pre-test – post-test), side (left-right), group (experimental-control) with respect to the knee extension at 300°/sec was not significant (F = .481, p = .497, $n^2$ = .026). Accordingly, no other significant interaction (side X group, time X group, time X side) or main effect (time, side or group) was found (Table 3). Therefore, no post hoc analysis was obtained.

The interaction time by side by group with respect to the knee flexion at 60° was not significant (F = 2.626, p = .123, $n^2$ = .127). The interaction between time by side was significant (F = 3.940, p = .063, $n^2$ = .180).

The interaction among time (pre-post), side (left-right), and group (EG - CG) with respect to the knee flexion at 300°/sec was not significant (F = 3.396, p = .082, $n^2$ = .159). However, the interaction between side by group was significant (F = 7.999, p = .011, $n^2$ = .308) and the t-parameter estimates were examined in a post hoc analysis. Specifically, no significant differences between the two group were found with respect to the flexion scores on the left knee (t= -1.395, p = .180). However, significant differences between the two groups were found with respect to the right knee values (t = -2.706, p = .014). Examinations of the mean values revealed that the EG had a significantly higher mean value in the right knee than the CG, while no significant differences were evident between the two groups in the left knee.

## DISCUSSION

This study examined the effects of 10-week isokinetic training on muscle strength and gymnastic performance in preadolescent female gymnast. The main finding was that both groups showed higher performance scores, but this difference was not significant between the two sets of measurements (pre- vs post-test). Another finding was that the knee strength at 60°/sec improved significantly in the EG after the 10-week intervention program in contrast to the CG that showed no significant improvement. Furthermore, the CG showed a significant reduction during knee flexion at both velocities which can be attributed to the type of training that was followed and which may not have been adequate exercise for the flexor knee muscles. Accordingly, the knee strength at 300°/sec revealed any significant improvement between these two measurements in neither group. However, it is well documented that one of the factors that influence performance score is springboard take-off velocity (Bradshaw, Hume, Calton, and Aisbett, 2010). The fact that no significant improvement was shown in knee strength at 300°/sec is one of the reasons why both groups failed to affect the take-off phase from springboard due to the fast duration of this phase.

Our results are in agreement with previous data that confirm the effectiveness of isokinetic training to improve muscular strength in healthy subjects (Ahmed et al, 2011) and trained

athletes (Zebrowska, Zajac, Poprzecki, and Waligóra, 2005), and verify findings of Pienaar & Van der Walt (1988) and Douda et al. (1997) which stated that young gymnasts improved vertical jumping performance and explosive strength of lower limbs after a specialized training program. In addition, results of the present study agree with data of Faigenbaum and his colleagues (1996; 2001) that showed a significant improvement in muscular strength after an extensive period of practice. However, the results of the present study are opposed to those of Seger and Thorstenson which indicate that strength adaptations are specific to different sports and that athlete's specialization and training determine the muscle groups where the adaptations occur (Seger and Thorstenson, 2000). The correct performance of handspring vault requires the correct body position during various phases of the vault and sufficient explosive power and speed in the lower limb musculature in order to fulfil body rotation whilst maintaining body control (Marina, and Jemni, 2014). Furthermore, practicing under isokinetic training, an enhancement will be achieved in the knee muscle strength that may influence the balance of joint function (Gioftsidou, Ispirlidis, Pafis, Malliou, Bikos, and Godolias, 2008). Nevertheless, our findings support the view that both training modalities (isokinetic and traditional training) are equally effective in artistic gymnastics concerning the lower limbs strength.

However, isokinetic exercises have several advantages over other exercise modalities, such as: (i) that a muscle group may be exercised to its maximum potential throughout a joint's entire range of motion; (ii) it provides a safer alternative to other exercise modalities. Isokinetic training is safer than isotonic training because the dynamometer's resistance mechanism essentially disengages when pain or discomfort is experienced by the athlete; it is, however, not representative in the case of pushing the springboard where the push is made by both feet together. More specifically, isokinetic training may be used to quantify a muscle group's ability to generate torque or force, and it is also useful as an exercise modality in the restoration of a muscle group's pre-injury level of strength (Rochcongar, 2004). In addition, isokinetic training in preadolescent females does not generate fatigue from repeated isokinetic muscle actions (De Ste Croix, Deighan, Ratel, and Armstrong, 2009). Certain limitations, however, do not allow for generalization of the present findings. First, these findings may not be applicable to high level gymnasts or other categories of athletes or male athletes (De Ste Croix, Deighan, Ratel, and Armstrong, 2009). Further, other factors such as run-up velocity or upper arm strength that have not been examined in our study may influence the performance score.

## CONCLUSION

This study investigated the effect of isokinetic training program on muscle strength and gymnastic performance in preadolescent female gymnast. However, handspring vault requires both technical skill and power production to achieve success. The 10-week isokinetic training that was added to the traditional training improved the knee strength, which consequently improved aspects of the vault, but did not affect other technical aspects of the handspring performance. However, further research should aim to examine whether the incorporation of additional specific exercises, such as sprinting or jumping movements, may have positive influence on the performance score. The results of our study confirm that optimal performance is the result of a complex interaction of several factors.

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Article received: 3.1.2021
Article accepted: 23.7.2021

# STRENGTH AND JUMPING ASYMMETRIES IN GYMNAST AND THEIR NON-GYMNAST PEERS

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*Original article* *DOI:10.52165/sgj.13.3.411-424*

***Abstract***

*While many studies investigated inter-limb asymmetries (ILAs) in different athletes, little is known about ILAs in the population of gymnasts. The first aim of our study was to compare differences between gymnasts and their non-gymnast peers in isometric knee maximal and rapid strength parameters (peak torque - PT and rate of torque development - RTD) and countermovement jump (CMJ) parameters (height, maximal force), as well as in ILAs in all outcome measures. The second aim of the study was to assess the relationship between ILA of maximal force and the ILAs of the isometric knee strength parameters. 15 gymnasts (aged 11.19 ± 1.89 years) and 15 non-gymnasts (aged 10.92 ± 1.96 years) performed unilateral isometric maximal voluntary contractions of the knee flexors and extensors on a dynamometer and CMJ on a force plate. ILAs were calculated and compared between groups across all outcome measures. We found that gymnasts reached statistically significant better results than non-gymnasts in most isometric knee strength parameters and CMJ height, but not on RTD of left knee flexion and maximal force in the CMJ. Meanwhile, we did not find significant differences between groups in ILAs. Linear regression showed no correlations between the ILAs measures separately for the groups. Even though we did not find any differences between the groups in the ILAs, we should be aware of it to prevent injury in young girls.*

***Keywords***: *isometric knee strength, countermovement jump, artistic gymnastics.*

## INTRODUCTION

Artistic gymnastics is characterized by early inclusion and consequently early specialization, with the goal of competing at an elite level (Caine et al., 2003). Therefore, the training routine of gymnasts lasts between 16 to 30 hours (Buckner, Bacon & Bishop, 2017; Caine et al., 2003, 2008; Frutuoso, Diefenthaeler, Vaz & Freitas, 2016; Hart, Meehan, Bae, D`Hemecourt & Stracciolini, 2018) and even up to 40 hours per week (Caine et al., 2003; Edouard et al., 2018; Frutuoso et al., 2016; Hart et al., 2018). Such exposure to a large number of training hours and high level of gymnastics are associated with an increased incidence of injury (Edouard, Steffen, Junge & Engebretsen, 2018; O'Kane, Steffen, Junge & Engebretsen, 2011; Saluan, Styron, Ackley, Prinzbach & Billow, 2015; Seegmiller & McCaw, 2003). The injuries in female gymnasts most commonly occur at the lower extremities, particularly at the ankle and at the knee (Kirialanis et al., 2002; Kirialanis,

Malliou, Beneka & Giannacopoulos, 2003; O'Kane et al., 2011; Seegmiller & Mccaw, 2003; Slater, Campbell, Smith & Straker, 2015; Sweeney, 2020). Most studies report these injuries occur during landing/jumping (Moresi, Bradshaw, Thomas, Greene & Braybon 2013; Seegmiller & Mccaw, 2003; Slater et al., 2015).

Imbalances (e.g., during movement) and body asymmetries can lead to injury risk. Asymmetries can be present between agonist and antagonist muscles, or between sides of the body (i.e., the inter-limb asymmetries (ILAs) (Keelley, Plummer & Oliver, 2011). ILAs can be calculated as the difference between stronger and weaker, dominant and non-dominant, right and left, or injured and non-injured limbs. ILAs > 15% have been found to place the athletes at higher risk of injury compared to those who have less than 15% of ILAs (Croisier, 2004; Kabacinski, Murawa, Mackala & Dworak, 2018; Knapik, Bauman, Jones & Harris, 1991; Murphy, Connolly & Beynnon, 2003). Meanwhile, Lilley, Bradshaw & Rice (2007) suggested that ILAs > 10% already pose a risk of injury to gymnasts.

When we talk about asymmetries, it is crucial to detect the risk of injury to gymnasts. Due to the large number of jumps/landings (Kirialanis et al., 2002), the tasks that are associated with most injuries in gymnastics, it is necessary to evaluate the strength and explosive qualities that are crucial in the context of gymnasts` physical abilities and fitness level (Impellizzeri, Rampini, Maffiuletti & Maroca, 2007; Michel, Monèm & Rodríguez, 2014; Moresi, et al., 2013). In recent years, detecting ILAs in athletes' populations to prevent lower extremity injuries has become a popular topic. For evaluating strength parameters, lower limb dynamometry is the most commonly used task (Smajla, Knezevic, Mirkov & Šarabon, 2020; Thompson, et al., 2013; Wilson & Murphy, 1996). Variables representing the strength profile and muscle strength deficit are peak torque (PT) and rate of torque development (RTD) obtained during maximal voluntary contraction (MVC). RTD is more relevant for the rapid strength production than PT, which is less a sensitive measure in the sports that include movement duration of less than ~ 100-200ms (Palmer et al., 2015; Šarabon, Kozinc, Bishop & Maffiuletti, 2020; Thompson, et al., 2013) and may also be useful to distinguish between athletes versus non-athletes. For detecting explosive power capacity (e.g., jumping performance), the countermovement jump (CMJ) is a widely used test in gymnastics (Dallas, Savvathi, Dallas & Maridaki, 2019; Donti, Tsolakis & Bogdanis, 2014; Marina & Torrado, 2013; Michel, Monem & Ferran, 2014; Pentidis, Mersmann, Bohm, Giannakou, Aggelousis & Arampatzis, 2019) and other sports (Bell, Sanfilippo, Binkley & Heiderscheit, 2014; Bencke, Damsgaard, Saekmose, Jørgensen, Jørgensen & Klausen, 2002; Bishop, Read, Chavda, Jarvis & Turner, 2019; Impellizzeri et al., 2007; Petrigna et al., 2019; Schons et al., 2019; Šarabon, Smajla, Maffiuletti & Bishop, 2020; Thompson et al., 2013;Young, Cormack & Crichton, 2011). Moreover, it is considered a reliable and valid test (Fernandez-Santos, Ruiz, Cohen, Gonzales-Montesion & Castro-Piñero, 2015; Marković, Dizdar, Jukić & Cardinale, 2004). CMJ is a vertical jump that can be performed in different ways, such as unilateral or bilateral, with arm swinging or held at the hip, or with additional loading (Young et al., 2011).

This study aimed: a) to compare differences in strength and power parameters between gymnasts and their non-gymnast peers, and b) to examine the relationship between CMJ ILAs parameters and knee isometric strength parameters (knee flexion and extension parameters - $T_{max}$, RTD), separately for the observed groups. Knee strength parameters and lower limb explosive power are important for performance and injury

prevention in gymnasts. Practitioners should be able to detect ILAs and provide interventions to reduce them if needed. It is useful to know whether ILAs in multi-joint movement are related to single-joint ILAs, both from the testing and the intervention perspective. The rationale for the comparison to the control group was to explore whether the selected ILA outcomes can be attributed to specific adaptations to gymnastic training or are present in young people in general.

## METHODS

Fifteen female artistic gymnastic athletes (age: 11.19 ± 1.89 years; height: 143.63 ±12.28 cm; weight: 37.25 ± 10.34 kg; BMI: 17.62 ± 2.40; training years 3.4 ± 1.8; weekly training hours: 22 ± 6) and 15 similar-aged female non-gymnast controls (10.92 ± 1.96 years; 146.71 ± 11.28 cm; 35.80 ± 11.03 kg; BMI: 16.36 ± 3.04) participated in the study. Inclusion criteria for our sample was age between 9 and 15 years. The main inclusion criteria for the non-gymnasts were a maximum of 2 hours of physical activity peer week and no skeletal, muscles, nerve or connective tissue injuries during the last 12 months. Inclusion criteria for the gymnasts were good physical health during the measurements and participation in the training process of one of the gymnastic clubs in Slovenia (e.g., SK Salto).

The study was conducted in accordance with the Declaration of Helsinki and the experiment was approved by the National Medical Ethics Committee of the Republic of Slovenia for research on children and adolescents, obtained on 23$^{th}$ of January 2018, (Approval No: 0120-631/2017/2). The subjects, their coaches and their parents/legal guardians were informed about the testing procedures and provided written informed consent prior to the study.

The study was performed in the laboratory of the Faculty of Health Sciences, University of Primorska. The test session lasted approximately 90 min per participant. The participants first completed a 6-min walk on a stepper, followed by dynamic stretches of the main muscle groups, and an activation exercise – 10 squats. The study consisted of five different sections: a) dynamometry of trunk, knee and ankle, b) lower limb passive range of motion assessments, c) handgrip and shoulder strength tests, d) jumps on a force plate, and e) dynamometry of hip. The order of the sections was randomly determined for each participant. In the present work we will consider measurements of isometric knee strength and CMJ on a force plate. Prior to the main measurements, participants underwent familiarization trials of each tasks (knee dynamometry and CMJ).

For the strength tests, the participants were seated in an isometric knee dynamometer (S2P, Science to Practice, Ltd., Ljubljana, Slovenia). The knee angle was set to 60° (0° = full extension) and the hips were set at 100° (0° = neutral position). Each participant was tightly fixed over the distal thigh and pelvis by a tight belt. The distal shin pad of the dynamometer was fixed with a strap 3–5 cm proximal to the medial malleolus. The seat position was individually adjusted and during the measurements, the participants were holding the hand grips along the seat (Figure 1). The participants were instructed to perform the tasks “as fast and as forcefully as possible” (Maffiuletti et al., 2016; Sleivert & Wenger, 1994) and to maintain the maximal effort for 3-5 sec. After the familiarization, the participants performed 3 maximal voluntary contractions (MVC) per task (flexion (FL) and 3 extensions (EX)) unilaterally, in a random order. The participants were loudly verbally encouraged throughout the trial in order to facilitate maximal effort. Between each trial on the same side, the participants rested for 30s, and for 60s when they needed to switch the leg. The rest interval was determined in accordance with previous studies (Harbo, Brincks &

Andersen, 2012; Koblbauer et al., 2011; Kozinc & Šarabon, 2020; Šarabon et al., 2020). We analysed both the maximal torque ($T_{max}$) and the rate of torque development (RTD) at 0-100ms time window. For all tasks the peak torque was determined as the maximum value in a 1-second interval. The outcome measures of isometric knee strength were normalized with the body weight of participants.

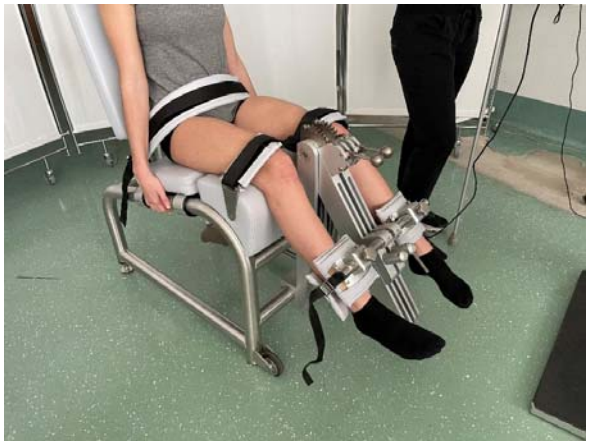

*Figure 1.* Participant in the isometric knee dynamometer.

The jumping tests were performed on a bilateral force plate (Kistler 3D, 9260AA, Winthertur, Switzerland). After familiarization trials, the participants performed 3 maximal countermovement jumps (CMJ). The rest between repetitions was at least 30 seconds. The participants were instructed to jump "as high as possible" and verbal encouragement was given to ensure maximal effort. The jump task was performed with the hands on the hips (Figure 2). The outcome measures were automatically calculated from the force-time data by the acquisition software (MARS, Kistler, Winthertur, Switzerland). The outcome measures that we included in the analysis were: a) jump height from take-off velocity, maximal force of the left leg, and maximal force of the right leg.

*Figure 2.* Position of the hands during vertical jump.

For all outcome measures of jumps (height, maximal force of the left leg – $F_{max}L$, maximal force of the right leg – $F_{max}R$) and isometric knee FL and EX strength ($T_{max}$ and RTD), the maximal value of the three trials for each task and each side was considered for calculating inter-limb asymmetry (ILA), using the equation:

$$\text{inter-limb asymmetry (\%)} = \left(\frac{\text{stronger} - \text{weeker limb}}{\text{stronger limb}}\right) \text{x } 100$$

Statistical analysis was conducted with IBM SPSS Statistic 26 (IBM, New York, USA). For all outcome measures we calculated descriptive statistics (mean value ± standard deviation, minimum and maximum value). We used the intraclass correlation coefficient (ICC) to test the intra-rater reliability of the strength and jump measurements, which reflects the variation of data measured by 1 rater. ICCs were interpreted according to Koo and Li (2016), where ICC >0.90 = excellent, 0.75–0.90 = good, 0.50–0.74 = moderate and <0.50 = poor. Before analysing the differences, we tested normality of distribution using the Shapiro-Wilk test. To determine the differences between gymnast and non-gymnasts in the strength

parameters of the knee and CMJ parameters, we used the t-test for independent samples for normally distributed parameters and Mann-Whitney U-test for the non-normally distributed parameters. To determine the effect size (ES) between the two observed groups (GG and NG), we used Hadges`g (i.e. corrected effect size) due to the small sample size (below 20). The associations between ILA outcomes were assessed with Pearson correlation coefficient which was interpreted as negligible (< 0.1), weak (0.1–0.4), moderate (0.4–0.7), strong (0.7–0.9) or very strong (> 0.9) (Akoglu, 2018). To investigate if the ILAs in single-joint strength outcomes could predict ILA in CMJ, we used a multiple linear regression, whereby the dependent variable was ILA of the maximal force during CMJ, while independent variables were those of the ILAs of the knee isometric strength (KFL $T_{max}$, KEX $T_{max}$, KFL RTD, KEX RTD). Significance level was set at $\alpha < 0.05$.

## RESULTS

From analysis of isometric knee strength, we excluded 1 participant from gymnasts due to the injury. Also, we excluded 1 participant from gymnasts (injury) and one non-gymnasts (incorrectly performed jump) from the analysis of CMJ. Note that we considered three measurements per participant that were included in the analysis of the reliability test, that demonstrated for the isometric knee outcomes and for the CMJ outcomes, good test reliability, with the confidence interval spanning from moderate to excellent (0.80; range = 0.65 - 0.95; 0.80; range = 0.67 - 0.98, respectively). Bogdanis et al. (2019) detect excellent ICC for the CMJ height of the young gymnasts (0.94).

Descriptive statistics and the differences between gymnasts and non-gymnasts in all outcome measures of the isometric knee strength and CMJ parameters are presented in Table 1. Statistically significant differences between groups ($p < 0.05$; ES = 0.94 – 1.19) were found in most of the isometric knee strength and in the height of the CMJ ($p = 0.02$; ES = 0.86), in favor of gymnasts. Meanwhile, there were no differences detected in the parameter of KFL RTD left ($p = 0.13$, ES = 0.56), and in the maximal force of left and right legs of the CMJ ($p > 0.05$; ES = 0.30 – 0.41).

Table 2 summarizes the differences between gymnast and non-gymnasts in the ILAs of the $T_{max}$ and RTD of the knee flexion and extension and of the maximal force obtained during CMJ. The results showed no statistically significant differences between the observed groups in the ILAs outcome measures.

The Pearson correlation was run to determine ILAs correlations of the knee isometric strength parameters and maximal force of CMJ. Table 3 demonstrates moderate, negative correlation only between $T_{max}$ of KFL and KEX, which was statistically significant ($r = - 0.471$, $n = 29$, $p = 0.01$). Meanwhile, there were no statistically significant correlations between other ILAs parameters.

Multiple linear regression was conducted to explain dependent variable, ILA of maximal force of the CMJ, with the independent variables of the ILAs of knee strength parameters (KFL and KEX $T_{max}$, KFL and KEX RTD), separately for the observed groups. The results showed that the single-joint ILA outcomes could not explain the ILA in CMJ, in none of the observed groups between parameters (G: $R = .290$, $F = .207$, $p = .928$ and NG: $R = .287$, $F = .179$, $p = .943$, respectively).

Table 1
*Differences between gymnast and non-gymnasts for all outcome measures normalized with the body weight.*

| | Outcome/task | Gymnasts (G) (N = 14) | | Non-gymnasts (NG) (N = 14) | | | |
|---|---|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD | P | ES |
| KFL | $T_{max}$ left (Nm/kg) | 1.19 | 0.26 | 0.94 | 0.22 | 0.01* | 0.99 |
| | $T_{max}$ right (Nm/kg) | 1.35 | 0.25 | 1.10 | 0.24 | 0.01* | 0.94 |
| | $RTD_{100}$ left (Nm/kg s) | 2.87 | 1.98 | 2.33 | 1.40 | 0.13 | 0.56 |
| | $RTD_{100}$ right (Nm/kg s) | 4.02 | 2.71 | 2.06 | 1.40 | 0.01* | 0.98 |
| KEX | $T_{max}$ left (Nm/kg) | 2.16 | 0.58 | 1.59 | 0.28 | 0.01* | 0.99 |
| | $T_{max}$ right (Nm/kg) | 2.21 | 0.47 | 1.73 | 0.30 | 0.01* | 1.00 |
| | $RTD_{100}$ left (Nm/kg s) | 8.09 | 4.56 | 3.70 | 1.85 | 0.005* | 1.11 |
| | $RTD_{100}$ right (Nm/kg s) | 8.51 | 3.95 | 4.16 | 2.69 | 0.003* | 1.19 |
| CMJ | Height (m) | 0.23 | 0.04 | 0.19 | 0.05 | 0.02* | 0.86 |
| | F left (% BW) | 117.66 | 11.19 | 122.02 | 16.15 | 0.41 | 0.30 |
| | F right (% BW) | 118.97 | 9.67 | 124.60 | 16.04 | 0.27 | 0.41 |

Note: KFL–knee flexors, KEX–knee extensors, CMJ–countermovement jump, $T_{max}$–maximal torque, RTD–rate of torque development, F–relative maximal force, BW–body weight, SD–standard deviation, ES–effect size (Hedges), * - $p < 0.05$, ** - $p < 0.001$

Table 2
*Differences in ILAs parameters between the gymnast and the non-gymnast group.*

| | ILAs | Gymnasts (G) (N = 14) | | Non-gymnasts (NG) (N = 14) | | | |
|---|---|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD | P | ES |
| KFL | $T_{max}$ | 13.52 | 8.16 | 17.15 | 10.21 | 0.31 | 0.38 |
| | RTD | 34.17 | 21.58 | 32.92 | 26.99 | 0.89 | 0.05 |
| KEX | $T_{max}$ | 14.59 | 9.23 | 11.74 | 7.63 | 0.38 | 0.33 |
| | RTD | 29.56 | 13.70 | 33.68 | 21.45 | 0.55 | 0.22 |
| CMJ | $F_{max}$ | 5.14 | 3.1 | 6.88 | 5.93 | 0.34 | 0.36 |

Note: KFL–knee flexors, KEX–knee extensors, CMJ–countermovement jump, ILAs–inter-limb asymmetries, $T_{max}$–maximal torque, RTD–rate of torque development, F–relative maximal force, SD–standard deviation, ES–effect size (Hedges), * - $p < 0.05$, ** - $p < 0.001$

Table 3
*Pearson correlation coefficient of the ILAs knee strength parameters and ILAs force of CMJ.*

| ILAs parameters | KFL–$T_{max}$ | KEX–$T_{max}$ | KFL–RTD | KEX–RTD | CMJ–F |
|---|---|---|---|---|---|
| KFL–$T_{max}$ | | | | | |
| KEX–$T_{max}$ | -.471** | | | | |
| | .010 | | | | |
| KFL–RTD | -.035 | -.321 | | | |
| | .856 | .089 | | | |
| KEX–RTD | -.026 | .037 | .288 | | |
| | .893 | .850 | .130 | | |
| CMJ–F | .057 | -.083 | .221 | .049 | |
| | .779 | .681 | .268 | .808 | |

Note: KFL–knee flexors, KEX–knee extensors, CMJ–countermovement jump, $T_{max}$–maximal torque, RTD–rate of force development, F–relative maximal force

## DISCUSSION

The purpose of the present study was twofold: a) to determine differences in isometric knee strength parameters and CMJ parameters between gymnasts and non-gymnasts, and b) to investigate the relationship between ILAs parameters of CMJ and isometric knee strength parameters (KFL $T_{max}$, KEX $T_{max}$, KFL RTD, KEX RTD), separately for the observed groups. The results showed statistically significant differences between the groups for most knee strength parameters and the height of the CMJ, but not for the maximal force of the CMJ. The results showed that there were no correlations in any of the observed parameters, separately for the groups.

To the best of our knowledge, there is no published study that has examined the differences in isometric knee strength between gymnasts and non-gymnasts. Our results showed that gymnasts had significantly higher peak torque (PT) and rate of torque development (RTD) of both legs during flexion and extension of isometric knee strength compared to their non-gymnast peers. One previous study examined the differences between female collegiate basketball players and gymnasts in PT and RTD of isometric knee strength normalized to participant body weight (Thompson et al., 2017), as we did in our analysis. In our study, gymnasts reached lower values of PT and RTD compared to the values of gymnasts in the Thompson et al. (2017) study. It is likely that the differences between the studies are due to the age of the participants, since our study included younger gymnasts (age 11.19 years; compared to 19.5 years of age). In addition, other researchers examining differences between elite athletes and control groups found that PT of knee extensors differed significantly between groups, but not in PT of knee flexors (Markström, Grip, Schelin & Häger, 2019), which partially contrasts with our study as it shows significant differences in both outcome measures. Adequate isometric knee strength provides the basis for the ability to perform many of the primary athletic tasks and prevent lower extremity injuries, particularly anterior cruciate ligament (ACL) injuries, which are more common in female athletes than male athletes (Hewett, Ford, Hoogenboom & Myer, 2010; Keelley et al., 2011; Thompson et al., 2017).

Our study also included force parameters and jump height of the CMJ. The study by Bencke et al. (2002) compared CMJ height between gymnasts, swimmers, handball and tennis players and a study by Bogdanis et al. (2019) compared CMJ height between gymnasts and a control group after the intervention. They found no significant differences in jump height between the observed groups, unlike the studies by Pentidis et al., (2019, 2020) that observed gymnasts and a control group of non-athletes, and the studies (Dallas, Kirialanis & Mellos, 2014; Dallas et al., 2019; Hall et al., 2016; Karagianni et al., 2020; Kinser et al., 2008) conducted on a gymnast and a control group after the intervention. The studies reported significant differences in jump height between the observed groups. Our results are consistent with the findings of previously mentioned studies, showing that gymnasts reached significantly higher jump heights than the control groups. Furthermore, the study by Ceroni, Martin, Delhumeau & Farpour-Lambert (2012), conducted on a large sample of female teenagers, found no significant differences between left and right peak force during CMJ. Since we did not find significant differences between the peak forces, our results could not be compared with the abovementioned study that was performed on non-athletes because they performed the single-leg CMJ, while we performed it with both legs.

Unfortunately, there are no published studies examining inter-limb asymmetries (ILAs) in young female gymnasts. Previous studies conducted on different

athletes with varying age and performance levels (Šarabon, Kozinc…, 2020; Šarabon, Smajla…, 2020) reported different results of ILAs from isometric knee strength measurements as we did. Our results showed slightly higher ILAs for parameters of isometric knee strength, while ILAs of maximal force of CMJ are slightly lower in comparison with the mentioned studies. It has to be noted that ILAs in RTD were very large (13.7-34.1 % in the gymnast group), compared to commonly suggested thresholds of 10-15 % for clinical relevance. However, it has been shown that the magnitude of the RTD ILAs is much larger than peak torque ILAs (Šarabon, Kozinc, et al., 2020), which means that the aforementioned magnitude of the threshold for clinical relevance should probably not be applied to RTD outcomes. Bilateral strength asymmetry calculated from CMJ and isometric knee strength measurements are highly reliable measures (Impellizzeri et al., 2007). In this study, correlations among knee isometric strength parameters and CMJ were present only between PT knee flexion and knee extension, unlike in the study of Impellizzeri et al. (2007) conducted on male athletes, which showed a moderate correlation coefficient between two tests (the isometric knee leg press and the CMJ). The results are in contrast with our findings, which demonstrated no significant correlation between the CMJ and the isometric knee tests. Different results of aforementioned studies can be explained by different knee tests (isometric knee leg press vs. our isometric knee extension/flexion test using dynamometry) and participant samples (older male athletes vs. our young female gymnasts). In contrast to the aforementioned study, Kozinc & Šarabon (2020) showed that most coefficients were small and not statistically significant. The choice for assessing each type of ILA should be based on previous evidence and the aim of the testing. For instance, ILAs in strength may be detrimental to jumping and kicking, and ILAs in jumping could be detrimental to agility (Bishop et al., 2018). In case of injury risk tracking, or making decision regarding return to support, both single-joint and multi-joint tasks are probably needed for comprehensive assessment (Kotsifaki et al., 2021). Together with findings from previous studies, our results suggest a largely independent nature of ILAs between multi-joint and single-joint tasks, and even within the tasks to some degree. Therefore, the practitioners cannot generalize ILAs across tasks, i.e., each task should be assessed separately.

There are a few important limitations of our study that we would like to highlight. The sample size was relatively small, but on the other hand, the groups were matched in sample size and age. The size of the sample could be the reason that some moderate differences (e.g., ES = 0.41 for the left leg force in CMJ) between the groups were not statistically confirmed. As for the differences in RTD, it has to be stressed that this metric has a very high between-participant variability, which also reduced the effect sizes and precluded confirming between-group differences. In addition, the biological maturation (Tanner stages) of the gymnasts was not examined, which could affect the results of the asymmetries, since it is known that the observed age of the participants is crucial for biological maturation. In the studies with observed isometric knee strength or CMJ parameters, the sample size varied but is comparable to our study (Bogdanis et al., 2019; Pentidis et al., 2019, 2020; Thompson et al., 2017), while other studies had larger sample sizes (Bencke et al., 2002; Ceroni et al., 2012; Hall et al., 2016; Karagianni et al., 2020; Kinser et al., 2008; Markström et al., 2019). However, the results showed good reliability for all observed parameters.

## CONCLUSIONS

This study examined differences in knee isometric strength and CMJ parameters and investigated correlations between ILAs of observed outcome measures between gymnasts and non-gymnast peers. The group of gymnasts showed superior performance in most knee flexion and all knee extension parameters, as well as in CMJ height, compared to the non-gymnast. The results of the ILAs showed that the gymnasts obtained ILAs of knee flexion and extension for the parameter maximal torque of less than 15%, while the group of non-gymnasts achieved for knee flexion 17%. Interestingly, the ILAs parameters were not statistically significantly different between the two groups. Nevertheless, we should be cautious and consider ILAs as an important factor for the prevention of injuries in gymnasts. It is already known that an adequate ration and ILAs of isometric knee strength below 15 % (Croisier, 2004; Kabacinski et al., 2018; Knapik et al., 1991; Murphy et al., 2003), and even below 10 % in gymnasts (Lilley et al., 2007), are crucial to prevent ACL injuries. Furthermore, there were no correlations in any of the knee strength parameters and maximal force of CMJ for each group. Therefore, whether in regard to injury risk or performance assessment, the practitioners cannot generalize ILAs across tasks, which means that each task should be assessed separately.

## ACKNOWLEDGEMENT

We would like to thank all participants, their parents or legal guardians and coaches of SK Salto that allowed us to performed project entitled “The Impact of Lifestyle on the Health of Young Athletes”. Also, our gratitude goes to the students who helped and realized the project that was supported by the European Social Fund Agency, the Public Scholarship, Development, Disability and Maintenance Fund of the Republic of Slovenia, and the Ministry of Education, Science and Sport for funding the student innovation project – ŠIPK. The Slovenian Research Agency provided author NS with support in the form of salary through the programme 'Kinesiology of monostructural, polystructural and conventional sports’ [P5-0147 (B)] and the project TELASI-PREVENT [L5-1845] (Body asymmetries as a risk factor in musculoskeletal injury development: studying aetiological mechanisms and designing corrective interventions for primary and tertiary preventive care).

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Article received: 7.7.2021
Article accepted: 18.8.2021

# THE RELATIONSHIP BETWEEN THE PERCENTAGE OF BODY FAT AND JUDGING IN GERMAN WHEEL GYMNASTICS

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*Original article* *DOI:10.52165/sgj.13.3.425-437*

***Abstract***

*In some sports which focus on aesthetic aspects, such as figure skating, gymnastics and dancing, there is a strong demand for athletes to be and look lean. This demand could lead to pressure on the athletes and cause health problems. It must be clarified whether this is also the case in wheel gymnastics. For this purpose, the percentage of body fat and competitive results of 203 wheel gymnasts (183 female, 20 male, age 21.2 ± 11.9 and 16.8 ± 4.9 respectively; body fat percentage 14.5 ± 3.4 and 8.0 ± 3.7 respectively) were assessed cross-sectionally and tested for correlation between the percentage of body fat and competitive results. Furthermore, their body fat percentage was compared to that of athletes from other aesthetic sports, and it was investigated whether judges might be influenced by percentage of body fat. For this purpose, technical difficulties in training and competition were compared for gymnasts with different percentages of body fat, at the same time taking into account the rating of judges` performance as perceived the gymnasts and their satisfaction with their results. The difference between the technical difficulty during training and competition correlates positively with the body fat percentage ($p \leq .010$, $r = .268$). Gymnasts who are a) not content with judges' ratings; b) content with their own performance, and c) have a higher percentage of body fat, significantly differed from gymnasts where fewer than three of these parameters were true regarding deductions for technical difficulty ($p \leq .000$, $\eta^2 = .323$).*

***Keywords***: *wheel gymnastics, body fat percentage, judges, competitive results.*

## INTRODUCTION

Wheel gymnastics originated in Germany in 1925 when Otto Feick built a two-rimmed wheel in which a person can stand while the wheel itself is moving (Sebesta, 2002). In current wheel gymnastics, there are four different disciplines: vault, straight line with/ without music, spiral and, more recently, cyr (Kauther, Rummel, Hussmann, Lendemans, Wedemeyer & Jaeger, 2015). In wheel gymnastics, points for overall merit are given to the athlete as a sum of points for composition, technical difficulty, and execution. The points earned for technical difficulty and composition of a routine are added to the remainder of the execution value. Deductions for the execution value are made if the athlete performs a movement technically correctly but inaccurately (Deutscher Turner-Bund (DTB), 2008). Literature states that wheel gymnastic disciplines demand strength, endurance, flexibility as well as core, explosive and jumping strength,

coordination of movement, concentration, emotional control, perception, stress resistance and self-esteem, as well as aesthetic expression (Hundrieser, 2012; Weyermann, 2016).

Mies (1994) states that wheel gymnastics can be counted among the aesthetic sports, that require, according to Potter, Lavery and Bell (1996), athletes to look slim. In aesthetic sports, such as artistic and rhythmic gymnastics, performance is related to thinnessand BMI or percentage of body fat (Harris & Greco, 1990; Claessens, Lefevre, Beunen & Malina, 1999; Avilla-Carvalho, Klentrou, da Luz Palomero & Lebre, 2013; Bacciotti, Baxter-Jones, Gaya & Maia, 2017) for female athletes, and this can apply to male athletes as well (Gurd & Klentrou, 2003).

Athletes in aesthetic sports display lower body fat values than non-athletes or athletes from other sports (Georgopoulos, Markou, Theodoropoulou, Bernadot, Leglise & Vagenakis, 2002; Parm, Saar, Pärna, Jürimäe, Maasalu, Neissaar & Jürimäae, 2011; Galetta, Franzoni, D'Alessandro, Piazza, Tocchini, Fallahi et al., 2015). Bacciotti et al. (2018) suggested that gymnasts should be selected according to the typical physical prototype. This view, however, must be contested, as the human body changes during puberty (Matthys, 2012) and a selection decision based on these factors may not be valid for long. Psychological factors may also be a valid criterion for selection (Gonçalves, Rama & Figueiredo, 2012; Moesch, Hauge & Wiekmann, 2013). The question is whether sports clubs should select athletes according to what judges like, and whether judges should judge performance rather than physical appearance.

This leads to the question whether wheel gymnastics as an aesthetic sport is subject to the same restrictions as, e. g., rhythmic (D'Alessandro, Morelli, Evangelisti, Galetta, Franzoni, Lazzeri, Piazza & Cupisti, 2007) and artistic gymnastics (Bacciotti et al., 2017; Bacciotti et al., 2018), dancing (Potter et al., 1996) and figure skating (Jonnalagadda, Ziegler & Nelson, 2004, amongst others) when it comes to the aesthetic aspects of the athlete. In the abovementioned disciplines, athletes are required to look lean in order to achieve reasonable competitive results; there is a proven connection between the aesthetic aspect and competitive results (Bacciotti et al., 2017; Bacciotti, Baxter-Jones, Gaya & Maia, 2018). Athletes in several gymnastic disciplines display low body fat percentages (see Supplementary Table).

So far, there has been no scientifically based study to determine whether wheel gymnastics should be counted among aesthetic sports. While Samuelsen (2003) claims that anthropometric factors are irrelevant for performance in wheel gymnastics because the wheels come in different sizes, Rummel (2016) names BMI as relevant for wheel gymnastics and claims that it is comparable to that in ski-jumping, where body weight is a performance-limiting factor due to its biomechanical aspects (Müller, Groschl, Müller & Sudi, 2006). Female gymnasts show a lower BMI than males and female wheel gymnasts's BMIs are in the lowest percentile within the German population (Kromeyer-Hauschild, Wabitsch, Kunze, Geller, Geiß, Hesse et al., 2001). Some gymnasts' BMI is below the z-scores recommended by the World Health Organization (De Onis, Onyango, Borghi, Syiam, Nishida & Siekmann, 2007). Low BMI is mostly prevalent in amateur wheel gymnasts according to Rummel (2016).

When considering aesthetic sports, athletes with a lower percentage of body fat show better competitive results in gymnastics (Vandorpe, Vandendriessche, Vaeyens, Pion, Lefevre, Philippaerts et al., 2011) and it is possible that too much value is attributed to thinness. Schek (2001, p. 22) calls this phenomenon "*anorexia athletica".* If judges are subconsciously influenced by the gymnasts' appearance, this could result in biased judging. According to Plessner &

Haar (2006), sports performance judgements are prone to bias. Findlay & Ste-Marie (2004) state that in figure skating expectations of the judges can show in the ratings. According to the authors, judges might, for example, associate low body fat percentage with a higher motivation for extensive practice and discipline and award marks accordingly, thus judging not the performance but the psychological characteristics supposedly displayed by the physical appearance of the gymnasts. It has to be stated that judging bias is present in gymnastic disciplines in relation to several factors, e. g., team order (Plessner, 1999, amongst others) and nationality (Leskošek., Čuk, Pajek, Forbes & Bučar-Pajek, 2012, amongst others); the percentage of body fat might also be one of them.

This probably also extends to younger athletes and might create a certain pressure: young athletes, not only from aesthetic sports, display a lower percentage of body fat than non-athletes (Granacher & Borde, 2017), which can lead to young athletes being underweight (Stokić, Srdić & Barak, 2005; Camargo, Gomez-Campos, Cossio-Bolaños, Barbeta, Arruda & Guerra-Junior, 2014), dissatisfied with their body image (Borrione, Battaglia, Fiorilli, Moffa, Tsopani, Piazza et al., 2013; de Oliveira, de Oliveira, de Pinho Gonçalves, Valentim Silva, Roquetti Fernandes & Fernandes Filho, 2017) and/ or developing other health-problems in order to achieve better results in competition. Their potential issues include pathologic eating behaviour (Schwidergall, Weimann, Witzel, Mölenkamp, Brehl & Böles, 1998), which can lead to amenorrhoea or malnutrition (Schek, 2001; Klentrou & Plyley, 2003; Schevchenko, Abramov, Gibson & Omar, 2008), delayed pubertal development and growth (Bayo, 2001), anorexia and bulimia. Athletes in aesthetic sports are at a higher risk of developing eating disorders than athletes in other fields, as found in a literature review by Schek (2001). In addition to creating pressure, the need to look thin can also cause an early dropout of promising athletes (Schek, 2001). A literature review shows that the body fat percentage of wheel gymnasts is similar to that of athletes in other aesthetic sports (see supplementary material.

These findings suggest that an overrating of the aesthetic aspect of athletes could be present in wheel gymnastics as well, and can thus endanger healthy development of young competitors. It is true that some athletes might receive low marks because they are overweight and technically not capable of performing difficult elements, but at the same time it is also possible that low marks are given due to the aesthetic aspect despite a flawless technical performance. If an overrating of aesthetic aspects takes place in wheel gymnastics, athletes and especially young athletes must be protected.

The main question whether judges rate gymnasts according to their body fat percentage and therefore whether wheel gymnastics has to be viewed as an aesthetic sport will be answered by researching the following, more detailed questions:

1. Is there a connection between body fat percentage and differences regarding deductions forplanned difficulty in the straight line discipline (correlation)?

2. Does body fat percentage differ significantly between athletes with varying deductions for planned difficulty in the straight line discipline (one-way ANOVA)?

3. Are there differences in the judging for athletes with different percentages of body fat performing in the straight line discipline (three-way ANOVA)?

The following hypotheses are examined: It is possible that judges are too strongly taking into account the physical appearance of wheel-gymnasts which might show in a) unjustified deductions for technical difficulty for less slim gymnasts

(gymnasts with a higher percentage of body fat might perform the difficulty safely during training, but are not given marks accordingly during competition even though they demonstrate the difficulty elements); b) a positive correlation between difficulty safely performed during training and difficulty earned during competition and percentage of body fat, and c) differences in judging for athletes with different percentages of body fat.

## METHODS

Measurements included 203 voluntary participants of the German Gymnastics Federation (Deutscher Turner-Bund/ DTB), section gym wheel. Informed consent was obtained from all participants. The age ranged from 6 to 58 for female (N = 178, age average = 21.17 ± 11.91) and from 7 to 27 for male (N = 20, age average = 16.84 ± 4.90) gymnasts.

Skinfolds were recorded using a calliper. Competitive results, performance during training, evaluation of a recent competition performance, gender, age, and competitive level were obtained using a specially developed questionnaire. All values were recorded at major national competitions in 2018.

Body fat percentage was calculated using the Siri equation (1956) for calculating body fat using three skinfolds for female gymnasts (Jackson, Pollock & Ward, 1980). For male gymnasts, Siri (1956) and Jackson & Pollock (1978) equations were used to calculate percentage of body fat using three skinfolds and two circumferences. Due to different compositions of body tissue, female and male athletes require individual calculation methods (Jackson & Pollock, 1978; Jackson et al., 1980. Due to different compositions of body tissue, female and male athletes require individual calculation methods (Jackson & Pollock, 1978; Jackson et al., 1980).

Percentage of body fat was calculated with $\%\_Bodyfat = (4.95 / Body\ density) - 4.5$ (Siri, 1956). Body density was calculated with $Body\ density = 1.096095 – 0.0006952 * sf\_tri + sf\_abd + sf\_sup + sf\_thigh) + 0.0000011 * (sf\_tri + sf\_abd + sf\_sup + sf\_thigh)^2 – 0.0000714 * age$ for female gymnasts (Jackson, Pollock & Ward, 1980), using age in years and four skinfolds, where sf = skinfold, tri = triceps, abd = abdominal, sup = suprailiacal and thigh = directly above the knee. Body density for male gymnasts was calculated with $Body\ density = 1.15737 – 0.02288 * ln(sf\_pect + sf\_abd + sf\_thigh) – 0.00019 * age – 0.0075 * c\_nav + 0.223 * c\_arm$ (Jackson & Pollock, 1978), using age in years, two skinfolds and two circumferences, where sf = skinfold, pect = pectoralis, abd = abdominal, c_nav = circumference at navel height and c_ arm = highest circumference of the lower arm.

There was a significant difference in percentage of body fat for male and female gymnasts (female: % body fat average = 14.54 ± 3.4; male: % body fat average = 8.00 ± 3.74) which is in accordance with earlier findings (see Table 3). Since there were not enough male gymnasts, the results for them were not evaluated further except for a short comparison to previous studies.

Since the sample displays a broad age-range, it was necessary to rule out any age effects. Age did not correlate in any way with deductions for difficulty or overall merit. There was no age-related difference in athletes who were content or not content with judges' ratings or their own performance. No difference in age was found between athletes who were in the highest quartile of body fat percentage, were content with their own performance, not content with the ratings and had deductions for difficulty, and all other athletes.

The questionnaire asked for age, gender, straight line difficulty (technical merit) achieved during training, straight line difficulty achieved at the recent

competition, self-rating of own performance at the recent competition and rating of the judges` performance who judged the athlete. The difficulty difference or planned difficulty was calculated as the difference between technical difficulty achieved during training minus technical difficulty achieved during competition. In German competitive wheel gymnastics, athletes are required to hand in a difficulty card before competition, stating what difficulty they were able to perform during training and are therefore intending to perform in competition. Usually, gymnasts hand in cards that show which difficulty was safely performed during training. Cards are prepared in cooperation with the coaches and it is a common practice to compose the card realistically. For this study, values from those difficulty cards were used to calculate the difference between difficulty safely performed during training and difficulty earned during competition.

To answer the first research question, correlations between the difference in technical difficulty during training and in competition (difficulty difference = difficulty_training – difficulty_competition) on the one hand and body fat percentage on the other hand were calculated via Spearman correlation with correlation levels >0.1 (weak), >0.3 (moderate) and >0.5 (strong).

To address the second research question, age controlled one-way ANOVA was performed for:

Testing for differences in body fat percentage between athletes who earned lower difficulty scores during competition than during training and athletes who received the same technical difficulty during both training and competition.

Testing for differences regarding deductions for planned technical difficulty between those in the quartile with highest percentage of body fat and those in the lower three quartiles.

To address the third research question, age controlled three-way ANOVA was performed for:

Testing for differences in the dependent factor “deduction to planned difficulty” using the following independent factors: “not content with judging performance”, “content with own performance” and “ranked within the quartile with the highest percentage of body fat”.

Finally, to address the third research question, age controlled one-way ANOVA was performed for:

Testing for differences between athletes who had different deductions for planned difficulty and discrepancies in the levels of satisfaction with the judges’ and their own performance.

The criterion level for significance was set at $p<0.05$ and the trend significance at $p<0.10$. The effect size was evaluated with $\eta^2$ (Eta partial squared), where $0.01<\eta^2<0.06$ constitutes a small effect, $0.06<\eta^2<0.14$ constitutes a medium effect and $\eta^2>0.14$ constitutes a large effect (Cohen, 1988).

Representativity was calculated according to Rinne (2008) with confidence interval 95% and delta_max = 3.45%. The tester had a retest-reliability of Cronbach’s alpha = 0.987 for the measurement of skin folds.

Statistical analysis was performed in SPSS, version 25 (SPSS, Inc., Chicago, IL).

## RESULTS

Regarding research question 1, there was a weak correlation for the difference in technical difficulty during training and competition (difficulty difference) and percentage of body fat ($r = .268$; $p < .010$, Figure 1), while elimination of one outlier with more than 25% of body fat did not change significancy nor correlation level.

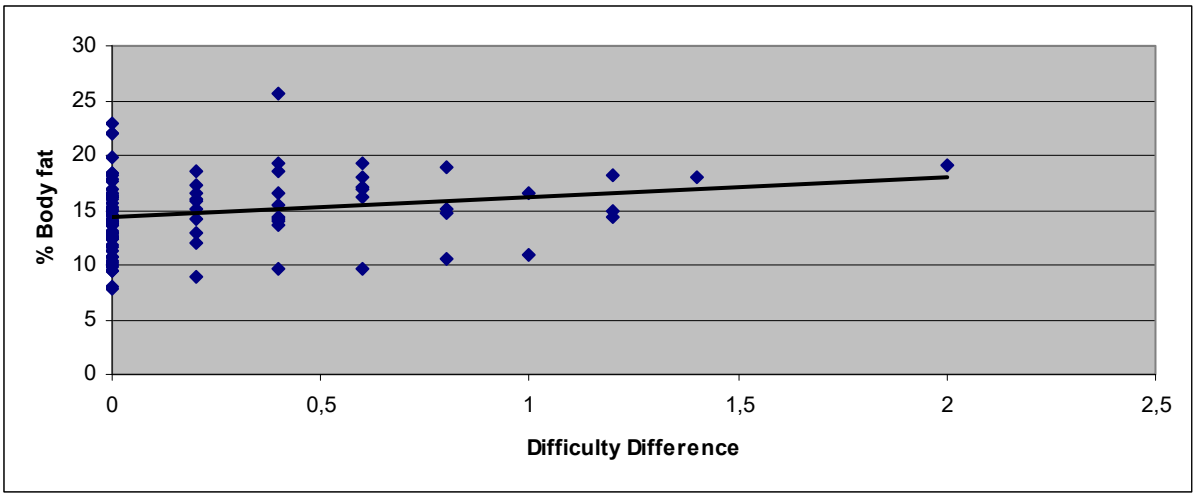


*Figure 1.* Correlation between deductions for planned difficulty and percent body fat.

Table 1
*Differences regarding percentage ofbody fat in respect of deductions for difficulty and deduction for difficulty for athletes in different quartiles body fat percentage.*

| Differences | N | $X \pm SD$ | $p$ | $\eta^2$ |
|---|---|---|---|---|
| % Body fat by deduction for difficulty for female athletes | 35 | 15.55 ± 3.41 | 0.050 | 0.066 |
| (deduction vs. no deduction) | 56 | 14.08 ± 3.28 | | |
| Deduction for difficulty by % of body fat for female athletes* | 25 | 0.40 ± 0.51 | 0.035 | 0.077 |
| (highest quartile vs. other quartiles*) | 62 | 0.17 ± 0.31 | | |

* Limits at 12.48, 14.41 and 16.47 %

Table 2
*Differences regarding deduction for difficulty in respect of percentage of body fat, judges' rating and performance self-evaluation.*

| Differences | N | $X \pm SD$ | $p$ | $\eta^2$ |
|---|---|---|---|---|
| Deduction for planned difficulty for gymnasts | | | | |
| "Not content with judges, content with own performance, in the highest quartile of body fat %" | 4 | 0.67 ± 1.15 | | |
| | | | 0.000 | 0.323 |
| vs. | | | | |
| "Not content with judges, content with own performance, not in the highest quartile of body fat %" | 3 | 0.10 ± 0.12 | | |
| Descriptive statistics (percentage of body fat) | | | | |
| In the highest quartile of body fat percentage | 44 | 18.96 ± 2.26 | | |
| In the lower three quartiles of body fat percentage | 133 | 16.45 ± 2.24 | | |
| Not content with judges, content with performance, deduction for planned difficulty (all true) | 4 | 15.67 ± 2.89 | | |
| Two or less of the above true | 87 | 14.65 ± 3.42 | | |

Table 3
*Percentage of body fat in relation to rating of judging/ performance and deduction for planned difficulty.*

| Ratings/ Difference | N | $X \pm SD$ |
|---|---|---|
| Judges ok, performance not ok, no deduction | 8 | 12.73 ± 3.18 |
| Judges not ok, performance not ok, deduction | 4 | 13.70 ± 2.11 |
| Judges ok, performance ok, no deduction | 41 | 14.14 ± 3.14 |
| Judges not ok, performance ok, deduction | 3 | 15.64 ± 3.53 |
| Judges ok, performance not ok, deduction | 15 | 15.73 ± 2.73 |
| Judges ok, performance ok, deduction | 12 | 15.99 ± 4.64 |
| Judges not ok, performance ok, no deduction | 4 | 16.86 ± 4.20 |

Judges ok/not ok: Gymnast was content/not content with difficulty ratings;
Performance ok/not ok: Gymnast was content/not content with own performance regarding technical difficulty;
Deduction/no deduction: Difficulty was not rated as planned/difficulty was rated as planned

When considering research question 2, the differences in percentages of body fat between athletes with or without deduction for planned difficulty is present in our sample (Table 1). Values differ significantly between athletes with higher and lower body fat in deductions for planned difficulty. Athletes received higher deductions for their planned difficulty when they had a higher percentage of body fat, as indicated by the ANOVA testing for differences in the amount of difficulty points lost when comparing training and competition within the highest quartile and the three lower quartiles (Table 1).

For research question 3, athletes, who at the same time a) were pleased with their own performance, b) did not agree with the rating of the judges and c) displayed a higher percentage of body fat, received a significantly higher deductions for planned difficulty compared to athletes who were dissatisfied with ratings but satisfied with their own performance and not in the highest quartile of body fat percentage. However, it has to be stated that due to further dividing into subgroups in the three-way ANOVA the, sample size for these two subgroups is quite small (Table 2).

Additionally, it is apparent that athletes with different levels of satisfaction with their own and the judges` performance as well as different deductions for difficulty scores showed characteristic percentages of body fat, but only by trend ($p < .072$; $\eta^2 = .148$, Table 3).

## DISCUSSION

The correlation between deduction for planned difficulty and body fat percentage suggests that judges may have deducted more difficulty points from less slim gymnasts (Figure 1). Judges may be biased against athletes with higher percentage of body fat, as has already been shown that they are prone to bias in terms of other factors, e. g., team order (Plessner, 1999) or nationality (Leskošek et al., 2012).

The results in Table 1 also lead to the assumption that judges could have been influenced by the physical appearance of the athletes, since they deducted more difficulty points from athletes with a higher percentage of body fat.

Furthermore, results in Table 2 suggest that athletes with a higher percentage of body fat were subject to higher deductions for difficulty despite having performed the difficulty safely during training and being content with their performance during competition. However, for a more accurate statement on the matter, a larger sample size would be required.

Table 3 shows that athletes who made errors in their routine during competition received their targeted difficulty scores from the judges anyway when their body fat percentage was lower and did not get it if their body fat percentage was higher. This might suggest that the judges favoured slimmer gymnasts since athletes who received their difficulty as planned had a rather low percentage of body fat. The athletes who did not mess up but still received deductions for their difficulty in comparison to their training may have also been subject to bias due to their higher percentage of body fat. Motivational factors which have been tested within the same sample for another project did not correlate significantly with deductions for difficulty. More detailed research might be necessary to test for connections between, e. g., age, percentage of body fat, self-esteem, and other psychological factors.

Our results suggest that judges may be prone to award points according to the physical appearance of the gymnasts. Athletes who performed well and were content with the judging performance despite deductions for their difficulty had a higher percentage of body fat (Table 3). This might be due to the fact that less slim athletes had already become used to being underrated. The highest percentage of body fat can be seen in athletes who were not content with judging performance and nevertheless earned their difficulty as planned while being content with their own performance. It is possible that they received deductions for other factors, like overall merit, composition or execution, t caused dissatisfaction. This can unfortunately not be clarified, since the composition value is not shown separately during competition and most athletes are not judged for their execution and overall merit during training. This makes it impossible to compare these three values in the light of the difference between competition and training.

When comparing wheel gymnasts to athletes from other aesthetic sports, especially gymnastics, it is evident that German wheel gymnasts display quite low body fat values in comparison to other athletes (see Supplementary Table). While body fat percentage in athletes in other gymnastic disciplines ranges between 9 and 22% for females and between 8 and 11% for males, wheel gymnasts in this study displayed values of 14.53% for females and 8.00% for males on average. This suggests that the aesthetic aspect might be important in wheel gymnastics. Thus, this study is not concurrent with the assumption of Samuelsen (2003) who stated, without having conducted a corresponding study, that it is irrelevant for performance if a gymnast does not have ideal body proportions.

The results of our study match those of, e. g., Schwidergall et al. (1998) and results from previous studies, because, as expected, females were leaner than males. 8.0% body fat of male wheel gymnasts is (although displaying broader variation) in line with the findings of Šibanc et al. (2000) and Gurd & Klentrou (2003), who further state that this has no effect on physical and pubertal development of male gymnasts. The lack of male participants as well as the small sample size in general have to be considered a strong limitation of this study.

## CONCLUSIONS

It must be taken into account that the present study could only produce reliable findings for female German wheel gymnasts. Analyzing male athletes separately was not possible due to too few cases, but descriptive statistics hint that a similar effect as for females might be present also for males. To make statements about male wheel gymnasts and provide more specifics for female wheel gymnasts, a larger sample is necessary. The study should also be repeated in other countries and at international tournaments.

Although biomechanical aspects can largely be ruled out as the cause of athletes earning lower difficulty scores during competition than during training, psychological factors could be the reason that athletes would not do their best in a competition, although they were able to perform at the intended difficulty level when training. Therefore, our findings have to be interpreted carefully. Nevertheless, they suggest that the aesthetic aspect is important in wheel gymnastics.

In summary, the abovementioned findings lead to the conclusion that physical appearance is overrated in wheel gymnastics and that the sport indeed is an aesthetic sport. Although the percentage of body fat can influence gym wheel performance via its biomechanical aspects, our study suggests that it most probably also influences the performance of judges. Female gymnasts are subject to underrating if they have a higher body fat percentage despite performing well. Judges should be educated about this fact so that they do not put undue pressure on young female athletes in particular, as this may lead to early dropout and psychological or physical harm to gymnasts.

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Article received: 16.2.2021
Article accepted: 23.7.2021

# SHORT HISTORICAL NOTES XXII

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. Short historical Notes XXII were written in collaboration with Michal Bábela, PhD.

**SAMUEL PIASECKÝ (October, 31, 1984 Košice, Slovak Republic)**

Samuel Piasecký began practising gymnastics at the age of 6. He became the Slovak representative in sports gymnastics on the horizontal bar and parallel bars. At the 2012 Olympic Games in London, he became the first male gymnast to represent Slovakia at the Olympic Games since the independence of Slovakia in 1993.

The best sports results of Samuel Piasecký:

Olympic Games, London, 2012 (Great Britain) – 11th place on parallel bars, points: 15,366

World Championship, Rotterdam, 2016 (Netherlands) – 8th place on parallel bars, points: 15,166

European Championship, Volos, 2006 (Greece) – 8th place on parallel bars, points: 14,3

European Championship, Milan, 2009 (Italy) – 5th place on parallel bars, 13th place in all-around

European Championship, Berlin, 2011 (Germany) – 12th place in all-around

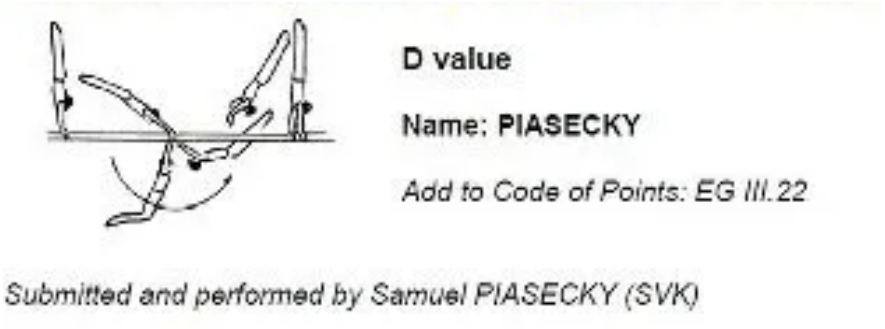
European Championship, Montpellier, 2012 (France) – 5th place on parallel bars, 7th place on horizontal bar.

He also became a multiple medalist at several World Challenge Cups (World Cup Artistic Gymnastics in Porto, 2010 – 3rd place on horizontal bar, Challenge Cup Artistic Gymnastics in Ljubljana, 2013 – 2nd place on parallel bars, Challenge Cup Artistic Gymnastics in Anadia, 2013 – 3rd place on parallel bars).

*Samuel Piasecký on parallel bars, Olympic Games, London, 2012*

He introduced his own gymnastic element at the World Championships in Rotterdam, Netherlands in 2010. His element is called *The giant swing to handstand on one rail (minimum one second)* on parallel bars is also known as the *'Piasecky'* in the field of sports gymnastics. The difficulty value is D.

*Pictorial representation of gymnastic element 'Piasecky' in FIG official documents.*




We wish *'Samo'* all the best and a lot of strength and enthusiasm in working with gymnastic youth.

Slovenski izvlečki / Slovene Abstracts

Salma Khalfallah, Bessem Mkaouer, Samiha Amara, Hamdi Habacha, Nizar Souissi

## VPLIV RAZLIČNIH JAKOSTI OBREMENITVE NA ČAS ODZIVA PRI TELOVADCIH IN NETELOVADCIH PRI PROSTORSKI NALOGI VRTLJIVIH KOCK

Namen raziskave je bil preučiti učinek različnih stopenj jakosti vadbe na zmogljivost miselnega vrtenja kock pri telovadcih v primerjavi z netelovadci. Enainštirideset merjencev (18 žensk; povprečna starost 20,94±0,89 let, višina 1,65±0,03 m, telesna masa 58,94±5,67 kg in 23 moških; povprečna starost 21,26±0,99 let, višina 1,70±0,05 m, telesna masa 66.87±4.52 kg), razdeljeni v dve skupini (tj. telovadci in netelovadci), so prostovoljno sodelovali v tej študiji. Obe skupini sta izvedli nalogo miselnega prostorskega vrtenja kock v mirovanju, nato pa sta izvedli isto nalogo, pred katero so bili kratke obremenitve vadbe pri 60%, 80%, 100% in 120% lastne največje aerobne hitrosti (MAS). Razčlenitev odzivnih časov je pokazala, da so telovadci nalogo miselnega vrtenja opravili hitreje po obremenitvi kot v stanju mirovanja, zlasti pri 60 % in 80 % MAS, medtem ko so netelovadci povečali odzivni čas po zmerni obremenitvi (tj. 60 et. 80 % MAS) in uravnali svojo zmogljivost (tj. enakovredno pri ostalih obremenitvah). Ta ugotovitev poudarja posebne gibalno znanje kot spremenljivko, ki lahko vpliva na uspešnost miselne dejavnosti.

**Ključne besede:** miselno vrtenje, razum, jakost, telovadno znanje.

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Laura de Oliveira, Vítor Ricci Costa, Kizzy Fernandes Antualpa, Myrian Nunomura

## TELO IN NJEGOVA PREDSTAVA PRI RITMIKI: ZNANOST ALI VEROVANJE?

Namen raziskave je ugotoviti, ali vrhunske telovadke čutijo nezadovoljstvo s lastnim telesom, in če je tako, razčleniti dejavnike, povezane z njegovim razvojem, in posledice za njihovo telo. Pogovorili smo se z 28 ritmičarkami starih od 13 do 16 let, iz treh vrst v eni brazilski državi. Izpostavimo lahko: »Telo, zmogljivost in napačne predstave v ritmiki« in »Telesna masa v ritmiki: prepričanje vs. znanost«. Zdi se, da na nezadovoljstvo ritmičark s svojim telesom vplivajo njihovi vaditelji, sodniki in drugi športniki, ki krepijo obstoj uveljavljenega "idealnega" modela telesa v tem športu. Zdi se, da športniki verjamejo, da bi jim ta telesni model pomagal pri izvajanju gibov pri sodniškem ocenjevanju in bi tako vplival na tekmovalno uspešnost. Njihov vaditelj je uporabil telesno maso, merjeno na nizu tehtnic, kot mero za nadzor in vodenje izgube telesne mase. Da bi shujšali za vsako ceno, so ritmičarkam omenili, da bi jemala odvajala in se držala samozadostne omejitve kalorij. Prevelik pritisk k hujšanju in doseganje rezultatov bi lahko povzročil ali ohranil nezadovoljstvo s telesom in škodil zdravju ritmičark. Tako morajo biti vaditelji previdni, ko hujšanje povezujejo z večjo uspešnostjo; upoštevati morajo značilnosti posameznice in jih ne smejo posploševati. Poleg tega je treba sprejeti strokovno spremljanje ter uporabo zanesljivih in upravičenih oblik ocenjevanja telesa. Izvajati bi bilo treba tudi preprečevalne ukrepe in izobraževanje vaditeljev, uradni organi pa bi morali urediti in kaznovati pretiravanja in zlorabe.

**Ključne besede:** mlade športnice, ritmika, nezadovoljstvo s telesom.

Johanna Weber

## POVEZANOST MED MAŠČOBNO MASO, TEKMOVALNO USPEŠNOSTJO IN MOTIVACIJO V PANOGI TELOVADNEGA KOLESA

Motivacija v športu je dejavnik, ki določa in omejuje uspešnost. Zato je bil preverjen pomen motivacije za uspešnost v panogi sestav na telovadnem kolesu. Vzorec so sestavljale 203 nemške telovadke. Ugotovljene so bile motivacijske razlike med različnimi disciplinami in stopnjami uspešnosti. Razlike med stopnjami uspešnosti so bile prisotne tudi v skupinah, razvrščenih po disciplinah. Poleg tega je bila ugotovljena povezava med upanjem na uspeh in odstotkom telesne maščobe ter motivacijskimi dejavniki in odbitki za oceno težavnosti. Več motivacijskih vidikov je povezanih s starostjo. Obstajale so pomembne povezave med motivacijskimi dejavniki in starostjo na različnih ravneh uspešnosti. Rezultati kažejo, da je motivacija lahko pomembna za razvoj nadarjenih pri izvajanju prvin na telovadnem kolesu.

**Ključne besede:** telovadno kolo, uspešnost, maščobna masa.

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Pauline Iglesias Vargas, Fabiana Della Giustina dos Reis, Neiva Leite, André Mendes Capraro

## TEKMOVALNA POT VRHUNSKIH TELOVADCEV V ORODNI TELOVADBI: PREGLED RAZISKAV

Na športni uspeh lahko vpliva več dejavnikov, katerih razsežnosti se razkrivajo skozi celotno vadbo športnikov. Ta študija je poskušala načrtno pregledati raziskave, ki se kakovostno ukvarjajo s športno potjo vrhunskih telovadcev in telovadk. Iskanja so bila izvedena v podatkovnih bazah Web of Science in Scopus, ob upoštevanju študij, objavljenih pred julijem 2020. Izločitev podatkov je bila izvedena glede na cilj in kraj študije (okvir), udeležence in uporabljene obdelave podatkov, pri čemer smo pregledali spremenljivke, povezane z potjo športnikov. Našli smo 318 člankov in po uporabi meril za vključitev in izključitev smo za pregled izbrali 15 izvirnih. V člankih so bili uporabljeni delno strukturirani pogovori s športniki, nekdanjimi športniki, vaditelji, sodniki in organizatorji. V dveh študijah sta pisca uporabila predpostavke ustne zgodovine: eden dokumentarno razčlenitev, drugi pa etnografsko. Pregled je razkril, da je podpora staršev nujna za vključevanje in zadrževanje v športu, tako iz logističnih (financiranje, prevoz, organizacija šolskih dejavnosti) kot tudi čustvenih razlogov. Denarna podpora in dobre zmogljivosti za usposabljanje so dejavniki, ki pozitivno vplivajo na uspeh v telovadbi. Zdrav odnos med vaditeljem in športnikom je bistven, vendar se ta odnos pogosto poroča kot avtoritaren. Obdobje po tekmovalni poti je treba načrtovati in voditi tako, da se prehod zgodi postopoma in da lahko športnik išče novo uveljavitev.

**Ključne besede:** telovadba, pot, športnik, pregled.

Elizabeth Allen, Alex Fenton, Keith Parry

## UPORABA RAČUNALNIŠKEGA NAČINA SOJENJA PRI TELOVADBI – POGLED UPORABNIKOV

Orodna telovadba je eden izmed prvotnih olimpijskih športov, ki ga ocenjujejo ljudje. Lahko pride do napak pri sojenju in pristranskosti, zaradi česar so medalje napačno podeljene. Mednarodna telovadna zveza (FIG) s Fujitsujem uvaja računalniško podprt sklop sojenja orodne telovadbe (CGJSS), tehnologijo, ki je namenjena izboljšanju pravičnosti in natančnosti, vendar je zelo malo virov, ki ocenjuje to tehnologijo. Namen je bil raziskati odzive zainteresiranih strani na CGJSS. Zato so bili opravljeni pogovori z vaditelji, sodniki, novinarji, nekdanjimi in sedanjimi mednarodnimi telovadci. Ugotovitve so se ujemale s pregledom virov o težavah pri presoji trenutnega načina, vključno s pristranskostjo. Nove ugotovitve med drugim kažejo, da se rezultati telovadcev lahko razlikujejo glede na to kdaj tekmujejo. Ugotovitve tudi kažejo, da bi bil CGJSS odlična inovacija za telovadbo za izboljšanje verodostojnosti z odstranitvijo pristranskosti in pomoč pri bolj objektivnemu športu. Vendar pa je večina udeležencev menila, da CGJSS ne more presojati umetniškega dela športa. Zato je potrebno natančno spremljanje učinkovitosti CGJSS, da se ugotovi izboljšanje in zagotovi, da naložba daje pravičnejše, zanesljivejše in verodostojne rezultate. Uspešna uveljavitev CGJSS, bi lahko omogočila tudi uvedbo v druge športe, kjer se ocenjuje tehnika gibanja.

**Ključne besede:** telovadba, sojenje, pristranskost, tehnologija, šport.

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Mateja Videmšek, Tjaša Logaj, Gregor Starc, Vedrana Sember, Damir Karpljuk, Ana Šuštaršič

## PORABA ENERGIJE PREDŠOLSKIH OTROK OB RAZLIČNEM POUČEVANJU PRVIN ABC TELOVADBE

Namen raziskave je bil ugotoviti, ali sta proga z ovirami in krožna vadba učinkovita učna metoda kot oblika vadbe po svoji jakosti, ki se spremlja z uporabo naprav za merjenje porabe energije. Proučene so bile ključne razlike v porabi energije med obema učnima oblikama. Za pridobivanje podatkov iz dveh oblik smo uporabili opremo BodyMedia SenseWear za merjenje porabe energije. Vzorec udeležencev je vključeval 24 petletnih otrok iz enega ljubljanskega vrtca, čeprav smo popolne podatke iz obeh popoldanskih vaj pridobili le pri 12 otrocih. Študija je pokazala, da sta proga z ovirami in krožna vadba ustrezni učni metodi, saj je bila z obema metodama dosežena zmerna do močna jakost vadbi ABC telovadbe. Povprečna poraba energije je presegla 7 MET v glavnem delu dveh vadbenih oblik tako za progo z ovirami kot za krožno vadbo. Rezultati niso pokazali statistično pomembnih razlik v porabi energije med spoloma ali posamezno uporabljeno obliko poučevanja.

**Ključne besede:** predšolski otroci, ABC telovadbe, poraba energije, jakost vadbe, proga z ovirami

Natalija Yu. Tarabrina

PARNA PRIMERJAVA RAZVOJA GIBALNIH ZMOŽNOSTI PRI RITMIKI BREZ ORODJA

Jakost vadbe in tekmovalne dejavnosti v športu povzroča potrebo po iskanju in razvoju novih oblik vadbe. Študija je bila izvedena z namenom preučiti vpliv parno-povezanega razvoja (PCD) telesnih zmožnosti na stopnjo tehnične pripravljenosti in izvajalskih veščin v ritmični prosti sestavi (AG). Za 13 deklet - ritmičark (12±1,2 let), vadba po ustaljeni obliki (nadzorna skupina) in 12 telovadk iste starosti in zmožnosti, ki uporabljajo PSD v vadbenem ciklusu (preskusna skupina). Proučevale so se gibljivost, moč, hitrost, skladnost gibanja, vzdržljivost, tehnična pripravljenost in tekmovalna uspešnost. Pokazalo se je, da uporaba PCD izboljša gibljivost v kolčnem sklepu za 4,24 % in za 2,28 % leve in desne noge, hrbtenice pa za 7,04 %. Kazalniki skladnosti gibanja so se izboljšali za 32,66-41,25 %, moč za 10,02 %. Povečanje kazalnikov hitrosti je bilo 18,71-21,09%, kazalniki posebne vzdržljivosti pa so se povečali za 11,13-25,16%. Za ravnotežje so se ocene zvišale za 25,75 %, za obrate za 19,38 %, za skoke za 24,58 % in za gibe gibljivosti za 15,47 %. Povprečne ocene tehnične vrednosti sestave so se zvišale s 4,5±0,07 na 5,45±0,06 točke (21,1 %), povprečni kazalniki končnih tekmovalnih točk pa s 14,49±0,04 na 15,73±0,08 (8,56 %). Kot rezultat poskusa je bil potrjen pozitiven vpliv razvite PCD vadbe na stopnjo telesne in tehnične pripravljenosti ritmičark ter na končni tekmovalni rezultat.

**Ključne besede:** ritmika, parna metoda, gibljivost, moč, hitrost, skladnost gibanja, vzdržljivost.

George C. Dallas, Costas Dallas, Maria Maridaki

UČINEK 10 TEDENSKE ISOKINETIČNE VADBE NA MIŠIČNO MOČ IN TEOVADNO USPEŠNOST PRI TELOVADKAH V PREDBUBERTETNEM OBDOBJU

Namen je bil raziskati učinek izokinetične vadbe na mišično moč in telovadno zmogljivost, če ga dodamo tradicionalni vadbi na preskoku pri telovadkah v predpubertetnem obdobju. V raziskavi je sodelovalo 20 telovadk s povprečno starostjo 10,50 ± 1,19 let, višino 125,50 ± 4,52 cm in telesno maso 27,30 ± 2,58 kg. Izokinetični dinamometer Cybex II je bil uporabljen za merjenje največjega navora kolenskega sklepa v iztegovanju pri kotnih hitrostih 60°/s in 300°/s. Hitro slikovna kamera Casio EX-F1 (Tokio, Japonska) je bila nameščena pravokotno na optično os odrivne deske in konja za preskok. Preiskovanke so vadile 10-tednov po tri (nezaporedne) dni, 2 uri na dan, in so bile ločene v dve enaki skupini. Poskusna skupina (EG) je sledila posebni vadbi (tehnična priprava in mišična moč preko Cybexa II), nadzorna skupina (CG) pa je sledila običajnemu načrtu vadbe (tehnična priprava in mišična moč). Rezultati so pokazali, da pri telovadni uspešnosti ni bilo ugotovljenega pomembnega vpliva; vendar je bil za tisti čas ugotovljen pomemben glavni učinek. Za izteg kolena pri 60°/s niso ugotovili pomembnega medsebojnega učinka med tremi neodvisnimi spremenljivkami (skupina, čas, telesna stran). Vendar pa je imela EG bistveno višje povprečne vrednosti v primerjavi s CG po končani celotni vadbi. Medsebojni vpliv med tremi neodvisnimi spremenljivkami glede na upogib kolena pri 300°/s ni bil pomemben. Vendar pa je bil vpliv med stranmi telesa po skupini pomembna. 10-tedenski izokinetični trening, ki je bil dodan običajni vadbi, je izboljšal moč kolen, kar je posledično izboljšalo vidike preskoka, ni pa vplivalo na druge tehnične vidike izvedbe premeta naprej. Poleg tega rezultati podpirajo trditev, da je najboljša učinkovitost rezultat sestavljen iz medsebojnega sodelovanja več dejavnikov.

**Ključne besede:** izokinetika, odriv, preskok, rezultat, mišična moč.

Urška Čeklić, Nejc Šarabon

## RAZLIKE V MOČI LEVE IN DESNE NOGE PRI TELOVADKAH IN NETELOVADKAH

Medtem ko so številne študije raziskovale razlike med okončinami (ILA) pri različnih športnikih, je malo znanega o ILA med telovadkami. Prvi cilj raziskave je bil primerjati razlike med telovadkami in njihovimi vrstnicami netelovadkami v izometričnih spremenljivkah največje in hitre moči kolena (največji navor - PT in hitrost razvoja navora - RTD) in spremenljivkah skoka s protigibanju (CMJ) (višina, najvišja sila), kot tudi v ILA pri vseh meritvah. Drugi cilj študije je bil oceniti razmerje med ILA največje sile in ILA izometričnih spremenljivk moči kolena. 15 telovadcev (starih 11,19 ± 1,89 let) in 15 netelovadcev (starih 10,92 ± 1,96 let) je izvedlo meritve enostranske izometričnega največjega prostovoljnega krčenja upogibalk in iztegovalk kolena na dinamometru in CMJ na pritiskovni plošči. ILA so bile izračunane in primerjane med skupinami v vseh spremenljivkah. Ugotovili smo, da so telovadke dosegle statistično značilno boljše rezultate kot netelovadke pri večini izometričnih spremenljivk moči kolena in višine CMJ, ne pa pri RTD upogiba levega kolena in največje sile v CMJ. Medtem ni bilo bistvenih razlik med skupinami v ILA. Linearna regresija ni pokazala povezave med meritvami ILA ločeno za skupine. Čeprav v ILA nismo našli razlik med skupinami, bi se morali tega zavedati, da preprečimo poškodbe pri mladih dekletih.

**Ključne besede:** izometrična moč kolen, skok iz proti gibanja, orodna telovadba.

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Johanna Weber

## POVEZANOST MED MAŠČOBNO MASO IN TEKMOVALNIMI REZULTATI V PANOGI TELOVADNEGA KOLESA

V nekaterih športih, ki se osredotočajo na lepotne vidike, kot so umetnostno drsanje, orodna telovadba in ples, obstaja veliko zahtev po vitki postavi. Ta zahteva bi lahko povzročila pritisk na športnike in povzročila zdravstvene težave. Treba je razjasniti, ali je tako tudi pri tekmovanju s telovdnim kolesom. V ta namen so ocenili odstotek telesne maščobe in tekmovalne rezultate 203 telovadcev in telovadk na kolesih (183 žensk, 20 moških, starosti 21,2 ± 11,9 oziroma 16,8 ± 4,9; odstotek telesne maščobe 14,5 ± 3,4 in 8,0 ± 3,7) Izračunana je bila povezanost med odstotkom telesne maščobe in tekmovalnimi rezultati. Poleg tega so primerjali njihov odstotek telesne maščobe z deležem športnikov iz drugih lepotnih športih in raziskali, ali na sodnike lahko vpliva odstotek telesne maščobe. V ta namen smo primerjali tehnične težave pri vadbi in tekmovanju telovadcev z različnimi odstotki telesne maščobe, hkrati pa so upoštevali oceno sodniške uspešnosti, kot jo zaznavajo telovadci in njihovo zadovoljstvo z rezultati. Razlika med tehnično težavnostjo med vadbo in tekmovanjem je v pozitivni povezanosti z odstotkom telesne maščobe ($p \leq .010$, $r = .268$). Telovadci, ki a) niso zadovoljni z ocenami sodnikov; b) zadovoljni z lastno zmogljivostjo in c) imajo višji odstotek telesne maščobe, se bistveno razlikujejo od telovadcev, pri katerih so bili manj kot trije od teh parametrov resnični glede odbitkov za tehnično težavnost ($p \leq .000$, $\eta 2 = .323$).

**Ključne besede:** telovadba na kolesih, odstotek telesne maščobe, sodniki, tekmovalni rezultati.

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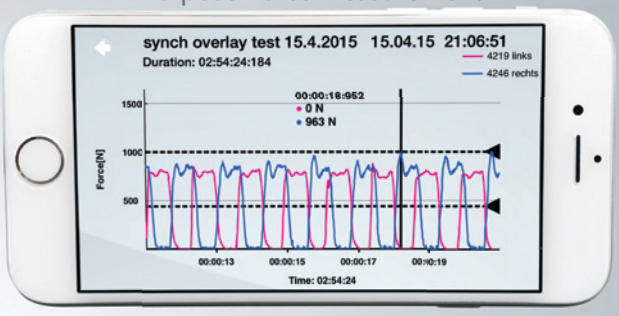


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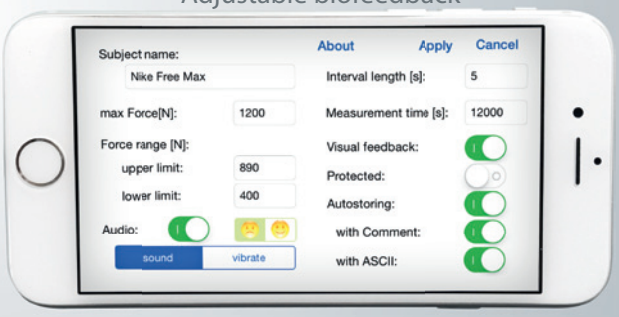


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