

SCIENCE OF GYMNASTICS JOURNAL

vol. 16, num. 1, year 2024



CONTENTS

Ivan Ćuk	EDITORIAL	3
Masaharu Matsushima	DIFFERENCE BETWEEN MUSCLE ACTIVITIES DURING JUMPING MOTION IN DESCENT AND ASCENT PHASES ON A TRAMPOLINE	5
Paulo Daniel Sabino Carrara, Gareth Irwin, Timothy Exell, Julio Cerca Serrão, Alberto Carlos Amadio, Luis Mochizuki	KINEMATIC ANALYSIS OF CROSS ON TRAINING AND COMPETITION RINGS: COMPARISON BETWEEN ELITE AND INTERNATIONAL LEVEL GYMNASTS	15
Megan Benzie	ACHILLES RUPTURES AND RETURN TO SPORT IN GYMNASTICS: AN OVERVIEW	29
Tamer Çankaya, Numan Yener, Muhammet Fatih Uysal	IS THERE ANY EFFECT OF THE SEVERITY OF FLEXIBLE PES PLANUS ON THE BALANCE PERFORMANCE IN ELITE GYMNASTS?	43
Gokhan Deliceoglu, Guler Atalay, Banu Kabak³	THE EFFECT OF LEG STIFFNESS ON REACTIVE AGILITY, JUMPING AND SPEED IN GYMNASTICS ATHLETES	55
Una T. Visser , Francois J. Cleophas	ROOTS, ORIGINS AND DEVELOPMENT OF RHYTHMIC GYMNASTICS: A HISTORICAL INSIGHT	67
Joseph Lobo	THE ROLE OF CURIOSITY TO STUDY ENGAGEMENT OF STUDENTS IN GYMNASTICS: EXTRAPOLATING RECIPROCITY	77
Sinem Yürük, Sibel Sönmez Feride Zişan Kazak	VALUES DEVELOPMENT THROUGH GYMNASTIC EDUCATION IN PRESCHOOL CHILDREN	92
Ivan Ćolakovac, Iva Barković, Lucija Milčić, Marijo Možnik	ANALYSIS OF THE SCIENTIFIC LITERATURE ON ARTISTIC GYMNASTICS IN SCOPUS DATABASE	105
Yeray Rodriguez-Redondo, Kiko Leon	ANALYSIS OF THE SCIENTIFIC PRODUCTION IN ARTISTIC GYMNASTICS, AND IN THE MEN'S AND WOMEN'S MODALITIES	123
Anton Gajdoš	SHORT HISTORICAL NOTES XXIX	150
	SLOVENSKI IZVLEČKI / SLOVENE ABSTRACTS	155
Miriam Kalichová	LETTER TO EDITOR	160

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EDITORIAL

Dear friends,

We are entering 16th year since we started to publish our journal. We are pleased we made a good development since beginning. Now we permanently publish around thirty (30) scientific articles per year, with Anton Gajdoš we have still look into the history of gymnastics and we have published also few Letters to Editor, where you can express some argument views or introduce some new book or other novelties for example.

Our friends in Brazil are preparing Symposium Gymnastics for All between 20.-23.3.2024. You can join them via FIG [www. FIG](http://www.fig.gymnastics.com). Flavio Bessi from University of Freiburg (Germany) in in October preparing symposium on gymnastics. Please be welcome on both event events, which are bringing new data about gymnastics.

We are still experiencing problems with our reviewers as, unfortunately, many of them have no time to review our submissions. I would like to appeal to you to please help us out. As a specialized journal, we have access to only a limited number of researchers. Let's all try an effort to remain a part of the prominent scientific community on the Web of Science and SCOPUS!

This issue covers a diverse range of content, the authors are coming from Japan, Brazil, United Kingdom, USA, Turkey, South Africa, Philipines, Croatia and Spain.

Anton Gajdoš with Ivan Čuk prepared 29th short historical note introducing the first World Championship after World War II in Basel (Switzerland).

Miriam Kalichová and her team prepared under Erasmus + project SAFE GYMNASTICS 4ALL with aim to give information on basis of artistic gymnastics for students and teachers of P.E., and can be also used by coaches of novice gymnasts. More information is presented in Letter to Editor.

https://is.muni.cz/do/fsp/s/e-learning/safe_gymnastics_4all

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

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

Ivan Čuk
Editor-in-Chief

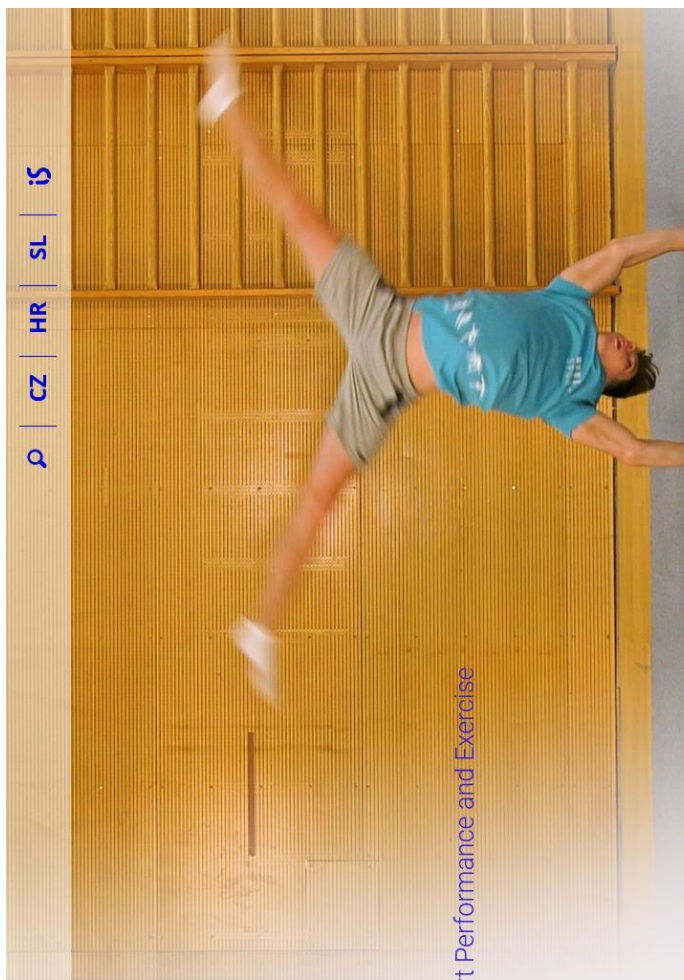
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Safe gymnastics 4all

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CHAPTERS



Characteristics of artistic gymnastics



Short History of Gymnastics



General didactic guidelines



Disciplines of artistic gymnastics



Tests

DIFFERENCE BETWEEN MUSCLE ACTIVITIES DURING JUMPING MOTION IN DESCENT AND ASCENT PHASES ON A TRAMPOLINE

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Original article

DOI: 10.52165/sgj.16.1.5-13

Abstract

Trampoline bounces are performed on a bed of a jumping surface that is stretched over the trampoline apparatus. The jumping motion is divided into a descent phase, i.e., from the landing to the maximum depth, and an ascent phase, from the maximum depth to the takeoff. Most studies on muscle activity during jumping have investigated muscle activity during the same phase between groups or between landing and release; however, no studies have investigated muscle activity between phases. Therefore, this study aimed to investigate muscle activity during the descent and ascent phases and obtain basic data on the jumping motion. For the trials, participants were instructed to perform 15 consecutive jumps on the trampoline bed from a standing still position, as high as possible, straight and straight up in the center of the trampoline bed. The muscle activities of the rectus femoris, tibialis anterior, and lateral gastrocnemius revealed significant increases and larger effect sizes in the descent phase than in the ascent phase ($p < 0.01$). The muscle activities of the sternocleidomastoid, trapezius, and biceps femoris demonstrated significant increases and medium effect sizes in the descent phase in contrast to the ascent phase ($p < 0.01$). Pushing down the bed by the muscular activity of the lower extremities is most pursued in the descent phase. Then, participants maintain a straight vertical posture for the body to receive the rebound force from the maximum depth of the bed. This suggests that the sternocleidomastoid and trapezius muscles were significantly active in controlling the head position. A high jump is achieved by pushing the bed down for a deep descent and maintaining a straight posture at the maximum depth. The elastic bed is similar to an Open Kinetic Chain in the descent phase because the load incrementally increases, and to a Closed Kinetic Chain in the ascent phase because the load begins at the maximum depth of the bed. Separating the elements of the jumping motion required in the descent and ascent phases is important in athletic training.

Keywords: *trampoline gymnastics, trampoline bed, electromyogram, Open Kinetic Chain, Closed Kinetic Chain.*

INTRODUCTION

The trampoline event, which was officially adopted for the 2000 Olympics, is judged by performing a continuous series of 10 different movements. Four main scoring methods were used, including execution, horizontal displacement, time of flight, and difficulty (2022–2024 Code of Points Trampoline Gymnastics, 2021). These four methods of scoring are determined by jumping out from the trampoline apparatus. Trampoline gymnasts find it difficult to change direction or body position significantly once they jump into the air in gravity. Therefore, jumping motion is important for trampoline gymnasts. Song et al. (2011, 2013) investigated muscle activity during jumping motion and reported that the active muscles and the landing position of muscle activity differed depending on the landing position of the trampoline's jumping surface (bed). Muscle activity was greatest during the jumping performed in the center of the bed, with greater activity in the gastrocnemius and tibialis anterior muscles. Athletes adapt to the hardness of the bed and force with good coordination. A comparison between elite and non-elite groups revealed significant differences in rectus femoris and biceps femoris muscle activity (Matsushima et al., 2017). A study examining horizontal movement bounce revealed a high correlation between the centrally made jumps and gastrocnemius activity (Matsushima et al., 2018a). The gastrocnemius muscle activity could be identified as an eccentric contraction. Several studies were conducted on muscle activity in the jumping motion on the trampoline.

The 4,260 mm (length) × 2,130 mm (width) bed produces a large vertical

deflection between landing and takeoff due to the jumping motion. Jumping on the bed consists of two phases: from landing to the maximum depth (descent phase) and from the maximum depth to the takeoff (ascent phase). The distance to the maximum depth where the bed extended the longest was approximately 0.8 m, and the duration of the descent and ascent phases was approximately 0.15 s each (David, 2015; David et al. 2012; Ito et al., 2000; Jingguang et al., 2020; Martin, 2001; Matsushima, 2021; Wojciech and Adam, 2001). A study that used two variables to indicate an index of jumping quality, including ascent phase time and deflection distance of the bed, revealed that jumping with a longer deflection distance of the bed and shorter time was better than jumping with a longer time of flight (Matsushima, 2021). The jumping ability to obtain long deflection distances and short times on the bed was discussed. Additionally, this study provided an index of relative jumping motion by determining the distance of bed deflection per body weight. Trampoline gymnasts receive different loads from the bed depending on the jumping phase because of the great elasticity of the bed. The load increases as the bed deflection distance increases in the descent phase; the load is greatest at the maximum depth, and least toward the takeoff in the ascent phase (Martin, 2001; Matsushima et al., 2018b, 2018c; Matsushima, 2023).

The required elements for jumping motion are different for the descent and the ascent phases on the bed. However, many previous studies compared different groups in the same phase or analyzed muscle activity from landing to takeoff without phase separation. No study has been

conducted on muscle activity concerning the two phases. Therefore, this study aimed to obtain basic data by comparing the muscle activities of the trampoline jumping motion in both phases on the bed. Participants were selected from individuals registered with the Japan Gymnastics Association who had competed in the All Japan Trampoline Championships.

METHODS

Participants included ten trampoline athletes, 5 females and 5 males, registered with the Japan Gymnastics Association who had competed in the All Japan Trampoline Championships (age: 19.5 ± 1.6 years, height: 163.9 ± 6.7 cm, weight: 58.5 ± 8.2 kg, athletic career: 7.9 ± 4.2 years). The details of the experiment were fully explained to the participants before the experiment using the protocol of the Mukogawa Women's University research ethics review committee (approval number No. 13-52). They were asked to provide their written consent.

The trampoline apparatus used in the experiment was a 4×4 Euro trampoline (5.20 m long, 3.05 m wide, and 1.15 m high) manufactured by EUROTRAMP, a company approved by the International Gymnastics Federation. For the trials, after a sufficient warm-up period, participants were instructed to perform 15 consecutive jumps on the trampoline bed from a standing still position, as high as possible, straight and straight up in the center of the trampoline bed.

The isometric maximal voluntary contraction (MVC) of each muscle was measured by manual muscle testing after each experiment (Hislop and Montgomery, 2002). Participants were instructed to exert force using manual resistance by the

examiner to incrementally increase the contraction force for >3 s and then hold the MVC for 2 s. MVC was used for a total of 1.0 s, including 0.5 s before and after the maximum amplitude. Eight muscles were measured in total: sternocleidomastoid (SCM), trapezius upper part (TR), rectus abdominis (RA), erector spinae (L4 level) (ES), rectus femoris (RF), biceps femoris long head (BF), tibialis anterior (TA), and lateral gastrocnemius (LG). The SCM was contracted by applying manual resistance to the frontal part of the head while the neck was flexed forward. The TR was contracted by applying manual resistance to the occiput while flexing the neck backward. The RF was contracted by sitting on a chair with the hip joint at 90 deg, and knee joint extension was performed while manual resistance was applied to the front surface of the lower leg. The BF was contracted in the prone position, and the knee joint was flexed with manual resistance applied to the posterior lower leg. The TA contraction was performed in a seated position with ankle joint dorsiflexion while manual resistance was applied to the dorsum of the foot. The LG contraction was measured by letting the patient perform ankle joint plantar flexion in a unilateral standing position. Maximal contractions of the ES and RA muscles followed the method of Vera-Garcia et al. (2010). The ES was contracted by holding the legs down in the prone position and applying manual resistance to the posterior back while the trunk was flexed backward. The RA was contracted by holding the legs down in the supine position and applying manual resistance to the shoulder while the trunk was flexed forward.

A compact tension/compression load cell (KYOWA ELECTRONIC INSTRUMENTS CO., LTD.: LUX-B-2KN-ID) was attached between the 17th

spring (counting from the right end) and the frame at the center of the trampoline side. The landing, i.e., where the subject touched the trampoline bed, the maximum depth - where the trampoline bed extended maximally descent, and the takeoff - where the subject left the trampoline bed, were determined from the load cell output using analysis software (KISSEI COMTEC CO., LTD.: BIMUTAS II) (Figure 1). The descent phase was defined as the phase between the landing and maximum depth, and the ascent phase between the maximum depth and takeoff. The sampling frequency was set to 1000 Hz, and the data was recorded on a personal computer (PC).

The skin was shaved and prepared with fine sandpaper and ethanol to lower its impedance. According to Aldo (Aldo and Hugh, 2005), wireless electrodes were placed and secured with surgical tape to stabilize them and minimize artifacts. A wireless electrocardiograph (multi-channel telemeter system WEB-7000, Nihon Kohden CO., LTD, Japan) was used to record the signals from each participant. The experiment derived electromyography (EMG) with a 1000Hz sampling frequency. Data was then transferred from the memory card to a PC and synchronized with the load cell signal.

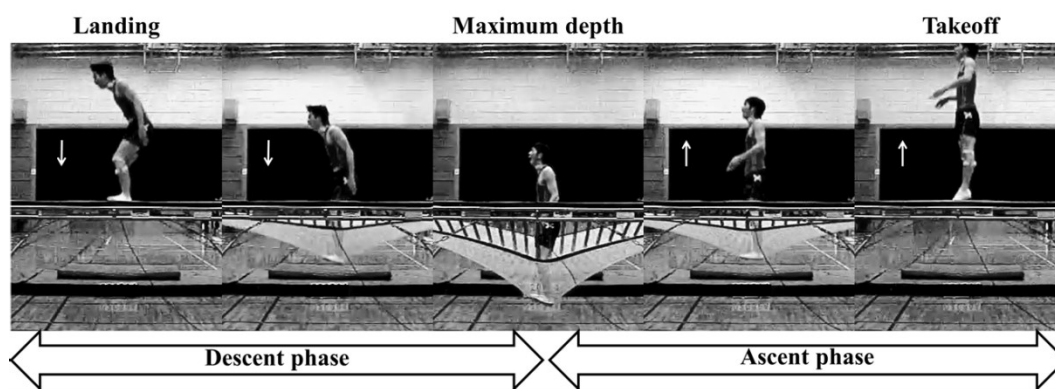


Figure 1. Definition of the jumping phase on the bed.

Of the 15 trial jumps, 9 jumps, 7th to 15th, were included in the analysis. The collected EMG data during each action were converted through a band-pass filter (20–500 Hz) and full-wave, rectified to the EMG amplitude of each jump per unit of time. Data were normalized using the EMG amplitude (%MVC) measured for each muscle during the time in which the muscle exerted MVC.

Data were presented as means (standard deviation). Paired Student's *t*-tests were used to assess statistical differences in EMG muscle activity (expressed as %MVC). *P*-values of <0.05

were considered statistically significant. To evaluate the magnitude of differences beyond statistical significance, Cohen's *d* effect sizes were calculated and interpreted as follows: small (0.20–0.49), medium (0.50–0.79), and large (≥ 0.80) (Cohen, 1992). Relative reliability was assessed using 95% confidence intervals.

RESULTS

Table 1 and Figure 2 show the results of each muscle activity during the descent and ascent phases. RF, TA, and LG muscular activities were significantly

greater in the descent phase than in the ascent phase, with a large effect size. SCM, TR, and BF muscular activities were significantly greater in the descent phase than in the ascent phase, with a medium effect size. ES muscular activity was

significantly greater in the descent phase than in the ascent phase but with a small effect size. RA muscular activity was not significantly different between the two phases, with a small effect size.

Table 1

Differences between the descent and ascent phases during EMGs amplitude(%MVC) of jumping motion on the bed.

	Descent phase		Ascent phase		95%CI	p value	Cohen's d
	Mean	(SD)	Mean	(SD)			
SCM	27.96	(20.47)	14.84	(15.50)	[0.42, 1.02]	<.01	0.72
TR	5.16	(4.35)	2.14	(5.13)	[0.34, 0.94]	<.01	0.64
RA	1.71	(3.22)	1.19	(1.65)	[-0.09, 0.49]	.18	0.20
ES	8.44	(6.05)	5.80	(7.73)	[0.09, 0.68]	.01	0.38
RF	8.92	(6.74)	4.66	(3.23)	[0.50, 1.11]	<.01	0.81
BF	21.06	(38.55)	6.46	(9.13)	[0.22, 0.82]	<.01	0.52
TA	13.33	(7.14)	6.99	(3.30)	[0.83, 1.46]	<.01	1.14
LG	17.56	(12.47)	7.34	(4.33)	[0.78, 1.41]	<.01	1.10

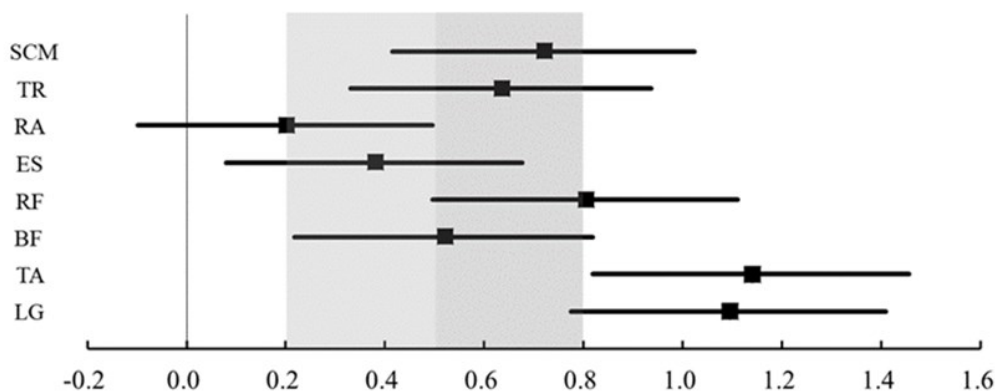


Figure 2. Effect sizes and 95% confidence intervals for both phases in EMG amplitude.

DISCUSSION

This study compared the muscle activity of the takeoff motion during the descent and ascent phases of a jump on the trampoline bed. The results showed that the activity of the LG, TA, RF, and BF muscles were all higher in the descent phase

compared to the ascent phase. The greater TA activity during descent can be attributed to its role in ankle dorsiflexion before landing, as reported in previous studies (Matsushima et al., 2017; Matsushima et al., 2018 b; Song et al., 2011;). This dorsiflexion helps in generating quick muscular strength during the short (approximately 0.15

seconds) descent phase. In essence, the plantar foot actively prepares for dorsiflexion even before landing to securely grip and push down on the bed. While TA contracts concentrically during dorsiflexion, the higher LG activity in the descent phase suggests an eccentric contraction (Matsushima et al., 2018a). This is consistent with the observed increase in ankle dorsiflexion angle from landing to maximum depth, followed by plantar flexion during ascent (Matsushima et al., 2018c). As an antagonist to TA, the eccentrically contracting LG helps control the rapid dorsiflexion in the descent phase, contributing to greater activity compared to the ascent phase. Several studies have reported a correlation between plantar pressure and jumping motion (Matsushima et al., 2018b, 2018c; Song et al., 2013). In this study, heel pressure likely peaked at maximum depth due to the dorsiflexion-induced downward push on the bed (Matsushima et al., 2018b, 2018c; SONG et al., 2013). RF and BF muscular activities pushed the bed down through hip and knee joint extension. Matsushima et al. (2017) found that the emphasis is different depending on the skill level and hip extension, jumpers prioritize either RF for knee extension or BF for hip extension. Furthermore, the angular change of the lower extremity joint was greater in the descent phase and smaller in the ascent phase. Lower extremity muscular activity contributes to the long deflection of the bed in the descent phase. Ueyama et al. (2007) emphasized the importance of pointing the body straight up vertically at the maximum depth to achieve a stable bounce. The extension of hip and knee joints during the descent phase pushes the bed down, and the vertical posture is then straightened at the maximum depth from landing. During the

ascent phase, the subject bounces up, receiving the restoring force of the bed. Consequently, the extension motions in the lower extremities are performed less during the ascent phase than during the descent phase. SCM muscular activity is crucial for controlling the head and maintaining a straight vertical posture, while SCM and TR muscular activities likely contribute to head control for maintaining that posture. Given that the head has the highest mass ratio after the torso and thighs in the body (Hai-peng et al., 1994; Michiyoshi et al., 1992), controlling the head becomes significant. The RA and ES muscles, as trunk muscles, showed no significant differences in activity between the two phases, stabilizing the trunk during the jumping motion. The muscles serve distinct functions in both phases, as discussed earlier. The muscular activity that facilitates pushing down the bed for an extended duration in the descent phase is particularly crucial. Additionally, the muscles must maintain a straight posture in the ascent phase to receive the restorative force of the bed on the body and enable upward propulsion.

The load on the trampoline bed gradually increases during the sinking phase because of its elastic nature, reaching its peak when the bed starts rising from its maximum depth in the ascent phase. In the descent phase, the trampoline gymnast gradually increases the load by pushing the bed downward through lower extremity extension while falling from the air. The extension movement initiates from the maximum depth, and in the ascent phase, the trampoline gymnast jumps upward, creating a Closed Kinetic Chain (CKC) (Matsushima, 2023). An Open Kinetic Chain (OKC) is characterized by the mobility of the distal part of the body not being immobilized, while CKC involves external forces

restricting the distal part's mobility (Steindler, 1977). Muscular activity in OKC and CKC exhibits contradictory characteristics. In OKC, the origin of the muscle is fixed, and muscle contraction moves toward the stop, whereas in CKC, the distal portion is fixed, and the muscle can move at the origin. Studies examining the relationship between lower extremity muscle strength and vertical jump in OKC and CKC revealed that lower extremity muscle strength in CKC was more strongly related to vertical jump than in OKC (Jonathan and Matthew, 1998). RF muscular activity, due to the knee joint extension movement, is significantly greater in OKC than in CKC (Escamilla et al., 1998; Spairani, 2012; Stensdotter et al., 2003). The distinct characteristics of OKC and CKC suggest the need for different training for each phase in the trampoline jumping motion. For instance, a squat exercise with the feet on the floor is CKC, while an exercise using a leg press machine (a machine with a fixed seat and a movable foot press plate) is OKC. Despite involving the same knee joint and hip joint extension movements, these exercises train different aspects due to the kinetic chain difference.

LIMITATION

A limitation of this study is that it was not possible to attach compact tension/compression load cells to many springs. If attached to too many springs, the elasticity of the spring will be lost. The next challenge will be to attach compact tension/compression load cells to many springs to accurately measure the tension of the springs so that their elasticity is not compromised. Alternatively, other methods may need to be explored for measuring tension in the springs. While this study

measured the activity of eight muscles, a future challenge lies in measuring the activity of even more detailed muscles.

CONCLUSIONS

The jump is executed by maximizing the bed's restoring force. The muscular activities of RF, BF, TA, and LG were significantly higher in the descent phase than in the ascent phase to deepen the bed deflection. SCM and TR muscles were active for straight postural control at the maximum depth. Additionally, RA and ES muscles remained active from landing to takeoff for trunk stability. The elements required for the jumping motion differ between the descent and ascent phases of the bed due to the elastic nature of the bed and the distinct kinetic chain. The descent phase represents OKC as it involves landing from the air and gradually increasing the load, while the ascent phase is CKC as the load peaks when the bed rises from its maximum depth. Athletic training needs to be tailored to each phase of the jumping motion.

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Article received: 16. 6. 2023

Article accepted: 24. 10. 2023

KINEMATIC ANALYSIS OF CROSS ON TRAINING AND COMPETITION RINGS: COMPARISON BETWEEN ELITE AND INTERNATIONAL LEVEL GYMNASTS

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Original article

DOI: 10.52165/sgj.16.1.15-28

Abstract

Auxiliary devices are used to train gymnastics skills. Based on the principles of training specificity, this study aimed to investigate the effectiveness of a training device for the static cross posture on Men's Artistic Gymnastics rings through kinematic analysis. Twelve national team gymnasts were divided into two groups, based on their competitive results: the elite group (age: 21.8±3.2 years) and the international group (age: 19.3±3.3 years) performed the cross three times under both conditions: standard competition rings, and training rings with an auxiliary device. The videos were digitised and analysed with shoulder angles as trunk and arm segments. The variables included the right and the left shoulder angles in the frontal plane, as well as any asymmetry of those angles. Two-way ANOVA (conditions versus groups) and individual t-test statistics were conducted. Both groups performed the cross on training rings with increased abduction at both right ($p<0.001$) and left ($p<0.001$) shoulders and reduced asymmetry ($p=0.01$) than on competition rings. These kinematic improvements would translate into competition-typical score improvements of 0.1 to 0.3 points, and enhanced shoulder joint stability. Hence, the training rings with an auxiliary device effectively replicate skill-specific joint angles, adhering to the kinematics principles of training specificity for the static cross posture on rings, thus benefiting both elite and international-level gymnasts.

Keywords: *Gymnastics; Sport Coaches; Shoulder Angle; video analysis; Symmetry Analysis; Strength Exercise.*

INTRODUCTION

The cross is a key posture on rings in men's artistic gymnastics (MAG). It requires maintaining 90° shoulder abduction with straight elbows for two seconds (FIG, 2018). In competition,

penalties (0.1, 0.3 or 0.5 points) apply, depending on how much the angle deviates (up to 15°, 30°, 45° or more) from 90° at the shoulder joints (FIG, 2018). Currently, even minor deviations of 0.1 points can impact

medal contention for international gymnasts. The unstable nature of the rings, comprised of 3-meter cables, adds to the skill's difficulty (FIG, 2018).

To help beginners and developing gymnasts master the cross, coaches often use a drill with belts attached to the rings. These belts support the forearms, reducing the effective mass and torque the gymnasts' shoulders need to handle (Bernasconi et al., 2004; Readhead, 1997).

Studies comparing the competition skill and training drill for cross posture on rings have focused on muscle activity patterns through EMG measurements (Bernasconi et al., 2004; Bernasconi et al., 2006), indicating similar overall muscle activation. However, measuring shoulder angles would provide additional clarity on the drill's effectiveness by revealing whether it helps maintain the required 90° shoulder abduction posture throughout the skill.

The effectiveness of training methods hinges on biomechanical similarity to the target sport, encompassing joint motions and muscle actions across relevant planes (Bompa & Buzzichelli, 2015). Thus, athletes require increasingly specific exercises and training methods to maximize competitive preparedness (Zatsiorsky et al., 2020).

Therefore, it is unclear whether the training device improves the gymnast's proficiency at the cross, particularly in reducing angular deviation from the required 90° shoulder abduction, remains unclear, especially across different competitive levels. For training specificity to be effective, drills need to closely resemble the target skills in terms of joint motions, muscle actions, and movement planes. While upper body strength training progressions are crucial for maximizing

technique (Holvoet, 2011), coaches also rely on the principle of training specificity to promote performance-related adaptations (Irwin & Kerwin, 2005). Despite its prevalence in gyms due to its ease of assembly and perceived competition specificity, further research is needed to determine if this drill truly adheres to these principles and provides sufficient overload for skill improvement (Bompa & Buzzichelli, 2015; Zatsiorsky et al., 2020).

The cross posture on rings demands 90° shoulder stability in the frontal plane, but this can paradoxically induce instability due to glenohumeral joint extension (Graichen et al., 2005; Ludewig et al., 2009). Therefore, appropriate physical preparation, especially in shoulder abduction positions, is crucial before practicing this complex skill. Unbalanced shoulder joint strengthening in the cross posture can exacerbate instability and potentially displace the glenohumeral joint (Labriola et al., 2005).

Information about gymnast's limb asymmetry can guide coaches by improving posture stability on rings (Irwin et al., 2013). Kinematic asymmetry in ring skills leads to cables instability and score penalties (FIG, 2018). Minimising kinematic asymmetry is vital for both successful performance and injury prevention, making it a valuable concept for coaches, clinicians and technology perspectives (Exell et al., 2016). Analysing asymmetry scores in the cross posture would be particularly useful for coaches to assess technical correctness and performance levels.

This study investigates whether the training device is a specific drill for the cross posture and whether it improves performance. It also examines the effectiveness of the training device across

different competitive levels. By understanding its effectiveness, coaches can better determine its value for training and developing the cross. Our specific objective is to analyze the left and right frontal plane shoulder angles and asymmetry of gymnasts performing the cross on both training and competition rings. The null hypotheses predict no performance differences due to either a) gymnasts' competitive levels or b) rings type.

METHODS

Twelve Brazilian national team gymnasts were divided into two groups based on their individual rings scores: six elite gymnasts (including one Olympic champion on rings, one top-ranked on rings, three Olympic National Team, and one junior national team member) and six international gymnasts (including senior and junior national teams, participants of World Championships and World Cup series). The elite gymnasts' group had a mean age of 21.8 ± 3.2 years, height of 1.67 ± 0.06 meters, weight of 63.2 ± 7.7 kg, and 14.2 ± 4.0 years of practice. The international gymnasts' group had a mean age of 19.3 ± 3.3 years, height 1.65 ± 0.04 meters, weight of 64.7 ± 7.2 kg, and 12.5 ± 2.8 years of practice. Ethical approval was

obtained from the University of São Paulo Ethics Committee prior to this study (CAAE: 32724014.2.0000.5390).

The gymnasts performed three trials of the MAG cross posture (shown in Figure 1) on both training and competition rings, in a random order, separated by a two-minute rest period per attempt (De Luca, 1997). The training device was placed on the forearm 0.15 m from rings. A platform near the rings allowed them to mount the apparatus independently. Starting from the support position, gymnasts lowered into the cross posture, holding their upper limbs abducted at approximately 90 degrees in the frontal plane for two seconds. A voice alert then signaled them to stop the cross, which was validated by a brevet international judge (FIG, 2018). Trials were recorded using a digital camera operating at 50 Hz with HD resolution, positioned five meters from gymnasts' frontal plane at rings height. The camera view captured the gymnast's entire body and the rings apparatus. Spherical reflective markers (radius 20 mm) were attached to specific locations on the gymnast (Rab et al., 2002) and on the rings frame to improve video calibration accuracy (Figure 2). Data collection occurred in the gymnasts' training gym, with the apparatuses they regularly practice with.

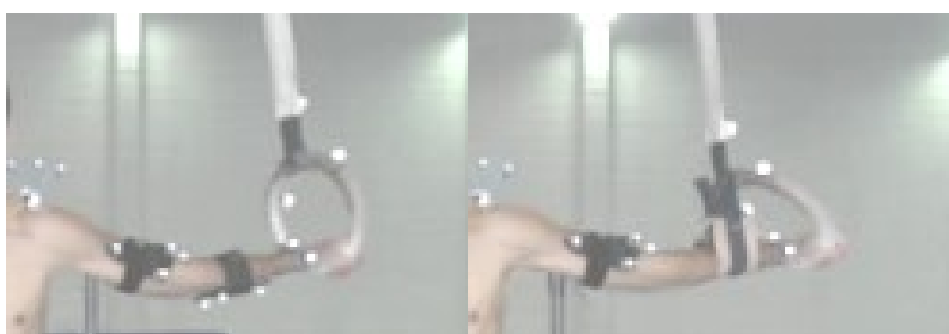


Figure 1A. Competition rings.

Figure 1B. Training rings.

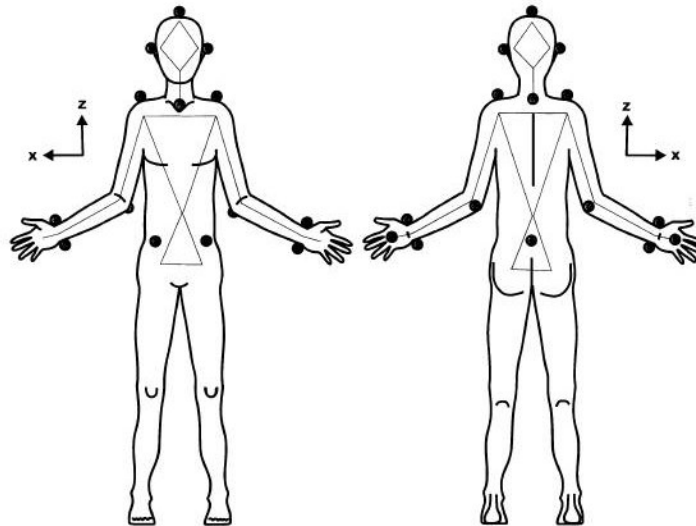


Figure 2. Upper extremity landmarks (Rab et al., 2002).

A single operator digitized all video trials, ensuring consistency. Data were filtered using a low-pass Butterworth filter with a cut-off frequency of 5.3 Hz, as determined optimal through residual analysis (Winter, 2009). Kinematic data were reconstructed using DLT via Matlab with specific routines (Hedrick, 2008). The data were then imported into Visual 3D software (version 5; C-Motion, Rockville, MD, USA). An upper limb model, based on the work of Rab et al. (2002), was applied to the data points. In this model, each segment is defined by a proximal and distal point located at a joint center, along with a third non-collinear point for determining rotational orientation. Shoulder angles were calculated as the angles between the trunk and humerus segments.

Each cross skill attempt was divided into three distinct sections: support, lowering, and static position. This

segmentation was achieved through a combined approach of validated computer algorithms and expert visual inspection of the trials, ensuring accuracy.

Data from all trials were time-normalized to account for potential variations in timing and then averaged to obtain representative values for each gymnast. Root Mean Square Difference (RMSD) values were calculated within each data sample across the three trials, and then averaged. Mean group RMSD and Asymmetry values were calculated based on the individual data from the six gymnasts within each group, rather than using shoulder group mean values.

To assess individual-level differences between left and right shoulder angles, asymmetry analysis was conducted using the asymmetry angle (Zifchock et al., 2008):

$$\theta_{\text{SYM}} = ((45^\circ - \arctan(X_{\text{left}} / X_{\text{right}})) / 90) \times 100\% \quad [1]$$

Where θ_{SYM} is the symmetry angle; X_{left} is the gymnast's mean left shoulder angle (LSHO θ) value and X_{right} is the

gymnast's mean right shoulder angle (RSHO θ) value. To facilitate direct comparison of asymmetry magnitudes

between conditions (training rings vs. competition rings), the asymmetry values were rectified.

Statistical tests were processed using SPSS software version 22.0 (IBM, Armonk, NY, USA). The normality assumption for the data set was verified using the Shapiro–Wilk test. A two-way ANOVA was applied to assess the impact of ring type (competition or training) and group level (elite or international) on discrete variables results (Right and Left shoulder angles and asymmetry). Additionally, a One-way ANOVA was utilized to identify differences within each factor level (effect of rings; effect of group) across discrete variables. Post hoc analysis of achieved power was calculated for the right (0.966), left (0.99) and asymmetry (0.99) using G*Power Version 3.1, (University of Dusseldorf, Germany). Effect sizes were calculated for ANOVAs, measured via partial η^2 , were interpreted as trivial (<0.01); small (0.01–0.06); medium (0.06–0.14), and large (>0.14)(Cohen, 1992).

Results of all trials were averaged, and subsequently, RMSD and Asymmetry values were calculated for each gymnast and condition. Means (M) and standard deviations (SD) were computed for RSHO θ , LSHO θ , RMSD and Asymmetry in each condition (training versus competition). The intraclass correlation coefficient (ICC) was calculated for both conditions, and the typical error of measurement was expressed as coefficients

of variation (CV%). Average variability, derived from both measures (ICC and CV), was considered small for an ICC > 0.67 and CV < 10% (Bradshaw et al., 2007). The significance level was set at $p < 0.05$. Mean group RMSD and Asymmetry values were calculated based on the values of the six gymnasts, rather than the group mean values.

RESULTS

The time series for right and left shoulder angles kinematics during three attempts are illustrated in Figure 3 and Figure 4. Right and left shoulder angles, RMSD and Asymmetry values from individuals and group means are shown in Table 1. The values of the ICC calculated from repeated measures were 0.95 for RSHO competition, 0.84 for RSHO training, 0.89 for LSHO competition and 0.84 LSHO training, while CV was lower than 10% for all measures, indicating small variability.

The type of rings affected the right ($F_{18.961}=424$ $p<0.001$, $\eta^2=0.22$, power 0.99) and the left ($F_{26.063}=979$ $p<0.001$, $\eta^2=0.28$, power 0.99) shoulder angles, as well as asymmetry ($F_{6.870}=19.0$ $p=0.01$, $\eta^2=0.10$, power 0.73). The group level influenced the right ($F_{68.781}=1541$ $p<0.001$, $\eta^2=0.50$, power 0.97) and the left ($F_{8.044}=302$ $p=0.006$, $\eta^2=0.11$, power 0.80) shoulder angles, but not asymmetry.

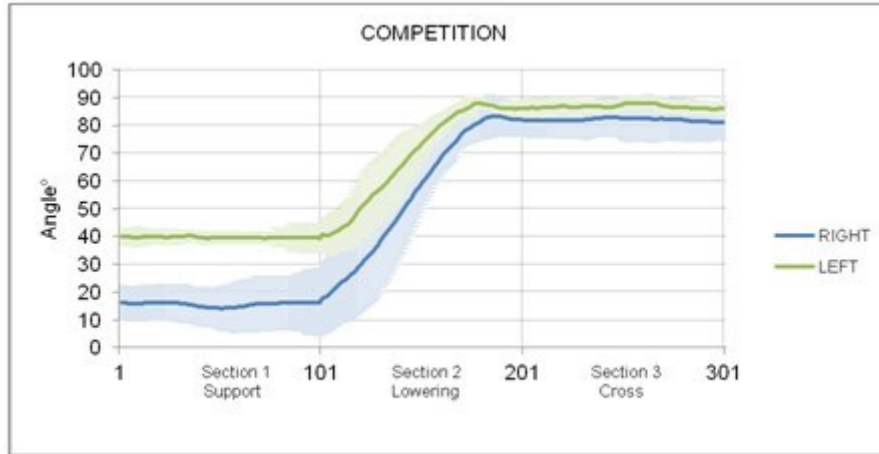


Figure 3A. Elite gymnast's shoulder angles profiles of three attempts ($M \pm SD$), for support to the cross performed on competition rings. Gymnast 2.

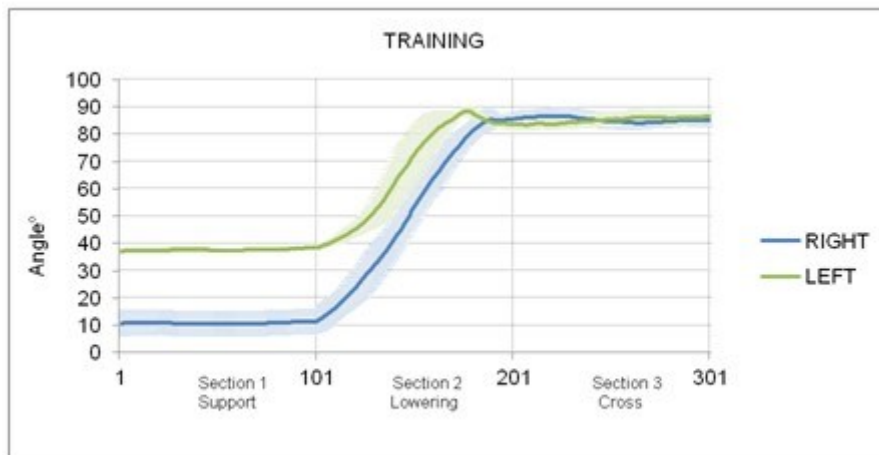


Figure 3B. Elite gymnast's shoulder angles profiles of three attempts ($M \pm SD$), for support to the cross performed on training rings. Gymnast 2.

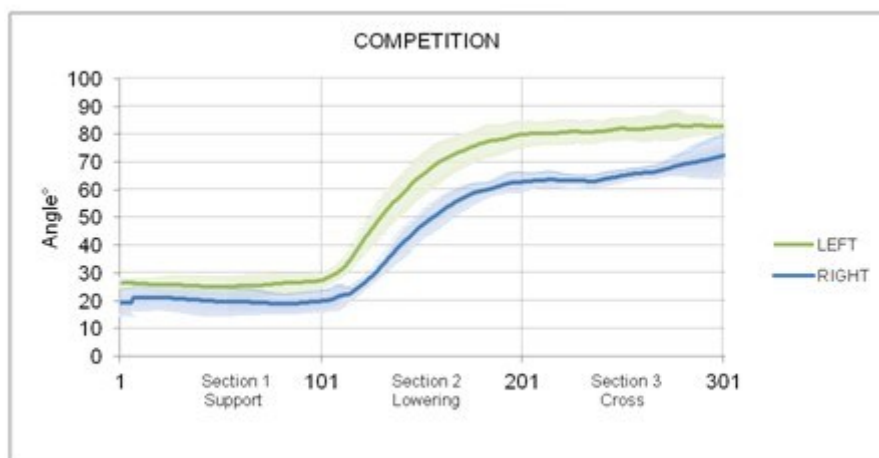


Figure 4A. International gymnast's shoulder angles profiles of three attempts ($M \pm SD$), for support to the cross performed on competition rings. Gymnast 12.

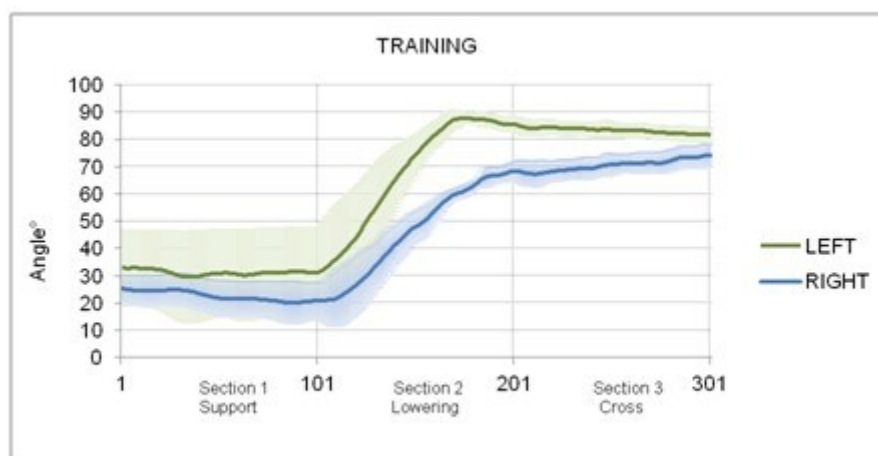


Figure 4B. International gymnast's shoulder angles profiles of three attempts ($M \pm SD$), for support to the cross performed on training rings. Gymnast 12.

Shoulder angles were higher (closer to 90°) with the training rings. The training rings influenced elite group right ($F_{7.290}=109$ $p=0.01$, $\eta^2=0.18$), and left shoulder angle ($F_{12.180}=411$ $p=0.001$, $\eta^2=0.26$); and international group right ($F_{11.719}=349$ $p=0.002$, $\eta^2=0.26$) and left ($F_{13.892}=575$ $p<0.001$, $\eta^2=0.30$) shoulder angles. Asymmetry values were lower (closer to zero) for training rings. The asymmetry values were affected by the ring type only for the elite group ($F_{4.779}=17.3$ $p=0.03$, $\eta^2=0.12$).

Shoulder angles were higher (closer to 90°) for the elite group. One way ANOVA was applied to check the effect of the group level (elite or international) over shoulder angles during the cross. The elite group influenced competition rings right ($F_{31.768}=1015$ $p<0.001$, $\eta^2=0.48$, power

0.95) but not left ($F_{3.967}=200$ $p=0.054$, $\eta^2=0.10$) shoulder angles; while training rings affected the right ($F_{43.540}=559$ $p<0.001$, $\eta^2=0.56$) and left ($F_{4.413}=108$ $p=0.04$, $\eta^2=0.12$) shoulder angles. Asymmetry values were lower (closer to zero) for the elite group. One way ANOVA was applied to check the effect of the group level (elite or international) over the asymmetry values. The asymmetry values for competition and training rings were not affected by the group level.

RMSD between groups on the competition rings were 10.62° for the right and 4.71° for the left shoulder; and on the training rings were 7.88° for the right and 3.48° for the left shoulder. Furthermore, there is a statistically significant interaction between the side and the ring type ($F_{4.985}=94.2$ $p=0.02$, $\eta^2=0.07$).

Table 1

Gymnasts' shoulder angles, RMSD and asymmetry values (θ_{SYM}) on cross for competition (C) and training (T) conditions.

Rings	Gymnast	Elite					International					
		RSHO θ (°)	CV (%)	LSHO θ (°)	CV (%)	θ_{SYM}	RSHO θ (°)	CV (%)	LSHO θ (°)	CV (%)	θ_{SYM}	
C		84.89±0.58	2	80.10±0.275	1	1.85		71.10±1.25	2	79.23±2.66	3	3.43
T	1	87.35±1.77	2	85.78±2.31	3	0.82	7	71.75±2.89	4	79.19±2.95	4	3.12
RMSD		2.46		5.68		-		0.65		0.04		-
C		86.82±1.88	3	82.08±6.83	8	2.55		77.35±2.31	5	76.94±4.19	10	1.76
T	2	85.16±2.15	3	85.33±2.27	3	0.86	8	79.69±3.93	5	85.94±2.68	9	2.42
RMSD		1.66		3.25		-		2.34		9.00		-
C		74.71±2.42	3	73.64±1.46	2	0.48		76.60±2.78	4	71.63±5.70	8	2.18
T	3	84.77±1.82**	4	82.67±1.22**	2	0.80	9	75.78±5.81	8	74.38±1.47	2	2.11
RMSD		10.06		9.03		-		0.82		2.75		-
C		77.28±2.19	3	71.95±2.13	3	2.27		68.29±6.04	9	64.04±3.18	5	1.99
T	4	85.28±0.75*	1	86.72±2.24*	3	0.81	10	75.95±0.88	1	75.56±2.14*	3	0.81
RMSD		8.00		14.77		-		7.66		11.52		-
C		85.32±3.04	2	67.73±3.34	4	7.28		61.33±2.77	5	62.74±4.59	8	2.75
T	5	84.02±3.02	1	74.66±2.23*	1	3.75*	11	79.36±4.86*	6	80.85±7.19*	9	0.95
RMSD		1.30		6.93		-		18.03		18.11		-
C		80.36±3.70	5	84.07±1.24	1	1.45		70.97±3.01	4	76.69±3.82	5	2.46
T	6	83.73±2.50	3	84.96±1.28	2	0.54*	12	80.47±3.92*	5	83.34±2.54	3	1.13
RMSD		3.36		0.88		-		9.50		6.65		-
C		81.56±5.05	3	76.59±6.71	3	2.65		70.94±6.20	5	71.88±7.47	7	2.42
T	Group Mean	85.05±2.14**	2	83.35±4.73**	2	1.26*	Group Mean	77.17±4.59**	5	79.87±5.19**	5	1.76
RMSD		3.49		6.76		-		6.23		7.99		-

Note: RSHO θ : Right shoulder angle; LSHO θ : Left shoulder angle; CV: Coefficient of Variation (%). θ_{SYM} : Asymmetry index; Rectified values of θ_{SYM} . C: Competition; T: Training. RMSD: Root Mean Square Difference. Group CV mean values of all gymnasts. Group θ_{SYM} mean values of all gymnasts. * p<0.05; ** p<0.01; between conditions (competition versus training, three trials of each gymnast considered).

DISCUSSION

This research aimed to verify the use of a training device as a specific drill for the cross static posture on rings and whether it may improve technical performance. Additionally, the study aimed to determine the suitability of the training device for gymnasts of different competitive levels in improving their performance at the cross.

Considering all gymnasts, the type of ring influenced shoulder angles and asymmetry, providing insight into training rings as a drill for improving the posture of the cross. To achieve maximum training specificity, an exercise must imitate the angle of the skill performed (Bompa & Buzzichelli, 2015; Zatsiorsky et al., 2020). Moreover, training improved the position of the body posture closer to the ideal 90° of shoulder frontal plane abduction position of the cross. Considering all gymnasts' attempts, the group level influenced shoulder angles but not asymmetry, indicating that group differences are more related to strength levels than the posture of the cross.

Both gymnast groups performed the drill on the training rings with fewer shoulder angle deviations from the 90° objective. High similarities between gymnastics skills over training and competition conditions are required to replicate the biomechanics of the target skill during the drill (Irwin et al., 2013; Irwin & Kerwin, 2005; Irwin & Kerwin, 2007). Improving the execution of the cross deviations on shoulder angle from 90° (up to 15°, 30°, 45°, or more without recognizing the skill value) consequently will lower score penalties (0.1, 0.3, or 0.5 points) (FIG, 2018).

Gymnasts shoulder angles RMSD from competition to training rings device were

larger within international gymnasts (6.23° right and 7.99° left) than within elite (3.49° right and 6.76° left), as the international group is farther to 90° ideal posture. Thus, the null hypothesis was rejected, as (a) the elite group performed the cross posture with less shoulder deviation than the international level group in both types of rings; and (b) both groups had a better performance using the training rings.

Analyzing CV, the gymnasts of both group levels in this study have showed reduced variability for shoulder angle, as expected for elite gymnasts, who presented low variability in the mechanically important aspects of gymnastics performance (Hiley et al., 2013). This constancy was also observed in former Olympic champion in the execution of the cross on rings, which is characteristic of high-level gymnasts (Carrara et al., 2016).

Considering MAG regulations, it is desirable to employ training devices that approach the drill execution to the accomplishment of the rules requirements (Readhead, 1997), as that facilitates training performance with less deviation from 90° of shoulder abduction. Research on gymnastic skills has suggested specific kinematic modifications to progressions in a trial to make them more similar to the target skill (Irwin & Kerwin, 2005). The training device improved the gymnast's proficiency at the cross, decreasing the angular deviation from the required position. It could thus be useful for technical preparation, which includes maintenance and improvement of the elements already acquired (Goto et al., 2022).

Group differences resting on maturational stage (2.5 years old) and training experience (1.67 years of practice) could justify the observed shoulder angles RMSD, as the cross depends on strength and posture coordination capacities to

accomplish the static posture (Arkaev & Suchilin, 2004). However, there are seniors and juniors gymnasts in both groups. According to the skill development table provided by the FIG (Fink & Hofmann, 2015), gymnasts around 16-17 years old should already perform the cross at a competent stage in their development, without other connected skills. The older international participants in the present study performed the cross in similar conditions. Gymnastics' skills analysis over a wider age range (14 to 20 years old) showed similar coordination for the longswing skill (Busquets et al., 2013). Although differences between groups in the present research might be dependent on the gymnast's level, age or time of practice.

The asymmetry shoulder angle values were lower when using the training device than on competition rings. This finding supports the use of the training device, allowing gymnasts to train closer to the desired 90° shoulder angle and positively influencing the important aspect of asymmetry. For the elite gymnasts, shoulder asymmetry was significantly ($P < 0.001$) larger on competition rings ($\theta_{SYM} 2.65$) than on training ($\theta_{SYM} 1.26$) rings, indicating an improvement in performing the drill posture. This suggests enhanced balance and stability distributed over shoulders on unstable support of rings.

While shoulder asymmetry did not show a significant difference between the competition and training device conditions for the international group, there was an improvement observed on the training rings. This improvement in shoulder angles and RMSD moved from a 0.3 points penalty (deviations of over 15° from 90°) to a 0.1 points penalty (deviations of less than 15° from 90°), as per FIG regulations (FIG, 2018). The close proximity of asymmetry

values between group levels suggests that the training rings serve as a specific drill that prompts international gymnasts to perform angles similar to those of elite gymnasts. This contributes to the development of gymnasts, enabling them to enhance the skill. Additionally, the isometric exercises on the training rings may lead to strength gains at the trained angle, as isometric strength training at longer muscle lengths is known to result in greater muscle hypertrophy and strength increments due to length-specific adaptations (Lum & Barbosa, 2019).

The deficiency in strength is closely linked to exercise execution and errors in meeting the requirements, such as maintaining a shoulder angle of 90°, for executing the cross (Smolevskiy & Gaverdovskiy, 1996; Zatsiorsky et al., 2020). As per the principle of specificity, when transitioning to specific strength, body positions and limb angles should resemble those required for the specific skills (Bompa & Buzzichelli, 2015). The transfer of angles to competitive rings relies on the improvement of specific strength coordination patterns in isometric conditions (Zatsiorsky et al., 2020).

Understanding shoulder asymmetries in different conditions can enhance the comprehension and development of gymnastic skills (Exell et al., 2016), ultimately improving gymnasts' performance and facilitating the safe and effective development of more complex skill combinations (Readhead, 1997). The use of training devices is suggested to be beneficial for enhancing the performance of key skills in Men's Artistic Gymnastics (MAG) (Irwin & Kerwin, 2007). The cross, being a key skill, can be incorporated into routines along with 34 other strength/swing skills, as

outlined in the current MAG code of points (FIG, 2018).

Asymmetries in strength skills on rings directly impact performance scores, with penalties of 0.1 points for holding static positions with swinging rings cables (FIG, 2018). The unstable nature of the apparatus construction can lead to unbalanced forces when there is asymmetry in the posture, causing rings to swing (Brewin et al., 2000). Therefore, the use of the training device is suggested to enhance the score performance of the cross on rings, especially for high-level gymnasts.

The training device enables gymnasts to train closer to the desired 90° target shoulder abduction angle, thereby improving posture stability as the postural position becomes better balanced within the rings' cables. Asymmetry values in the present study were small, with the largest value being 7.28%. In comparison, other kinematic studies involving non-static skills, such as gymnasts performing handsprings in floor exercises (ranging from 4% to 25%) (Exell et al., 2016) and in sprinting (6.68%) (Exell et al., 2012) using the same θ SYM method. The description and analysis of the left and right shoulder angles during the cross performance on training and competition rings provide novel insights into understanding gymnastics skills, especially for coaching this specific gymnastic skill. While it may subjectively appear symmetrical (Exell et al., 2016), the findings reveal significant asymmetry improvement with training rings. Understanding these asymmetries can contribute to the development of insights into the mechanisms of this gymnastic skill, thereby informing strength and conditioning regimes (Arkaev & Suchilin, 2004; Smolevskiy & Gaverdovskiy, 1996).

This research faced logistical constraints related to the availability of expensive cameras at gymnast training locations. However, the training facilities and apparatuses employed advanced the ecological validity of the study compared to previous research on rings. One limitation is the potential influence of the rings' movement on shoulder angles, even in a static posture, as the rings were assembled as a pendulum, and gymnasts performed the cross independently.

This is particularly relevant for rings apparatus, considering that 3D sensing technology is still under development in collaboration with the FIG (Fujiwara & Ito, 2018). Future developments in this technology aim to establish digital judging rules, involving the creation of a database for joint position recognition software (Fujiwara & Ito, 2018). Concerns about the accuracy of the system have been raised by gymnastics stakeholders (Allen et al., 2021). As a result, efforts are underway to create scoring rules for all elements, incorporating joint angles measured and applicable penalties (Fujiwara & Ito, 2018). Additionally, asymmetry values may contribute to the need for data input into database models or the development of new rules for evaluating gymnasts, aiming to prevent shoulder overloads.

Future research endeavors could expand beyond video analysis to incorporate additional instruments, such as force-instrumented rings and electromyography (EMG), to achieve a more comprehensive understanding of the neuromuscular and kinetic demands associated with gymnastics skills (Irwin et al., 2013; Irwin & Kerwin, 2007). Subsequent investigations should focus on elucidating the similarities in coordination and musculoskeletal demands between the training drill and the targeted

skills. While existing biomechanical research has primarily concentrated on the mechanical loads on the shoulders in gymnastics (Brewin et al., 2000; Irwin & Kerwin, 2005; Irwin & Kerwin, 2007; Serafin et al., 2008), studies specifically on rings are not as extensive as those on other apparatuses (Prassas et al., 2006). Future studies could explore the generalizability of the findings from this study to different group levels, including gymnasts in the developmental stages of acquiring the skill.

CONCLUSIONS

The use of training rings with forearm support appears to provide benefits for both elite and international gymnasts in performing the cross posture with shoulders more abducted (closer to 90°) and reducing asymmetry between limbs. This suggests that the drill aims to meet the specific requirements of gymnastics. Following the principle of training specificity, it is reasonable to infer that the cross drill is effective in developing the ideal shoulder angle posture of 90°. The drill is expected to facilitate the transfer of training to gymnastics performance, allowing improvement in the execution of the cross and other complex skills that involve strength or swing movements through the cross posture position.

The use of the training device could enhance the performance of the cross on rings. However, to ensure the similarity between the types of rings investigated, replication of biomechanics should encompass kinematics, kinetics, and neuromuscular activity.

ACKNOWLEDGEMENT

The authors would like to acknowledge Dr. Scott Selbie from C-motion, Robson Cassefo from Apamed, Esporte Clube Pinheiros and Agith São Caetano for their assistance and help in this research. The authors also thank the gymnasts and coaches who participated in the study.

This research was supported by the National Research Council (CNPq) - Science Without Borders [grant number 249500/2013-2].

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Article received: 21. 9. 2023

Article accepted: 30. 11. 2023

ACHILLES RUPTURES AND RETURN TO SPORT IN GYMNASTICS: AN OVERVIEW

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Original article

DOI: 10.52165/sgj.16.1.29-41

Abstract

Achilles tendon ruptures in collegiate gymnastics have significantly increased in the past few years, with 20 ruptures in the first three weeks of competition alone in 2020 according to Bonanno et al., 2022. Female gymnasts are ten times more likely to tear their Achilles than any other college athletes, with an incidence of 16.73/100,000. Men's basketball has the next highest incidence at 4.26/100,000 (Bonanno et al., 2022). Contributing factors for the increase in ruptures are not well researched or understood. This paper will explore the relevant literature on the risk factors of tears and return to sport protocols. It will touch on early rehab but mainly focus on return to sport testing and progression for gymnastics from a physical therapy perspective. It will explore topics discussed in interviews with numerous sports physical therapists with extensive gymnastics or collegiate athletics experience. Gymnastics is a very technical sport where each athlete has individual skills with different biomechanical requirements; therefore, needs vary between athletes. This paper aims to address the transition phase between the time when surgical protocols allow a return to sport and the actual return to performance during recovery. In this specific domain, there is an ongoing need for prospective, longitudinal studies to investigate testing and outcome measures tailored to gymnastics. These studies can play a crucial role in guiding athletes, trainers, coaches, and therapists in facilitating a safe and effective return to performance after surgery.

Keywords: *gymnastics, Achilles Rupture, Return-to-Sport, Physical Therapy*

INTRODUCTION

Achilles tendon ruptures in collegiate gymnastics have significantly increased in the past few seasons, with a study finding 20 ruptures in the first three weeks of competition alone in 2020 (Bonanno et al., 2022). A study published in 2022, *Factors Associated with Achilles Tendon Rupture in*

Women's Collegiate Gymnastics, investigated rupture rates and risk factors (Bonanno et al., 2022). They found that females engaging in gymnastics are ten times more likely to tear their Achilles tendon than in any other college sport, with an incidence of 16.73/100,000. In men's categories,

basketball was the next most common sport with the injury, showing an incidence of 4.26/100,000. There is currently no published return to sport protocol for Achilles ruptures in gymnastics. Given the significant increase in rupture rates, there is a need for research and collaboration between healthcare providers, coaches, and strength and conditioning staff, to understand the increase in rupture rates and the best way to return these athletes to gymnastics.

The Achilles tendon is the strongest tendon in the body, yet the most ruptured one in the lower extremity (Jarvien et al., 2001 & Shamrock & Varacoola, 2023). The average return to sport timeline for professional athletes is 11 months compared to the six-month recovery for the general population (Johns et al., 2021). Ruptures typically occur in dorsiflexion and knee extension. The more dorsiflexion the ankle is in, the more tension there is on the tendon (Yeh et al., 2020). The injury also commonly occurs with sudden plantar flexion, such as a jump takeoff (University of Wisconsin Sports Medicine). Both positions are common in gymnastics, specifically on backward tumbling takeoffs. According to data collected in a cross-sectional study by Bonanno et. al, 91% of Achilles tears in gymnastics occur on floor exercise, most of which are from a backward tumbling takeoff. This places the athlete in dorsiflexion and knee extension, putting extreme stress and tension on the gastroc-soleus complex and the Achilles tendon. Among athletes who experienced a rupture, 70.9% reported tendon pain in the preceding four weeks (Bonanno et al., 2022). This suggests that with increased interprofessional communication, some of these season-ending injuries may be preventable.

A key rehabilitation objective is to mitigate the risk of a re-rupture. Establishing a robust strength and conditioning foundation that aligns with specific gymnastics skills proves to be one of the most effective strategies. Gymnastics is a very technical sport and there is a lack of evidence-based, gymnastics-specific protocols to guide clinicians. This paper aims to offer a framework for clinicians and coaches to understand the gymnastics-specific considerations in rehabilitating gymnasts. It provides benchmarks utilized by therapists specializing in gymnastics and serves as a starting point for discussions between medical providers and the gymnastics community. The paper also underscores the rising incidence of ruptures, emphasizing the need for further high-quality research in this field.

METHODS

This study looks to combine the current research with expert opinion to serve as a guide for returning to sport in a safe, efficient manner. This study seeks to build upon the discussion started with *Factors Associated with Achilles Tendon Rupture in Women's Collegiate Gymnastics* (Bonanno et al., 2022) by delving into available research concerning rupture rates and risk factors, return-to-sport protocols and testing, and gymnastics-specific considerations. Moreover, the study incorporates insights from interviews with multiple top-level clinicians selected on the basis of their experience in treating gymnasts and proficiency in developing return-to-sport testing batteries. Figure 1 provides a list of clinicians included in this study.

Clinician's Name	Credentials	Current Position/Relation to Topic
Dr. Dave Tilley	DPT, SCS, CSCS, C-PS	-Current clinician at Champion Physical Therapy Waltham, MA -Owner of Shift Movement Science, an educational platform that aims to educate coaches, athletes, and providers about performance, gymnastics rehab, prevention -Co-author of <i>Factors Associated with Achilles Tendon Rupture in Women's Collegiate Gymnastics</i>
Dr. Stacie Barber	PT, DPT, CSCS, DN cert., USAW-L1SP, FRCms	-owner of <i>The Physio Fix</i> in Phoenix, Arizona, a private practice that specializes in gymnastics -special interest in Achilles ruptures
Dr. Whitney Kramer	DPT, PT, SCS	-Therapist at a Duke University outpatient clinic, specializing in gymnastics -head of Duke's outreach program for gymnastics in the Durham Triangle area
Dr. Drew Lukes	PT, DPT, SCS, CSCS	-Sports Physical Therapist through Duke University Athletics -Treats Olympic Sports athletes
Dr. Matt McDougal	PT, DPT, CSCS	-Sports Physical Therapist in Raleigh, NC -specializes in gymnastics and runs an outreach program at a local gym

Figure 1: Clinicians' opinions

RESULTS AND DISCUSSION

Tendon Degeneration

Achilles tendon rupture is multifactorial and the increase in rupture rates calls for more research. Pre-existing chronic tendon degeneration in the form of microtrauma is the most common explanation for rupture. Microtrauma can come from repeated forces, long training hours without adequate recovery, and early specialization. Healthy Achilles tendons are 95% type I collagen, characterized by organized, parallel fibers designed to give high tensile strength. Ruptured and tendinopathic tendons show an increase in type III collagen, unorganized fibers with lower tensile strength (Mansfield et al., 2022).

Gymnastics-Specific Risk Factors

The nature of gymnastics requires extremely high training hours, with elite gymnasts training upwards of 35 hours a

week. Additionally, early specialization in the sport is extremely common. With early specialization, athletes are performing difficult floor passes, such as double backs, at an extremely young age, which is another risk factor for rupture (Bonanno et al., 2022). Gymnasts with a habit of landing "short" on their skills are at a greater risk for developing anterior ankle impingement. Landing "short" puts the talocrural joint in maximum dorsiflexion and large amounts of knee flexion. It occurs when the athlete lacks the height or rotation to complete their attempted skill. This may accelerate the degeneration of the Achilles tendon, leading to an increased risk of rupture (Wertz et al., 2010).

According to *Biomechanics Related to Injury* by Bruggemann and Hume, the force applied to the Achilles tendon during backward tumbling is about 15 times the gymnast's body weight (Bruggemann & Hume, 2013). These forces taken over years of training may have a significant impact on

chronic tendon degeneration (Bonanno et al., 2022). These extreme forces are nearly impossible to replicate in the clinic, which poses the question of how to ensure athletes are ready to take such forces after a rupture.

Gymnastics-Specific Range of Motion

Gymnasts are known for being hypermobile and flexible. Studies show that 62% of gymnasts score greater than four on the nine-point Beighton scale, indicating generalized joint hypermobility. Being hypermobile may be advantageous in gymnastics, as it is a sport based on aesthetics. The more mobile a joint is, however, the more it is at risk of instability. The athlete's ability to control their range of motion and have strong musculature surrounding joints can decrease the risk of injury (Armstrong, 2018).

Dr. Dave Tilley (DPT, SCS, CSCS), the owner of Shift Movement Science and clinician at Champion Physical Therapy in Boston, MA, shared his perspective on post-surgical range of motion. In his experience, about half of gymnasts have difficulty regaining dorsiflexion range of motion after surgery. Younger athletes, such as those with ruptures while still in high school, tend to have an easier time. A possible explanation is that their tissue quality is better, as they have taken less load than college athletes. College athletes are more likely to have changes in their talocrural joints from repeatedly landing short over the years. (Tilley, D., oral communication, 2023). Other factors associated with early range of motion may include surgical protocols, location of the tear, and management of swelling (Tilley, D., oral communication, Feb 2023).

After the protective phase, it is important not to overstretch the tendon. Dr. Lukes (DPT, SCS, CSCS), a DPT for Duke Athletics, spoke about a certain level of tension in the Achilles tendon that is necessary to utilize its ballistic qualities with the stretch reflex, which allows the athlete to generate enough force output for their sport. For this reason, we do not want to overstretch the tendon (Lukes, D., oral communication, Mar 2023). In Tilley's experience, soft tissue work to the gastrocnemius heads has been successful in taking the tension off the Achilles tendon without the worry about overstretching the tendon (Tilley, D., oral communication, Feb 2023). Dr. Matt McDougal (DPT, CSCS), who also works with gymnasts, said he would be cautious performing posterior talocrural joint mobilizations. While the mobilization is thought to help increase dorsiflexion, it may place unnecessary stress on the posterior lower leg in early rehab (McDougal, M., oral communication, Mar 2023).

Creating a Strength and Conditioning Base

A good strength foundation, including a gradual, individualized rehab program is vital when creating a plan of care. Outcome measures help track athletes' progress and the return to sport process. Much of rehab is walking the line between regaining strength and motion without overloading or causing excessive scarring (Lukes, D., oral communication, Mar 2023). This underlines the importance of having a certified practitioner to guide the athletes each step of the way and adjust the program as necessary. A study conducted in 2020, *Exercise Progression to Incrementally Load the Achilles Tendon*, by Baxter et al., investigated

tendon load with different exercises. It is a great reference for better understanding the demands placed on the body for exercise progression (Baxter et al., 2021).

Tilley emphasized the concept of creating an "insurance policy" to optimize the athlete's readiness for gymnastics. This policy involves maximizing the athlete's overall abilities. By enhancing strength and power in various lower extremity movements and plyometrics across the sagittal, frontal, and transverse planes, the risk of re-rupture is reduced. Prior to commencing gymnastics-specific return-to-sport progressions, athletes should engage in high-force, high-volume, single-leg, multi-directional plyometric exercises (Tilley, D., oral communication, Feb 2023). Strengthening within different ranges of a joint is also important because different skills in gymnastics require the body to adapt and perform in various ranges (Barber, S., oral communication, Mar 2023). The landing phase in gymnastics demands greater eccentric braking force compared to take-offs. Although landings generally don't lead to ruptures, it's crucial to incorporate landing mechanics into the return-to-sport protocol. When reintroducing landings in the gym, a suitable initial step is to perform depth drops onto a firm 20 cm (8-inch) landing mat or a resistance pit landing. Using older mats with excessive variability may elevate the risk of ankle rolling, while transitioning straight to a floor presents a substantial spike in load (Tilley, D., oral communication, Feb 2023).

Blood Flow Restriction (BFR) is the utilization of a tourniquet to decrease blood flow to the affected limb. It is a safe way to increase muscular strength post-injury and it stimulates hypertrophy at significantly lower

loads than without BFR (Hughes et al., 2017). In Achilles ruptures, BFR has been shown to increase calf strength (Hansen et al., 2022). Dr. Barber has also found BFR helpful in early rehab. This is because patients can experience the advantages of working at 80% of their one-repetition maximum (1RM) while actually exerting only 20-30% of their 1RM (Barber, S., oral communication, Mar 2023). Combining traditional resistance rehab programs and BFR may correlate with improved athletic performance (Wortman et al., 2021).

Return to Sport Testing

Outcome measures allow for the tracking of quantitative and qualitative data over time. Many clinicians rely on outcome measures or a performance battery when deciding if an athlete is ready to return to sport. The return to sport is a gradual process, and passing a battery of tests does not automatically clear an athlete for all activities. The introduction of predetermined "benchmarks" before initiating gymnastics-specific skills can aid in reducing the risk of setbacks attributed to pain, weakness, or the possibility of a re-rupture (Tilley, D., oral communication, Feb 2023). Regrettably, there is no universally accepted gold standard, leading to significant variations in clinicians' opinions. The multitude of available tests makes it challenging to determine the most appropriate ones. Opting for tests that align closely with the skill requirements of gymnastics enhances content validity. This section will briefly discuss components of various testing batteries employed by clinicians, along with a few existing return-to-sport protocols. Although the Orthopedic Associates of Hartford has

introduced a return-to-sport protocol for Achilles injuries, it lacks gymnastics-specificity. Nevertheless, it serves as a reference for return-to-sport testing. The protocol establishes criteria for patients to achieve a Limb Symmetry Index (LSI) of 95% or higher on hop tests. The LSI compares performance between the injured and non-injured limbs, offering a baseline for monitoring progress over time. It is applicable to nearly any objective test involving single-leg use, with its validity increasing when used as part of a battery of tests rather than a singular measure (2018 & Orthopedic Associates of Hartford (OAH)).

Strength Testing

Prior to commencing sport-specific activities, Dr. Barber sets a target for her patients to achieve 90% or more limb symmetry in the quadriceps and hamstrings. She assesses heel height during a single-leg heel raise and employs a dynamometer to evaluate soleus strength. For the seated heel raise, her goal is for patients to train at $\frac{1}{2}$ of their body weight at three months post-op, 100% of body weight at six months, and 1.5 times body weight at nine months, with 3-4 sets of 6 repetitions. Dr. Barber also utilizes a handheld dynamometer for measuring quadriceps and hamstring strength, assessing both side-to-side and front-to-back (Barber, S., oral communication, Mar 2023). Duke Athletics incorporates the isometric seated calf raise test, using force plates to evaluate gastrocnemius and soleus strength. Force plates provide metrics on force output, rate of force development, and fatiguability (Lukes, D., oral communication, Mar 2023).

An isokinetic dynamometer is the gold standard for isometric testing and is a part of

rehab at Duke Athletics for quantifying limb symmetry for quadricep and hamstring strength (Lukes, D., oral communication, Mar 2023). Isokinetic dynamometers are very expensive and are not typically available in outpatient clinics; therefore, handheld dynamometers are becoming more common in clinics. A systematic review by Stark et al. concluded that handheld dynameters show minor differences in data collection when compared to isokinetic testing (Stark et al, 2011). The intrarater reliability has also shown to be reliable for lower extremity strength testing (Jackson et al., 2016). If dynamometers are unavailable, it is even more important to look at main lifts and loaded functional activities to watch for asymmetries or weaknesses. These may include but are not limited to squats, single-leg squats, deadlifts, single-leg Romanian Dead Lifts (RDLs), and heel raises.

Plyometrics and Power

A study conducted at Duke University aimed to identify a set of performance metrics that are both valid and efficient for assessing performance and limb symmetry. They employed five tests, with two focusing on plyometrics: the forward single-leg hop and the timed single-leg hop (Lentz, 2020). For squat jump or countermovement jump (CMJ) testing, Champion Physical Therapy and Duke Athletics use force plates, providing quantitative data on peak torque and symmetry, among other values (Tilley, D., oral communication, Feb 2023 and Lukes, D., oral communication, Mar 2023). If force plates are not available, the Sargent vertical jump test is an alternative to assess lower extremity power, though asymmetries may be

more challenging to detect visually compared to using a force plate (Clanton et al., 2012).

Tilley employs specific plyometric exercises as a "tester" to evaluate how athletes respond to the initiation of plyometrics. The sample plyometrics include pogo hops, scissor hops, and in-and-out hops, with 20 repetitions for each. Additionally, athletes perform jogging, skipping, and side shuffling for the length of the floor exercise, with one round consisting of going down and back. This routine involves around 200 ground contacts. If repeated sessions of this regimen do not result in increased symptoms, athletes may gradually progress to performing it on the rod floor three times a week, allowing them to acclimate to the impact of springs once again (Tilley, D., oral communication, Feb 2023).

Balance and Range of Motion

Hartford's protocol recommends achieving greater than 35 degrees dorsiflexion on a Dorsiflexion Lunge Test before attempting sport-specific activities (OAH). The Y-Balance Test is widely employed, providing an overall assessment of single-leg balance and the ability to control dorsiflexion (Shirley Ryan). The anterior part of the Y-balance test assesses ankle stability and range in a dorsiflexed position, crucial for tumbling (Cook et al., 2015). Duke University's study for younger athletes found that in addition to the Y-Balance test, stork balance and single leg stance on a BOSU ball offer concise ways to evaluate performance and leg symmetry (Lentz, 2020). Champion Physical Therapy and the Orthopedic Associates of Harford protocol use the kneeling dorsiflexion test throughout the

rehabilitation process (Tilley, D., oral communication, Feb 2023 and OAH).

Rehab Considerations for Younger Athletes

High school gymnasts experience fewer ruptures compared to collegiate athletes, but occurrences still happen. An obstacle in rehabilitation is the limited availability of weights in most gymnastics gyms. Effectively loading athletes without external load options can be challenging, especially during physical therapy sessions held in the gymnastics gym. Dr. Kramer (DPT, SCS), engaged in outreach at local gyms through Duke Sports Medicine, finds her athletes often use the heaviest weights available in their gyms, but may still not be adequately loaded for the sport's demands (Kramer, W., oral communication, Mar 2023). In response to this, McDougal emphasizes the importance of focusing on functional movement patterns and creatively utilizing external loads when faced with such limitations (McDougal, M., oral communication, Mar 2023). For all athletes, and particularly those without full access to weights, personalized care provided by a practitioner who comprehends the sport's demands is crucial for a successful recovery.

Return to Sport: Gymnastics Skills and Progression

The return to gymnastics skills is a highly individualized process, influenced by factors such as the gymnast's abilities, available equipment, strength levels, and more. There is no universal progression for regaining gymnastics skills, and the following section serves as a guide, with a primary focus on floor exercises due to the significant force exerted on the foot and ankle.

Back tumbling poses the highest risk of Achilles rupture and is typically the last skill to be reintroduced. Progression is influenced by the equipment used, ranging from the bounciest and most forgiving (tumble track) to less forgiving surfaces (rod floor and competition floor). While many gyms have all three, some may lack specific equipment, emphasizing the importance of a robust plyometrics foundation. Collaboration with strength and conditioning coaches can be beneficial in tailoring the best program for each athlete, aiming to enhance strength and plyometric abilities before allowing them to resume tumbling (Tilley, D., oral communication, Feb 2023).

Floor and vault require more force and pounding than bars and beam. Consequently, clinicians often recommend alternating between floor and vault activities during the return-to-sport progression. An example could involve starting with one day of floor exercises and one day of vault per week, gradually increasing to two days each week. As the gymnast regains skills, the tendon's endurance can be assessed, potentially progressing to a single day combining both floor and vault exercises, with responses carefully monitored (Barber, S., oral communication, Mar 2023, and Kramer, W., oral communication, Mar 2023).

Bars

McDougal takes into account the risk of rupture when guiding athletes through their progression. Since there have been no reported ruptures on bars, he permits athletes to proceed unrestricted on the bars before other events (McDougal, M., oral communication, Mar 2023). Dr. Barber adopts a similar approach, allowing her athletes to start bars exercises once they have

achieved full plantarflexion and can tolerate the transition from end-range plantarflexion to end-range dorsiflexion. This consideration is particularly important due to the force exerted on the ankle in plantarflexion during various skills, especially giants. Wearing shoes can assist in alleviating fears and protecting the ankle in the initial stages (Barber, S., oral communication, Mar 2023). Caution is advised on dismounts, and landings should be directed into a pit for as long as necessary.

Beam

If the gymnast has experienced a rupture in their dominant leg, the progression of beam skills may require adjustment. Numerous skills on the beam necessitate a single-leg landing onto the dominant leg. Performing a single-leg landing is challenging due to the increased eccentric loading on the tendon compared to a double-leg landing. A cross-sectional study investigating loading rates and eccentric forces post-tendon rupture found that the involved leg continued to experience increased loading rates, indicating decreased strength up to six years after surgery (Powel et al., 2018). In light of this information, skills involving a two-legged landing or a single-legged landing on the non-injured leg should be reintroduced first. However, when the athlete receives clearance to resume beam skills, they should possess the requisite strength to manage these loads. Fear is a significant factor on beam, and skill progression is therefore largely driven by the athlete (Barber, S., oral communication, Mar 2023).

Vault

9% of tears occur on the springboard impact for a Yurchenko (Bonanno et al., 2022). Additionally, sprinting puts greater

load on the Achilles tendon than jogging during warm-ups. A study on endurance runners demonstrated that dorsiflexion requirements increase proportionally to velocity, with runners exhibiting over 24.5 degrees of dorsiflexion and over 6,043 N.s/km of weighted force on the tendon (Starbuck et al., 2021). To provide context, the general population typically utilizes 10 degrees of dorsiflexion in normal gait (Yoon et al, 2021). This underscores the significance of a robust strength program focusing on the calf and extending up the kinetic chain to the glutes and hamstrings to mitigate some of the imposed load.

A vault runway typically consists of a two-inch pad over concrete with no springs underneath. Many athletes report more pain while sprinting down the runway than in any other event (Barber, S., oral communication, Mar 2023). It is crucial to approach the progression of springboard impacts gradually, acknowledging that longer and faster runs toward the springboard will exert more force on the repair site. Gradually increasing the number of impacts and considering shorter runs or jogging into the springboard for drills are prudent progressions. Initiating vault drills on a Tumble Track and rod floor can be a viable option to manage load. If feasible, setting up a vault off the rod floor into a pit can decrease load by making the springboard "bouncier," thereby reducing forces on the ankle joint. This approach may feel better for the athlete, as they won't have to push off as hard (Barber, S., oral communication, Mar 2023).

Floor

As discussed previously, 91% of ruptures occur on floor. Therefore, it should

be a top priority in planning the return to gymnastics. Clinicians generally suggest that athletes begin tumbling two to three times a week, with a day of rest in between to monitor symptoms and adjust the plan based on progress or regression. The progression should be gradual, with skills not advancing drastically faster than every two weeks. Pain and swelling should serve as key indicators for guiding the process. (Barber, S., oral communication, Mar 2023, Tilley, D., oral communication, Feb 2023, and Kramer, W., oral communication, Mar 2023).

The provided schematic outlines a sample return-to-tumbling plan, considering three variables: skill difficulty, landing surface, and volume. Only one of these variables should be progressed at a time. The plan begins with all skills on the Tumble Track, then transitions to 50% Tumble Track and 50% rod floor. Subsequently, it moves to 50% rod floor and 50% hard floor. Throughout the process, the "hardest skills" are performed on the softest surface. When entering a new phase, activities from the previous phase are conducted on a harder surface 50% of the time. It's essential to understand that a phase does not equate to a week. Both Tilley and Barber recommend at least two weeks exclusively on a trampoline or tumble track at the beginning (Barber, S., oral communication, Mar 2023; Tilley, D., oral communication, Feb 2023). Understanding the biomechanical and physiological requirements of each skill performed before the injury is crucial, as different skills may necessitate varied considerations and timelines.

Phase	Tumble Track	Rod Floor	Hard Floor: onto sting mat, 10 cm (4"), or 20 cm (8") when able
1	2 legged jumps (straight, tuck, split, etc.)	NA	NA
2	50% of time with 2 legged jumps	50% of time with 2 legged jumps	NA
3	NA	50% of time with 2 legged jumps	50% of time with 2 legged jumps
4	Single BHS, front tuck, back tuck, snap down from a block push back	NA	2 legged jumps
5	RO scoop through drills, RO	Single BHS, front tuck, back tuck, snap down from a block push back	2 legged jumps
6	RO BHS, FHS front tuck	50% of time with Single BHS, front tuck, back tuck, RO, snap down from a block push back	50% of time with Single BHS, front tuck, back tuck, snap down from a block push back
7	Multiples of BHS, FHS, front tucks, FHS front tuck/layout	RO BHS, FHS front tuck	Single BHS, front tuck, back tuck, RO, snap down from a block push back
8	RO BHS layout (into pit or resi with scoop through to their back)	RO BHS, FHS front tuck	Single BHS, front tuck, back tuck, RO, snap down from a block push back
9	RO BHS full (into pit), combination front tucks	Multiples of BHS, FHS, front tucks, FHS front tuck/layout	Single BHS, front tuck, back tuck, RO, snap down from a block push back
10	RO BHS double backs (into pit)	RO BHS layout, front layouts	RO BHS, FHS front tuck
11	RO BHS double pikes (into pit, upper-level front tumbling), RO BHS full onto resi landing or 20 cm (8") in the pit	RO BHS layout, front layouts	Multiples of BHS, FHS, front tucks, FHS front tuck/layout (onto resi if able)
12	Double backs onto resi landing or 20 cm (8") in the pit	Back fulls into pit, basic front combination passes	Multiples of BHS, FHS, front tucks, FHS front tuck/layout, RO BHS layout (onto resi if able)
13	Full tumbling onto resi landing or 20 cm (8") in the pit	Back fulls to resi or 20 cm (8") in pit, Double backs into pit	RO BHS BHS, FHS front tuck, RO BHS layout (onto resi if able)
14	Full tumbling onto resi landing or 20 cm (8") in the pit	Double backs into pit	Back fulls, basic front combination passes
15		Double backs onto resi or 20 cm (8") in the pit	Back twisting, Full front tumbling passes
16			Double backs
17			Full tumbling

*BHS = back handspring; FHS = front handspring; RO = round off

Figure 2: Sample Return to Tumbling

CONCLUSION

The primary goal of medical providers is to assist patients in achieving their goals safely and effectively, minimizing the risk of re-rupture. Achieving this goal requires a comprehensive understanding of sport-specific considerations for each skill. Decision-making regarding the return to sports is a complex process, taking into account factors such as mobility, stability, strength, movement quality, power, perception of injury, and confidence, among others. It's crucial to acknowledge the individuality of each athlete, leading to variations in timelines. Effective programs should be progressive, systematic, adjustable, and personalized to optimize athletes' success. This paper serves as a guide for clinicians, aiming to enhance awareness and education on crucial factors in gymnastics rehabilitation. The gymnastics field would benefit from additional research, especially in areas such as the psychological impact of injuries, Blood Flow Restriction, the recent surge in rupture rates, and the establishment of a gold standard for a performance battery.

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Article received: 23. 7. 2023

Article accepted: 25. 10. 2023

IS THERE ANY EFFECT OF THE SEVERITY OF FLEXIBLE PES PLANUS ON THE BALANCE PERFORMANCE IN ELITE GYMNASTS?

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Original article

DOI: 10.52165/sgj.16.1.43-53

Abstract

Flexibility is an important component of athleticism in gymnasts' training, as its insufficient development can significantly complicate the process of formation of specific skills and movement coordination and limit the possibility of manifesting and increasing strength and speed abilities (Дейнеко & Біленька, 2021). The aim of this study was to analyse the impact of the severity of FPP on balance performance in different planes (frontal, sagittal and overall balance) in the Turkish national youth team. This study is a prospective and double-blinded cohort study conducted in the Department of Physiotherapy and Rehabilitation of Bolu Abant İzzet Baysal University. The evaluation protocol consists of two main phases: first, the measurement of joint positions or angles (subtalar joint position, subtalar joint angle, first metatarsophalangeal (MTP) extension angle and tibia-femoral angle measurement), second, the measurement of balance. 20 participants aged 13-18 years, male and female, from the Turkish national youth gymnastics team were included in this study. Linear regression analysis was performed to determine whether there is an effect of severity of FPP on balance performance. There is no clear effect of FPP severity on balance performance in youth gymnastics at the national level. However, some evaluations show significant associations in the frontal plane in relation to the mediolateral stability index. None of the assessments showed a significant association with the anteroposterior stability index.

Keywords: elite gymnasts, pes planus, balance performance.

INTRODUCTION

Gymnastics has been accepted as a framework for many different disciplines since ancient times. It is a professional, popular and attractive sport. The International Gymnastics Federation has classified gymnastics into 8 categories: rhythmic, artistic, acrobatic, aerobic,

trampoline, group gymnastics, parkour and tumbling (FIG, 2023). Optimal performance in gymnastics is associated with many factors such as sensory-motor, physiological and balance (Ahmadabadi, Avandi, & Aminian-Far, 2015). Balance is one of the crucial factors because it is

related to the level of flexibility, reaction time, motion control, injury rate and the number of falls (Cottyn, De Clercq, Pannier, Crombez, & Lenoir, 2006; Wrisley & Whitney, 2004). According to the definition, balance is 'the ability to retain equilibrium by positioning the gravity center over the support base (Browne & O'Hare, 2001). Single leg stance tests are frequently used both for testing and training balance in sports medicine (Riemann & Davies, 2013).

Since the lack of balance control is related to an increased risk of injury or falling (Wrisley & Whitney, 2004), the prophylactic programs or rehabilitation protocols should be maintained to enhance postural balance (Cobb, Tis, Johnson, & Higbie, 2004). It is clear that changes in foot posture such as pes planus, cavus, or rectus, may affect human balance in all axes, such as the sagittal plane (anteroposterior), frontal plane (mediolateral) or overall balance (Hertel, Gay, & Denegar, 2002; Park, Lee, & Park, 2021). Most published studies have demonstrated that pes planus or cavus is associated with less postural balance when compared to pes rectus (Cote, Brunet, Gansneder, & Shultz, 2005; Kabak, Kocahan, Akinoglu, Genc, & Hasanoglu, 2019; L.-C. Tsai, Yu, Mercer, & Gross, 2006). According to Cobb et al. (2004), pes planus showed reduced postural balance in anteroposterior direction compared to pes rectus.

Pes planus is a common condition for both children and adults. An epidemiological study on 825.964 adolescents showed a high prevalence of pes planus with 12.4% mild pes planus and 3.8% severe pes planus (Tenenbaum et al., 2013; Yucesan et al., 1993). Another study on 19.750 children, between 6-15, demonstrated the prevalence of flexible pes

planus (FPP) as 0.23% (Yucesan et al., 1993). Pes planus is a general term that consists of various definitions and may be classified into two forms: rigid and flexible (Dars, Uden, Banwell, & Kumar, 2018). First, pes planus is related to forefoot supination with heel eversion or pronation (Ferciot, 1972). Second, Staheli (Staheli, Chew, & Corbett, 1987) describe pes planus as a wide base foot contact. Third, pes planus is associated with the lack of longitudinal arch or the abnormally collapsed longitudinal arch in the foot (Forriol & Pascual, 1990). If the longitudinal arch on the foot changes during weight-bearing compared to non-weight bearing, it can be considered as flexible pes planus (Roth, Roth, Jotanovic, & Madarevic, 2013). The difference in foot posture between weight-bearing and non-weight-bearing in FPP is rearfoot eversion (Kothari, Dixon, Stebbins, Zavatsky, & Theologis, 2015). If the rearfoot shows the same rearfoot eversion during both weight-bearing and non-weight-bearing, it can be called rigid pes planus (RPP) (Evans, 2008). The RPP accounts for only 1% of total pes planus cases (Evans, 2008). There is no gold standard diagnostic technique for FPP (Stavlas, Grivas, Michas, Vasiliadis, & Polyzois, 2005). For the diagnose of FPP, the heel position (varus/valgus), rearfoot angle, arch formation and navicular height may be evaluated during weight-bearing and non-weight-bearing (Dars et al., 2018). The combination of some assessments and the analysis of foot postures may be performed to reach high accuracy in RPP diagnosis (Evans, 2008). Many treatment options have been proposed for FPP in both childhood and adulthood. Some clinicians prefer not to administer any treatment because they claim asymptomatic pes planus does not reduce sports performance

and motor ability (Pfeiffer, Kotz, Ledl, Hauser, & Sluga, 2006; Tudor, Ruzic, Sestan, Sirola, & Prpić, 2009). However, others suggest that FPP may cause abnormal gait, pain, poor balance and motor dysfunction (Harris et al., 2004; Rome, Ashford, & Evans, 2010). Many studies have shown reduced FPP after implementing interventions such as stretching and strengthening exercise, foot orthosis, joint manipulations and activity modification (Halabchi, Mazaheri, Mirshahi, & Abbasian, 2013; Harris et al., 2004). It is clear that many studies have focused on the relationship between pes planus and balance performance (Cote et al., 2005; Hertel et al., 2002; Kabak et al., 2019; Park et al., 2021; L. C. Tsai, Yu, Mercer, & Gross, 2006). However, there is limited knowledge regarding the effect of FPP degree on balance performance. This study aims to analyze the impact of FPP severity on balance performance in different planes (frontal, sagittal, and overall balance) in Turkish National Team Juniors Gymnastics. It is hypothesized that gymnasts with higher FPP severity may exhibit lower balance performance.

METHODS

This prospective cohort study was carried out at the Bolu Abant Izzet Baysal University Physiotherapy and Rehabilitation Department. Participants, both females and males, aged between 13-18, from the Turkish National Team Junior Gymnastics, were recruited for this study. All volunteer participants' parents/guardians or coaches were informed about the study and signed consent forms. This study was conducted with a double-blinded design, ensuring that both the examiner physiotherapist and the

participants were not aware of its aim. This study was approved by the Bolu Abant Izzet Baysal University Research Ethics Committee. Participants were included if they met the following criteria (1) aged between 13-18, (2) uninterrupted training for at least 4 years, (3) having 1- or 2-degree pes planus (4), not having rigid pes planus (5), not having any pathological disease related to the foot, ankle, knee or hip, and (6) competing at the National Team Gymnastics level.

The measurements were executed in the following order: Feiss line test, body measurements (Tanita TBF-310), joints position or angle measurements, and balance measurements (The Biodex Balance System).

To assess whether the participants had 1- or 2- degree pes planus, the Feiss line test was conducted. A physiotherapist was trained to perform this test. The physiotherapist drew a line between the first metatarsal head and the medial malleolus, and this line was compared with the position of the navicular head on the medial side. The gap between the line and the navicular head divided into 3 equal gaps, determining first, second or third grades pes planus or pes cavus. This test was repeated in sitting and standing positions to ensure the absence of RPP (navicular drop test).

The evaluation protocol was explained to the participants at the beginning. The evaluation protocol consisted of two main stages: first the joints positions or angle measurements (subtalar joint position, subtalar joint angle, first metatarsophalangeal (MTP) extension angle and tibia-femoral angle measurement), second, balance measurement. Each evaluation test was performed by the same examiners.

1. Joints positions or angles

measurements

a. Subtalar joint position measurement

This measurement was conducted both during prone and standing on a podoscope for both legs. For this measurement, the subtalar joint center was determined as the pivot, and then the position between the calcaneus center and Achilles tendon was recorded in terms of varus or valgus with a goniometer. The difference between standing and prone positions was determined as the FPP degree. This measurement was modified from the navicular drop test.

b. Subtalar joint angle measurement

When the gymnast was in the prone position, the first examiner was asked to do ankle active inversion and eversion, and the active range of motion (ROM) was measured with a goniometer. Then, the second examiner performed passive inversion and eversion, and these ROMs were also recorded. For inversion or eversion, the subtalar joint posterior aspect at the malleoli level was determined as the pivot, and then the angle between a line passing from the lower foot and a line bisecting calcaneus was measured. All ROMs for both feet were recorded in terms of degrees.

c. First metatarsophalangeal extension angle measurement

When the participant was standing, the first examiner was asked to perform MTP active extension, and then the examiner measured and recorded it with a goniometer. Then, the second examiner made passive MTP extension, and it was measured and recorded for both feet. For the first MTP extension, the MTP joint center was determined as the pivot, and then the angle between the metatarsal midline and phalanx midline was measured.

d. Tibia-femoral angle extension

This measurement was conducted both during the supine and standing position for both legs. For this measurement, the patella center was determined as the pivot, and then the angle between the femur midline and tibia midline was recorded with a goniometer.

2. Dynamic balance measurement

Balance measurement was performed using The Biodex Balance System (Biodex Medical Systems Inc, Shirley, New York). The Biodex Balance System has been developed for assessment, treatment and training during both dynamic and static motions. Initially, the examiner demonstrated the Biodex Balance System to the participants, and the participants were given enough time to warm-up and train on the System. Single-leg stance tests on both legs and double-leg stance tests were performed while the participants had both eyes first open, and then closed. The system's degree of mobility was set at 1 (the highest mobility level) during closed and opened eyes in the sagittal plane (anteroposterior), frontal plane (mediolateral), or overall balance. All tests were repeated 3 times, and the best score was recorded.

Linear regression analysis was performed to determine whether there is an effect of FPP severity. The regression analyses were between the mediolateral stability index and the following variables: subtalar joint position, subtalar joint angle, and tibia-femoral angle. Additionally, regression analysis was performed between the anteroposterior stability index and the first metatarsophalangeal extension angle. Moreover, analyses between the overall stability index and all joints' positions or angles measurements were conducted. Statistical analyses were performed using SPSS (Version 26, IBM Corporation,

Armonk, NY, USA). The level of significance (p-value) was set at <0.05.

RESULTS

Demographic information including sex, education level and the gymnastic specialization is shown in Table 1. Physical information, including age, height, mass, year in gymnastic, continuous year sin gymnastic, number of trainings, and Tanita

information, is presented in Table 2. Table 3 displays the minimum (min), maximum (max), mean, and standard deviation (SD) of evaluated results, including subtalar joint position, subtalar joint inversion angle, subtalar joint eversion angle, MTP extension angle and tibia-femoral angle. Table 4 presents the measurements of overall, anteroposterior and mediolateral stability index in dynamic measurements

Table 1: Demographic information including sex, education level and special area

		n	%
Sex	Female	10	50
	Male	10	50
Education level	University	1	5
	High school	15	75
	Secondary school	4	20
Gymnastics category	Artistic gymnastics	16	80
	Trampoline gymnastics	4	20

n: Number of Participants, **%:** Percentage of Participants

Table 2: Physical information including age, height, mass, year in gymnastic, continuous years of training gymnastics, number of trainings, and Tanita information.

	Mean	SD
Age (year)	15.75	1.77
Height (cm)	159.60	14.11
Mass (kg)	76.20	11.23
Training history in gymnastics	9.10	2.12
Years in gymnastic (continuous)	9.05	2.16
Number of training sessions per week	7.80	2.04
BMI	19.60	2.34
Fat (%)	13.34	5.35
Minerals (%)	4.47	0.27
Protein (%)	18.78	1.22
Muscle Mass (kg)	40.58	9.54

SD: Standard Deviation **BMI:** Body Mass Index

	n	Min.	Max.	Mean	SD
<i>Science of Gymnastics Journal</i>					
	47				
<i>Science of Gymnastics Journal</i>					

Right Subtalar Joint Position	20	12.00	26.00	19.35	4.48
Left Subtalar Joint Position	20	5.00	26.00	16.00	5.60
Right Subtalar Joint Inversion Angle	20	0.00	25.00	8.25	7.44
Left Subtalar Joint Inversion Angle	20	-5.00	19.00	6.90	6.78
Right Subtalar Joint Eversion Angle	20	0.00	20.00	4.90	5.97
Sol Subtalar Joint Eversion Angle	20	0.00	19.00	7.45	6.57
Right MTP Extension Angle	20	10.00	35.00	21.35	7.04
Left MTP Extension Angle	20	11.00	31.00	19.65	5.41
Right Tibiofemoral Angle	20	-7.50	7.60	0.94	3.95
Left Tibiofemoral Angle	20	-5.70	8.00	1.00	3.69

Table 3: The results of evaluated joint measurements.

n: The Number of Participants, Min: Minimum, Max: Maximum, SD: Standard Deviation

Table 4: The measurements of overall, anteroposterior, and mediolateral stability index.

	n	Min.	Max.	Mean	SD
Right Overall Stability Index	20	1.10	17.10	5.20	4.75
Left Overall Stability Index	20	0.60	12.30	5.23	3.46
Right Anteroposterior Stability Index	20	0.60	7.50	2.74	2.06
Left Anteroposterior Stability Index	20	0.50	6.40	2.72	1.84
Right Mediolateral Stability Index	20	0.70	14.70	3.87	4.15
Left Mediolateral Stability Index	20	0.30	9.80	3.93	2.86

n: The Number of Participants, Min: Minimum, Max: Maximum, SD: Standard Deviation

Table 5: The statistical analysis of linear regression between joint angle positions and stability indexes.

	Right Overall S. I.	Left Overall S. I.	Right AP S. I.	Left AP S. I.	Right ML S. I.	Left ML S. I.
Right Sub. J. P.	p=0,73				p=0.65	
Left Sub. J. P.		p=0.21				p=0.28
Right Sub. J. Inv. A.	p=0.16				p=0.11	
Left Sub. J. Inv. A.		p=0.01*				p=0.01*
Right Sub. J. Ev. A.	p=0.57				p=0.20	
Left Sub. J. Ev. A.		p=0.10				p=0.05*
Right MTP Ex. A.	p=0.60		p=0.56			
Left MTP Ex. A.		p=0.64		p=0.59		
Right TF. A.	p=0.09				p=0.09	
Left TF. A.		P=0.05				p=0.03*

J.P: Joint Position, Inv: Inversion, Ex: Extension, A: Angle, MTP: Metatarsophalangeal, TF: Tibiofemoral, S.I: Stability Index, AP: Anteroposterior, ML: Mediolateral, * = p <0.05.

A regression analysis between the balance measurements and the measured joint positions and angles is presented in Table 5. Both right and left subtalar joint positions did not exhibit any significant associations with their related stability indexes. Similarly, both right and left MTP angles did not show any significant relations with anteroposterior stability. However, significant relationships were observed between left mediolateral stability and certain assessments, such as left subtalar joint inversion ($p=0.015$), left subtalar joint eversion ($p=0.05$), and left tibiofemoral angle ($p=0.039$). Notably, the left subtalar joint eversion angle had a significant impact on overall left stability ($p=0.019$)

DISCUSSION

The study found that there is no significant relationship between the severity of FPP and balance in Turkish National Team junior gymnasts. As a result, the initial hypothesis suggesting a negative impact of FPP severity on balance stability was rejected. The findings highlight that FPP severity may not be the sole determinant affecting balance. Previous research has indicated that individuals with abnormal foot posture, such as pes planus, tend to exhibit compromised balance ability (Hertel et al., 2002; Park et al., 2021). However, these studies have not specifically delved into the impact of the severity of abnormal foot postures. It is noteworthy that flexibility in pes planus may manifest as a lack of apparent rearfoot eversion during non-weightbearing, with clear rearfoot eversion evident when transitioning to weightbearing conditions (Kothari et al., 2015). This study provides a comprehensive evaluation, considering

motion changes from prone or supine to standing, and distinguishing between active and passive ranges of motion (ROMs). By recruiting exclusively gymnasts with FPP, the research focused on understanding the flexibility grade of pes planus. Despite the absence of clear associations between the subtalar joint and balance, the study revealed notable relations between left foot mediolateral stability and subtalar eversion, inversion, and tibiofemoral angle. Previous studies have indicated a connection between abnormal subtalar joint, particularly eversion, and FPP attributed to a lowered medial longitudinal arch (Ledoux & Hillstrom, 2002; Sinclair, Svantesson, Sjöström, & Alricsson, 2017; Zaret & Myerson, 2003). The findings of this study suggest that the relationship between the subtalar joint and balance may be more dependent on the subtalar joint's passive angle rather than its position.

Balance in gymnastics is associated with several determinants such as muscle strength, flexibility, reaction time, core stability, endurance, agility, and velocity (Ahmadabadi et al., 2015; Kabak et al., 2019; Pollock, Durward, Rowe, & Paul, 2000; Russo et al., 2021). Apparently, the severity of FPP or subtalar joint position represents just one element within the broader framework of factors contributing to balance. When analyzing balance performance in gymnastics, it can be more meaningful to take into consideration some of the previously mentioned determinants.

The mention of high joint range of motions and low body fat percentage among National Team Gymnasts raises intriguing considerations. The correlation between these factors and the observed high level of FPP, especially the substantial difference in subtalar joint positions between prone and standing positions, adds depth to the

analysis. Furthermore, the gymnasts' ability to perform well when falling from significant heights onto one leg suggests a potential relationship between this performance and the high level of FPP. The notion of compensation by high muscle contraction and strength adds an interesting layer to understanding the complex interplay of factors influencing gymnastic balance.

Single-leg stand on a dynamic surface is not a difficult evaluation method for gymnasts. It can be safely assumed that gymnasts from the National Team would exhibit significantly better balance performance when compared to healthy sedentary peers. Maybe, a more complex analysis method should be used for further studies. However, the Biodex Balance System is a reliable and objective assessment method for athletes, capable to assess in different planes (sagittal, frontal and overall) (Dabbs, Sauls, Zayer, & Chander, 2017). Integrating data on muscle strength could potentially unveil additional insights into the intricate dynamics of balance in gymnasts.

For this study, 20 junior gymnasts on the national level were recruited. The sample size may be too small. However, it was a deliberate choice to recruit only national-level gymnasts. Further studies focusing on multiple centers may counterbalance the small size and provide more meaningful results.

CONCLUSION

There is no clear impact of the FPP severity on balance performance among national-level junior gymnasts. However, some analyses show significant relations on the frontal plane (mediolateral stability index). There is no significant association

with the anteroposterior stability index. These findings provide a better understanding of the relationship between the severity of FPP and balance. Future studies should employ more complex assessment tools for both FPP and balance assessments and recruit a larger national-level sample size.

ACKNOWLEDGMENT

We would like to thank the members of the Turkish Junior Gymnastics National Team and the officials of the Turkish Gymnastics Federation.

No external financial support was received for this study.

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Article received: 29. 5. 2023

Article accepted: 25. 9. 2023

THE EFFECT OF LEG STIFFNESS ON REACTIVE AGILITY, JUMPING AND SPEED IN GYMNASTICS ATHLETES

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Original article

DOI: 10.52165/sgj.16.1.55-65

Abstract

In reviewing the literature, it was decided to conduct this study due to the lack of studies investigating the influence of leg stiffness on performance parameters such as reactive agility, jumping power and speed in gymnasts. The aim of this study is to investigate the effects of gymnasts' leg stiffness on performance parameters such as reactive agility, jump and speed. For this purpose, 65 gymnastics athletes aged 12-22 years were included in the study. The drop jump test (with Optojump measuring device) was used to evaluate the jump, and the vertical jump test (Optojump measuring device) for the evaluation of leg stiffness, while the 20m sprint test (with Witty measuring device) was made for speed evaluation. The measurements of reactive agility were performed with the SpeedCourt™. As a result of our study, we found a moderate positive correlation between the leg stiffness values and the reactive strength index (RSI) values obtained from the gymnastics athletes' jump tests. In addition, we found a negative relationship at a low level between speed and agility with leg stiffness values. It can be concluded that increasing gymnasts' leg stiffness contributes positively to jumping power, speed and reactive agility. In this case, it is recommended to include plyometric exercises in the training programs to improve the leg stiffness of trampoline gymnasts, rhythmic gymnasts and artistic gymnasts who focus on jumping.

Keywords: *gymnastics, jumping, leg stiffness, reactive agility, speed*

INTRODUCTION

Leg stiffness is a quantitative measure of the body's elastic properties and determines its ability to accumulate potential elastic energy (Butlar et al.,2003: 511-517; Struzik et al., 2021:1). The ability to absorb and return potential elastic energy is also observed in the muscle-tendinous

groups in the human body. During the contractile cycle of a muscle, for example, during the lengthening of the entire muscle-tendon unit, the potential elastic energy stored by passive structures (tendon and aponeurosis) can increase the energy supplied by adaptive tissues during the

progressive shortening phase. Consequently, the capacity of the tendon and aponeurosis to store elastic tension energy can increase the total mechanical energy produced by the muscle-tendon unit during the concentric phase of muscle work or decrease muscle fiber work and metabolic energy expenditure. The potential elastic energy stored in the muscle-tendon units reduces the metabolic energy expended by the muscles responsible for movement in certain joints and is associated with the change in the kinetic energy of the moved body. (Struzik et al., 2021:1; Zawadzki & Struzik, 2019:154-160). Therefore, stiffness, which is a quantitative measure of the resistance of an elastic body to deformation, can be seen as an important factor in optimizing human movement as it is related to the maximum performance of cyclic and single dynamic movements. (Butlar et al., 2003: 511-517; Dalleau et al., 2004:170-176; Maloney & Fletcher, 2021:109-130).

Gymnastics includes a range of activities ranging from slow extension-shortening cycles (ground contact time >250ms; e.g. acrobatic skills on the beam) to fast extension-shortening cycle activities (ground contact time <250 ms; e.g. rolling) (Mcneal et al., 2007:375-390). The elongation-shortening cycle performances can be evaluated by the reactive strength index (RSI) and leg stiffness in athletes (Lloyd et al., 2012: 2812-2819; Lloyd et al., 2015:1239-1247). Leg stiffness represents the average stiffness of the musculoskeletal system during ground contact (Farley et al., 1998:1044-155). The ability to generate and maintain high stiffness is an important factor of maximum performance in explosive exercises and is generally thought to affect the mechanics and kinematics of contact with the ground, where it affects

muscle performance through changes in strength, power, and flexibility (Maquirriain, 2013:48-53).

Speed is defined as the ability to cover distances quickly. Speed is necessary in most sports to show a successful level of efficiency, as it allows athletes to move quickly in a straight direction (Bompa & Haff, 2015:315-320). Agility, on the other hand, can be defined as a sudden change in speed of whole-body movement or change in direction in response to a stimulus (Sheppard et al., 2006: 342-349). Agility commonly preserves motor control in either the vertical or horizontal direction. It also provides an effective combination of stopping, changing direction and acceleration (Verstegen & Marcello, 2001: 139-166). Arampatzis et al. (1999: 1349-1353), in their published study, stated that running speed was associated with leg stiffness.

While the existing literature offers insights into the connection between leg stiffness in gymnastic athletes and various performance aspects, specific studies directly examining this link remain scarce. Notably, Marina et al. (2012) employed a similar metric (albeit under a different name) to analyze jumping performance extensively. Their work identified and differentiated key components of jumping force associated with distinct gymnastic techniques, particularly in floor and vault routines. Furthermore, a longitudinal study by Marina and Jemni (2014) tracked the effectiveness of jumping training in female elite gymnasts over two competitive seasons using this same ratio. Building upon this established link, the present study aims to delve deeper by investigating the specific impact of leg stiffness on reactive agility, jump, and speed parameters in elite gymnasts.

Our study sought to find answers to the following questions:

- Does leg stiffness affect reactive agility in gymnasts?
- Does leg stiffness affect the reactive strength index (RSI) measured in jumps in gymnastics?
- Does leg stiffness affect speed in gymnasts?

METHODS

Ethical approval for the study was obtained from Gazi University Ethics Committee (E-77082166-604.01.02-322274). Sixty-five athletes between the ages of 12-22, affiliated with the Turkish Gymnastics Federation, who have been engaged in gymnastics for at least 3 years were included in the study. Only athletes who had not competed in the past and had no lower extremity injuries in the last 6 months were included in the study. It was planned to evaluate the athletes who met the above criteria over the period of two days. After the demographic information (age, gender, height, weight, sports age) of the athletes was taken, warm-up exercises were performed for 15 minutes. The drop jump test for jump evaluation, the vertical jump test for lower extremity stiffness, and the 20m sprint test for speed evaluation were all conducted on the first day. On the second day, reactive agility measurements were made with a Speedcourt device. Athletes underwent tests ranging from easy to difficult exertion levels. Athletes first completed measurements by participating in the leg stiffness test, followed by the drop jump, and finally the 20-meter sprint test. On the first day, they concluded their initial assessments. On the second day, athletes participated in the reactive agility test. A five-minute rest period was provided

between the two different tests (Bishop et al., 2011).

In this section, data collection tools, data gathering procedures, and statistical analyses are detailed.

For the leg stiffness test, athletes were asked to jump as high as possible 7 times without stopping, keeping the minimum contact time with the ground, hands at the waist, feet parallel to each other and without bending the knees. The leg stiffness test was carried out using the OPTO-Jump® sistemi (Microgate, Bolzano, İtalya) device. 1 m Opto-Jump sticks (With a 96-diode resolution and a 1 kHz sampling rate, this enables the measurement of flight and contact times with a precision of 1/1000th of a second during the execution of a series of jumps) were placed on the ground with a maximum distance of 6 m between them. The athletes jumped between these two bars 7 times without interruption. Using the mean contact and flight times from all jumps and the participant's body mass, leg stiffness was calculated using the equation. The Leg Stiffness test involves having the athlete stand with hands on the hips, feet parallel, and knees minimally flexed in an upright position, ensuring minimal ground contact time by jumping as high as possible without leaving the ground. The measurement protocol involved initiating the jump on a signal and stopping after 10 seconds based on an alert. Athletes received a practice trial followed by two actual measurements with a 30-second rest between them.

Leg stiffness values are calculated using the formula below, utilizing the best flight and ground contact times:

$$KN = M \times \pi (T_f + T_c) \div T_c^2 [(T_f + T_c \div \pi) - (T_c \div 4)] \text{ (Dalleau et al., 2004).}$$

In this case, M represents body mass, T_f is the flight time, T_c is the ground contact

time, and π is the mathematical constant pi (approximately 3.14159).

When examining the structural characteristics of the discipline, it is observed that during competitions, techniques involve explosive features, particularly encompassing jumps and descents. In this context, a test protocol incorporating the characteristic of drop jump has been considered. The evaluation involved calculating the reactive strength index (RSI) using the drop jump test (depth jump), and measurements were conducted using the Opto-jump device. Athletes performed a drop jump starting from a 20 cm frame height, and the crate height was increased until the maximum breakage point was achieved. The test for each athlete was completed by noting the height at which the breakage occurred (for safety reasons, the crate height was increased to a maximum of 60 cm, considering the participants were younger gymnasts). Gymnasts performed drop jump (DJ) performances barefoot from step heights of 20, 40, and 60 cm. Athletes demonstrated two DJ performances at each height with a 1-minute rest between measurements. The Reactive Strength Index (RSI) was calculated as the ratio of the athlete's jump height in meters to the ground contact time (Ramirez-Campillo et al., 2023; Young, 1995). The best RSI value obtained from the two measurements was used in the analyses.

Running speed was assessed utilizing the Opto-jump modular system (Microgate, Bolzano, Italy), an optical measuring device. The Optojump Modular is an optical measurement system consisting of transmitter and receiver bars, each equipped with 96 LEDs and a resolution of 1.0416 cm. LEDs on the transmitter bar maintain constant communication with those on the receiver bar. The system identifies

interruptions in communication between the bars, calculates their duration, and facilitates the measurement of flight and ground contact times with a precision of 1/1000th of a second during running. The running system is achieved by using consecutive one-meter modules connected to each other. OptoJump is employed in conjunction with the Witty Timing system (Microgate, Italy). Athletes commenced from the starting line and completed the distance of 20m at their maximum speed. The finishing time was for each athlete recorded in seconds (sec), and the finishing speed in m/sec. Each athlete's performance was measured twice with a 2-minute rest interval between them. The best measurement result obtained from these repetitions was used in the analyses.

All tests were conducted in a closed area on the SpeedCourt™ system (Globalspeed GmbH, Hemsbach, Germany). Speedcourt™ is a recently employed method designed for the development and evaluation of deflection speed and reactive agility. The Speedcourt™ has demonstrated utility, validity and reliability in detecting multidirectional deflections (Duking et al., 2016: 130-136). The Speedcourt™ comprises a TV screen, a square area (6.20 x 6.20 m) with 10 pressure sensors and a personal computer. Pressure sensors are arranged in 50 x 50 cm squares on the site. The entire area and the 10 pressure sensors are displayed on the TV screen. Each pressure sensor detects a minimum force of 150 N, and contact times are determined in milliseconds. The test begins with a countdown, and one of the square areas (pressure sensors) turns white on the screen. Athletes are required to run and touch the sensor with the white light. Participants must monitor the screen, following the

white square area both while running on the field and touching the appropriate square area. As soon as the athlete touches a square, another square sensor is illuminated in white, and the athlete must touch that square area as quickly as possible. The test is completed after 10 frames. Measurements were taken from each athlete with a 30-second rest interval between them, and the best result obtained from these measurements was used in the analyses.

Mean and standard deviation values were taken for descriptive statistics. The Kolmogorov-Smirnov test was employed for the normality analysis of the obtained data. Data demonstrating normal distribution were further examined for the relationship between predictor and response variables using regression analysis. The

results of the T-test within the regression analysis were interpreted to assess the variability of variances. A regression analysis was conducted to predict the leg stiffness using the speed and reactive force index values obtained from the gymnasts. Statistical operations were carried out using the SPSS 20.0 software package. $P < 0.05$ was accepted as a significance value.

RESULTS

The regression analysis results regarding the prediction of leg stiffness ($X=17.20\pm 6.56$) values along with the intermediate values of agility and speed obtained from gymnasts are given in Table 1.

Table 1. Regression analysis results on predicting leg stiffness of gymnasts' agility and at different distances speed values.

Variable	Mean	SD	B	Std Error	β	T	p	Zero-Order	Partial r
Constant			59.805	12.965		4.613	.000		
Agility	25.39	2.24	-.335	.452	-.115	-.741	.462	-.368	-.097
0-5 m	.90	.068	7.420	136.965	.078	.054	.957	-.259	.007
5-10 m	.78	.055	-1.220	138.183	-.010	-.009	.993	-.343	-.001
0-10 m	1.69	.11	-5.507	136.885	-.094	-.040	.968	-.327	-.005
10-20 m	1.40	.12	6.202	15.919	.120	.390	.698	-.332	.051
0-20 m	3.10	.23	-	6.845	-.455	-1.843	.070	-.461	-.235
			12.615						
R=.476			R ² =.226						
F _(6,58) =2.828			P=.017						

SD, Standard deviation; * $p < 0.05$

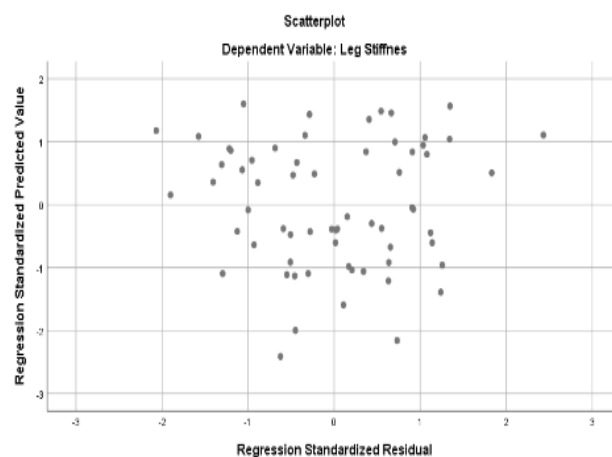
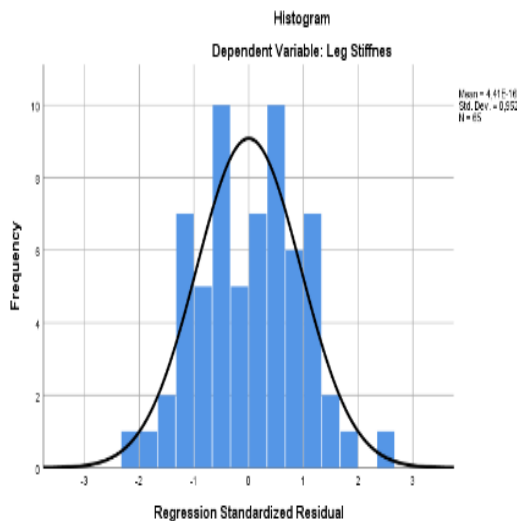
When Table 1 is examined, the intermediate values of agility and speed together show a moderate and significant relationship with leg stiffness ($R=0.476$, $R^2=0.226$, $p < 0.05$). The mentioned variables together give approximately 23% of the variance in the leg stiffness. According to the standardized regression coefficient (β), when the relative importance order of the predictor variables on leg stiffness is examined, 0-20 m sprint value has the most

significant effect, while 5-10 m sprint value has the least effect. When the t-test results related to the significance of the regression coefficient are examined, it is seen that the variables discussed do not have a significant effect. When the bilateral and partial correlations between the predictor variables and leg stiffness were examined, low-level and negative relationships were found. Upon examination of the T-test results, it can be concluded that leg stiffness does not

have a significant impact on the changes in speed and agility values. In other words, it can be stated that leg stiffness does not influence the specified parameters. Regression analysis results for predicting leg stiffness value together with Reactive Strength Index (RSI) values obtained from gymnasts are given in Table 2.

When Table 2 is examined, the RSI values collectively demonstrate a moderate and significant relationship with the leg stiffness. ($R=.670$, $R^2=.449$, $p<0.05$). The combined variables account for approximately 45% of the variance in leg stiffness. The standardized regression coefficient (β) indicates that the RSI

significant effect, while the RSI obtained from 30 cm has the least effect when considering the relative importance order of the predictor variables on leg stiffness. The T-test results regarding the significance of the regression coefficient suggest that the considered variables do not have a significant effect. Upon analyzing the bilateral and partial correlations between the predictor variables and leg stiffness, moderate and positive relationships were observed. Examination of the T-test results implies that leg stiffness does not significantly impact the changes in Reactive Strength Index (RSI) values. In other words, it can be stated that leg stiffness does not



obtained from 50 cm has the most

influence the specified parameter.

Figure 1. Normality distribution according to histogram test results.

Table 2. Regression analysis results on predicting leg stiffness together with RSI values obtained from gymnasts

Variable	Mean	SD	B	Std Error	β	T	p	Zero-Order	Partial r
Constant			2.487	4.149		.599	.555		
30 cm RSI	1.38	.46	.362	7.080	.024	.051	.960	.545	.011
40 cm RSI	1.46	.48	-6.836	9.790	-.473	-.698	.493	.565	-.151
50 cm RSI	1.55	.50	15.012	8.783	1.070	1.709	.102	.643	.349
60 cm RSI	1.67	.49	-4.169	8.089	-.294	-.515	.612	.581	-.112
20 cm RSI	1.64	.49	4.390	6.550	.306	.670	.510	.606	.145
R=.670			R ² =.449						
F ₍₆₋₅₈₎ =3.419			P=.020						

SD, standart deviation; *p<0,05

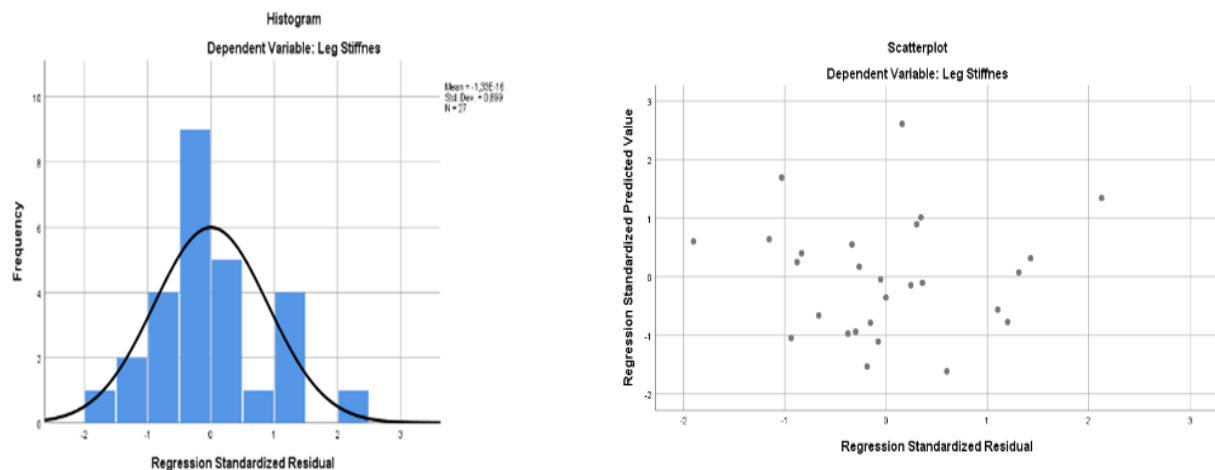


Figure 2. Normality distribution according to histogram test results.

DISCUSSION

In our study, we found a moderately positive correlation between leg stiffness and RSI values in gymnasts. We found a negative low-level relationship between speed and agility and leg stiffness values.

Leg stiffness can be defined as a mechanical property that determines the efficiency with which the external forces, absorbed by the soft tissues and transmitted to the skeletal system, can be utilised (Riemann et al., 2001: 369-375). Recent studies indicate that during running and jumping activities, tissues such as muscles, tendons and ligaments work in unison with the body's musculoskeletal system, functioning like a single spring by maintaining consistent movement centers. This can be effectively modeled using a simple spring-mass system, incorporating a linear leg arc and concentrating body mass at the endpoint of that arc (Ferris et al., 1999: 787-794). Despite the complexity of the neuromuscular system, the simplicity of the spring mass model aptly describes the mechanics of all movements involving jumping. (Salsich & Mueller, 2000: 207-216).

Increased leg stiffness during jumping and vertical jump performance has been associated with shorter ground contact times, increased ground contact frequency, and increased vertical ground reaction forces (Arampatzis et al., 2001: 355-364). It has been observed that depth jump 20cm, 40cm and 60cm heights reach their peak levels with leg stiffness training (Arampatzis et al., 2001: 355-364).

Jumping and leaping are crucial skills that gymnasts need to acquire at an early age, providing them with the ability to perform somersaults, as well as twisted or untwisted double somersaults. A gymnast's jumping ability, especially in ground movements and vaulting, is closely linked to successful performance (Marina et al., 2013: 378-386; Marina et al., 2012: 1879-1886) and is sometimes considered a general indicator of gymnastic proficiency. This ability is defined by the individual's capacity for leaping while successfully executing complex forward and backward rotation sequences (Mkaouer et al., 2012:61-62).

Reactive Strength Index (RSI) was initially defined by Bosco (1985). This metric is calculated by dividing flight time

by ground contact time and was developed to assess the stress on the muscle-tendon complex during activities like depth jumps and plyometric exercises. In gymnastics-related studies, Marina and Jemni (2014) conducted research on elite gymnasts. Over a longitudinal period of 20 months, they implemented incremental plyometric training with drop jumps (DJ) at heights of 20, 40, 60, 80, and 100cm. Before and after the training, they measured flight time, contact time, and power outputs at each height.

The study revealed improvements in flight and contact time durations, and consequently, RSI values, especially in the 80 and 100cm hurdles for elite gymnasts. Based on these findings, they suggested that reducing the time spent on technical routines and initiating 2 to 3 intensive physical conditioning sessions aimed at optimizing gymnasts' plyometric skills would be beneficial.

However, leg stiffness is required for optimum use of the strain-shortening cycle. Adequate leg stiffness ensures efficient use of the elastic energy stored in the musculoskeletal system that emerges during the loading portion of the movement (Maloney & Fletcher, 2018: 109-130). Sert (2016: 76-77), in his study on young tennis players, found a relationship between muscle stiffness of the players and their speed of change of direction in the negative direction at the $p < 0.05$ level ($r = 0.441$); between speed performance in the positive direction at the $p < 0.05$ level ($r = 0.474$), and between jumping performance in the negative direction at the $p < 0.05$ level ($r = 0.430$).

In gymnastics, the demonstration of speed involves making rapid changes in the rhythm and tempo of movements, sequentially relaxing and contracting

muscles, and showcasing these movements at maximum speed (Hekim & Hekim, 2015:110-115). Additionally, speed can be exhibited by coordinating the movements of various body parts to match the rhythm and tempo of the music. Apart from the application of technical structures in movement presentations, speed in consecutive movements is crucial (Altay & Doğan, 1996).

Several studies have suggested an association between speed and leg stiffness. For example, Rabita et al. (2008:163-171), in their study on French athletes, demonstrated a strong negative relationship between muscle stiffness and jump height. Duran et al. (2010:882-886), in their study on elite male tennis players, reported a positive correlation between leg stiffness and jump height, (CMJ) and 20-meter sprint, but there was no significant correlation between squat jump and 40-meter running speed. Bret et al., (2002:274-281) found that athletes with more vertical stiffness achieved higher acceleration between the first (0-30 m) and second (30-60 m) intervals during the 100 m sprint performance, with greater acceleration between the second and third intervals leading to a slowdown. Girard et al. (2006: 791-796) showed that the decrease in running speed in the last 50m distance range of 100, 200 and 400m sprint performances was accompanied by a decrease in stride length, stride frequency and vertical stiffness, and an increase in ground contact.

CONCLUSION

It can be argued that an increase in leg stiffness positively contributes to both variables measured in gymnasts. The rise in leg stiffness parameters, particularly in the vertical direction, appears to have a greater

impact on the jump parameter compared to speed and agility values. This suggests that the leg stiffness value of the dominant muscle may exhibit more substantial improvement in the jump parameter, given their biomechanical similarity. Consequently, exercises incorporating concentric and eccentric phases, such as plyometric exercises aimed at enhancing the leg stiffness of athletes, could be beneficial additions to training programs, especially in sub-categories like trampoline, rhythmic gymnastics, and artistic gymnastics where jumping is a primary focus.

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Article received: 7. 9. 2023

Article accepted: 30. 11. 2023

ROOTS, ORIGINS AND DEVELOPMENT OF RHYTHMIC GYMNASTICS: A HISTORICAL INSIGHT

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Original article

DOI: 10.52165/sgj.16.1.67-76

Abstract

Rhythmic gymnastics is a sport that was designed to be the more feminine sister discipline of women's artistic gymnastics. Its roots, however, are embedded in a male hegemonic European history that manipulated elements of dance, physiology and pedagogy. Key role players were François Delsarte, Émile Jaques-Dalcroze, Isadora Duncan and George Demeny who greatly influenced the development of rhythmic gymnastics. These individuals extended previous work of the earlier gymnastics pioneers – Johan Guts Muths, Ludwig Jahn and Per Ling. Since its inception as a competitive sport in the former Union of Soviet Socialist Republics during the 1940s, rhythmic gymnastics expanded greatly until it was officially recognised by the International Federation of Gymnastics (FIG) in 1962. In 1963, the first World Championship competition was held and the sport gained increased international traction. This study aims to investigate social and political factors that contributed to the development of rhythmic gymnastics, from its origins in the European systems up to its recognition as an independent sport in 1973. We conclude our article with the supposition that the sport did not directly challenge male hegemonic systems, but that women in this sport started shifting gender expectations and norms.

Key words: *European systems, rhythmic gymnastics, male hegemony, femininity*

INTRODUCTION

Rhythmic Gymnastics (RG) has been recognised by the International Gymnastics Federation (FIG) since 1962 (Jastrejskaya, 1995). It remains one of the few sports still exclusively practised by women, distinguished by its aesthetic nature. RG requires well-developed strength, power, endurance, flexibility, balance, and coordination, integrating gymnastics and dance elements. Performances, set to music, involve the use

of a hand-held apparatus such as rope, hoop, ball, clubs and ribbon, and can be individual or group events (Hamza, Zahraa, & Wahed, 2020; Schmid, 1976). Routines encompass balances, rotations, jumps or leaps, integrated into body difficulties, apparatus challenges, dynamic elements with rotation, and sequences of dance steps (Coppola, Albano, Sivoccia, & Vastola, 2020). Judges evaluate performances during competitions according to the Code of Points (CoP) set

out by the FIG. The sport underwent several name changes. It was initially referred to as “modern gymnastics” (1961-1971) to indicate its departure from other forms and becoming a new discipline with its own independent characteristics (Quin, 2016; Schmid, 1976). From 1971 to 1973, it was called “modern rhythmic gymnastics” and from 1975 to 1998 it was known as “rhythmic sportive gymnastics”. Since then it has been known as “rhythmic gymnastics” (RG) (Quin, 2016). This study ends with 1973, and future work will focus on the later period.

RG emerged as a gender-specific alternative to Women’s Artistic Gymnastics (WAG), which was becoming increasingly masculinised. This article illuminates this transformation and traces the historical route of modern-day global RG from 19th century European gymnastics systems to its organisational foundation years of 1963-1973, when it gained international recognition as a competitive sport. The article also explores the extent to which the evolution of RG both supported and challenged male hegemony. Additionally, the study examines the level of socio-political agency women possessed in this context, with a particular focus on 20th-century northern hemisphere regions such as the former Union of Soviet Socialist Republics (USSR), Bulgaria, and Canada. The scarcity of material related to the global south underscores the northern hemisphere dominance of the sport. Such an investigation necessitates an intersectional analysis of performance and broader gendered societal norms.

RHYTHMIC GYMNASTICS’ ORIGINS

Conventional thought attributes the origins of modern gymnastics to the work of the Prussian Friedrich Ludwig Jahn (Cervin, 2021). Jahn, in turn, was influenced by the male schoolteacher, Johann Christoph Friedrich Guts Muths (1759-1839) at Schnepfenthal from 1785 onwards (Cuddon, 1980; Obholzer, 1939). Guts Muths, a prolific writer, set the tone for later genderised gymnastics practices. These include: *Gymnastik für die Jugend* (1793); *Spiele zur Uebung* (1796); and *Turnbuch für die Söhne des Vaterlandes* (1817) (Guts Muths, 1793; Guts Muths, 1796 & Guts Muths, 1817). These works promoted male gymnastics which strengthened hegemonic European nationalism that lasted well into the 20th century. Guts Muths categorized gymnastics into “natural” and “artificial” streams. “Artificial” gymnastics, akin to 20th century artistic gymnastics, included activities such as mounting and dismounting horses, relevant for military service. Conversely, “natural” gymnastics focused on a healthy body, resembling the later Swedish gymnastics system. These methods laid the foundation for gymnastics as training programmes to strengthen male soldiers and cultivate healthy citizens (Cervin, 2021).

However, it was the Swede Pehr Henrik Ling (1776-1839) who, during the early 1800s, linked gymnastics to physiology and anatomy (May, 1969). Ling and his followers developed physical exercises rooted in scientific principles, known as Swedish gymnastics. This system incorporated movements with and without apparatus, as well as individual and partner exercises under the guidance of an

instructor, with the goal of perfecting the rhythm of movement. Despite this scientific basis, Swedish gymnastics, like Guts Muths' methods, remained militaristic in nature (McKenzie, 1924; Van der Merwe, 2007).

The history of gymnastics is inseparable from broader societal issues of gender and class. Swedish gymnastics, for instance, was embedded in a class-based hegemony that separated middle- and working-class girls (Pfister, 2003). Sport historian Else Trangbæk (1997) linked the Swedish system to 19th century European society's perceptions of gendered bodies. These perceptions emerged as advances in science promoted the existence of two biologically different sexes in which one was inferior to the other sex. As a result, women were not encouraged to focus their energy on anything other than their reproductive capabilities. This contributed to the construction of a male dominant social order, based solely on body characteristics.

From the mid- to late 19th century, sport became associated with masculinity and played a pivotal role in constructing rites of passages from boyhood to manhood. Sport was also aligned with capitalist principles, featuring individualism, entrepreneurship and a marketplace economy (Trangbæk, 1997). Conversely, gymnastics was practiced in closed, private spaces such as training halls, reflecting women's expected roles of domesticity and confinement to the private sphere of the home. This was particularly evident in Swedish gymnastics, increasingly linked to 19th and early 20th-century constructs of femininity. These constructs, supported by scientists (mostly men) in terms of physiology and anatomy, served as justification for women's involvement in

gymnastics. Initially performed as a collective group effort, Swedish gymnastics emphasized 'correct' movements and timing under the instructor's supervision, fostering a culture of collective group subordination to an instructor—fitting the societal expectations for 19th-century women (Trangbæk, 1997).

Madame Martina-Bergman Österberg played a pivotal role in introducing Ling's gymnastics from Sweden to Britain starting in 1881 among women (May, 1969). Ling's gymnastics further spread to the European mainland through individuals like the Frenchman François Delsarte and Swiss composer Emile Jaques-Dalcroze (Cervin, 2021; Vertinsky, 2009). Delsarte (1811-1871) claimed his system to be a scientific approach designed to accompany oratory, emphasizing "gestures as the direct agent of the heart" (Vertinsky, 2009). The Delsartian system, primarily focused on women, was exported to America around 1873 by Steele Mackay, a fellow student of Delsarte in Paris (Toepfer, 1997). Mackay's system gained popularity among America's middle- and upper-class women as expressive dance (Vertinsky, 2009). Individuals such as Genevieve Stebbins, Hedwig Kallmeyer, Dora Menzler, and Gertrud Leistikow further developed this system into the realm of modern dance (Toepfer, 1997).

However, it was the American dancer Isadora Duncan (1878-1927), a follower of the Delsarte system, who influenced the emergence of the gymnastics discipline, Rhythmic Gymnastics (RG). Duncan, through reinterpretations of classical music, experimented with expressive body movements that departed from Ling's geometric-linear constructions. Rejecting the strict confines of ballet, she introduced a free-spirited dance style that challenged

the reserved nature of dance and societal ideals about appropriate physical activity for women. Duncan's incorporation of walking, running, jumping, and various arm and trunk movements as exercises contributed to the formation of RG as known today (Jastrejskaya, 1995).

Jacques Dalcroze (1865-1950), a music teacher and conductor influenced by Delsarte and others, developed a movement system called eurhythmics, initially designed to teach rhythm to his musical students at the Geneva Conservatory (Jastrejskaya, 1995; Vertinsky, 2009). Dalcroze's eurhythmics became a key component of the syllabus at the Educational Institute for Music and Rhythm in Hellerau, Germany, where he served as director from 1910 onward. This technique involved execution of movements attuned to music rhythms, with variations sound reflected through corresponding body movements. Dalcroze himself later introduced this technique to the USSR by. However, Dalcroze was not the sole contributor to spreading this technique to the USSR. Delsarte and Duncan also played significant roles in disseminating new ideas of expressive movement to the USSR, as well as to Europe and North America (Jastrejskaya, 1995).

George Demeny (1850-1917), a French physiologist and photographer, also played a crucial role in the development of female gymnastics. Through scientific analysis of the sharp and angular movements present in existing European gymnastics systems, he advocated for women to engage in exercises that are dynamic, natural, and flexible. Consequently, his exercises emphasized aesthetic movement as a means of physical development, incorporating classical ballet and various apparatuses such as clubs,

garlands, sticks, and hoops. Demeny's methods, alongside those of Delsarte, Duncan, and Dalcroze, laid the groundwork for 20th-century Rhythmic Gymnastics (RG). Dance emerged as a central element in women's gymnastics systems, providing a gateway to sports that highlighted expressiveness, gracefulness, and aestheticism, inherently considered feminine. Notions of expressive femininity propagated and were internalized by women worldwide. As Ruth Schnepfel, a lecturer at the first department of physical education in Africa at Stellenbosch University, remarked in 1939: "... Rhythmical movement [for women] is more suited for women [implying not for men] because it is much more in accordance with nature and expressive of feeling" (Schnepfel, 1939).

Isodora Duncan opened schools in Germany in 1904, and later in France, the USA, Greece and Russia (Toepfer, 1997; Vertinsky, 2009). In 1912, a school for RG was established in St. Petersburg, Russia, following Dalcroze's presentation of his system during his visit there (Jastrejskaya, 1995). Three years later, K. Isachenko-Sokolova opened a school on expressive movements in Russia under the inspiration of Duncan, Delsarte and Dalcroze. Towards the end of the 1920s in Leningrad, Russia, the Association of Workers of Expressive Movements was formed, collaborating with the Peter Lesgaft Institute of Physical Culture. This collaboration led to RG becoming a compulsory subject at the Institute and the establishment of the High School of Artistic Movement (HSAM) in 1932, widely recognised as a cradle of RG. The curriculum of HSAM was shaped around the teachings of Duncan, Dalcroze, Delsarte and Demeny. By 1936, an artistic

movement program for athletes became a compulsory component of the USSR high school curriculum. Simultaneously, organisational structures were put in place, establishing RG as a sport for women and girls (Jastrejskaya, 1995). The first graduation of specialists in RG occurred at HSAM in 1938. On 8 March 1939, the first RG competition was held in Leningrad, dedicated to International Women's Day. The HSAM graduates - Julia Shishkareva, Anna Larionova, Tatyana Varakina, Ariadna Bashnina, Lydia Kudryashova, Tatyana Markova, Sofya Nechaeva and Lev Orlov, the first head of the gymnastics department and teacher, are considered pioneering figures for RG.

After the Second World War, the first All-Soviet Union RG group competition was held in 1947 in Tallinn, Estonia, an event marked by misunderstanding between competitors and the competition rules. In the following year, the second RG competition in the USSR was held in Tbilisi, Georgia, featuring individual and team competitions. Since 1949, yearly RG championships were held in the USSR (Jastrejskaya, 1995).

INTERNATIONALISATION OF RHYTHMIC GYMNASTICS

During the late 1940s, RG was introduced to Bulgaria, Romania, Czechoslovakia and Poland after delegates visited a championship in Leningrad. In 1947, friendly competitions were arranged between gymnasts from Leningrad, Sweden, and Finland, primarily influenced by Soviet experiences. In the following year, The USSR affiliated with the FIG in 1948. However, the FIG recognised RG as an official discipline only in 1962, with limitations, offering RG as an optional

event at FIG-sanctioned competitions (Jastrejskaya, 1995).

In 1950, the first RG handbook, *Rhythmic Sportive Gymnastics*, compiled by Yulia Shishkareva, was published. This publication played a significant role in popularizing the sport in Western Europe, Bulgaria, China and Romania (Jastrejskaya, 1995). In the following year, the USSR affiliated with the International Olympic Committee (IOC). Women's Artistic Gymnastics (WAG) entered the Olympic Games in 1952 as a competitive event. At these Games and the subsequent one, an event known as "portable apparatuses" was part of the WAG program, alongside the individual competition. After the 1956 Olympic Games, the "portable apparatuses" event was separated in its own discipline, RG (Cervin, 2021). In the previous year, Soviet gymnasts introduced RG to Belgium, Yugoslavia, France, Czechoslovakia and Bulgaria, further popularising the sport (Jastrejskaya, 1995). The 1956 Olympic Games played a pivotal role in the international expansion of RG, with people like Bertha Villancher from France and Valerié Nagy Herpich from Hungary advocating for its international recognition as a competitive sport (Schmid, 1976).

During a 1961 Gymnaestrada in Stuttgart, West Germany, Soviet specialists compiled and presented a report on RG for national representatives attending the Gymnaestrada, hoping to secure a place for RG in official FIG-sanctioned competitions. Despite pleas from top Soviet gymnasts, the sport was considered too complex by the FIG and merely received general recognition. As mentioned previously, it did, however, receive official recognition by the FIG at the 41st Congress in Prague, Czechoslovakia in June 1962

(Jastrejskaya, 1995). Consequently, in 1963, the first official RG competition, the European Cup, was held in Budapest, Hungary. Here, twenty-eight gymnasts from ten European countries competed. Upon processing the results, it was discovered that competitors were not exclusively from Europe. Hence, the competition was the first World Championship, with Lyudmila Savinkova from Moscow being crowned the first world champion. Three routines were included in this competition, two with apparatus (rope, hoop and/or ball) and one without apparatus ("free"). Since there were no standardised rules, judging was conducted according to the WAG CoP. The FIG decided that the RG World Championships were to take place every two years henceforth (Jastrejskaya, 1995; Schmid, 1976).

In the same year, the Bulgarian Rhythmic Gymnastics Federation was established. Bulgarian gymnasts soon became known for their expressiveness, and in the early days of competitive RG, almost every international-level elite gymnast had received training in Bulgaria (Anon., n.d.). At the Tokyo Olympic Games of 1964, delegates from Japan, Korea, China and the Philippines met to discuss the inclusion of gymnastics at the Asian Games, which effectively led to the formation of the Asian Gymnastics Federation (AGF) (Anon, n.d.). The following year, three months before the second RG World Championships in Prague, Czechoslovakia, the FIG conducted the first international judges' clinic for RG in order to standardise competition judging rules. A FIG Committee of Women provided the guidelines that an independent RG should follow. The committee made it clear that RG should have its own style; not in the form of modern dance or ballet but based on

self-expression and natural movement. Thirty-two gymnasts from twelve countries competed in the second World Championships in 1965 (Jastrejskaya, 1995). The program consisted of four events: a compulsory free routine to establish the standard for future RG, and three optional routines (rope, ball, free). Czechoslovakia dominated the event with first, third and fourth places. As a consequence, Czechoslovakia shaped the direction of RG styles in the following years with effective combinations of ballet techniques and whole-body movements into flowing routines (Schmid, 1976). The FIG executive remained a European male-privileged enclave for many years. In 1966, the Swiss Arthur Gander became the next president of the FIG. Before him, another Swiss, Charles Thoeni, served in this position from 1956-1966. The executive committee included Klas Tharsson, Max Bangerter, Nicolai Popov, Mario Gotta - all male - and one woman, Bertha Villancher - an advocate for RG on the FIG executive (FIG, n.d.).

During the third World Championship held in Copenhagen, Denmark, 1967, group routines were included in the competition. Individual routines consisted of one compulsory rope routine and three optional routines, namely, rope, hoop and "free". Groups comprised six gymnasts performing their routine with an equivalent number of hoops. The competition marked the beginning of the rivalry between the Russians, with their "graceful, clean lines" based on their training in Russian ballet, and Bulgaria whose gymnasts outperformed the opposition with high throws and sophisticated catches and rotations. The Russians however won both the individual and group competitions (Jastrejskaya, 1995; Schmid, 1976). After this World

Championship, the FIG established the Commission for Modern Gymnastics in order to determine the international rules for competition. This included clarifications on deductions for possible errors, elements, and their respective techniques. Three apparatus routines were also approved for rope, hoop and ball (Schmid, 1976).

The spread of the sport to North America, and specifically across Canada, can be attributed to Evelyn Koop, a graduate from the Ernest Idrå Institute in Sweden. Koop became known as the mother of RG in Canada, as she passionately worked to advance the sport throughout the country. From 1951-1964, Koop lectured at the University of Toronto, focusing on rhythmic gymnastics. Under her guidance, the Kalev Estonian Club was established in Ontario in 1951. During the 1960s, Koop accompanied teams from this club on tours throughout Canada and the United States of America (USA) in order to showcase RG. In 1968, Koop was appointed as the first national coach for Canada. The Canadian Modern Gymnastics Federation (CMGF) was established the following year, with her as president. Additionally, this was the first year that RG received a federal grant in Canada (Anon., n.d). Evelyn Koop, the official Canadian coach during the 1950s and early 1960s, played a pivotal role in many developments in RG in Canada. In 1971, the Hungarian rhythmic gymnast Maria Patocska arrived in Canada, where she conducted a workshop, performed in a gymnaestrada, toured the country and showcased the sport extensively. In the same year, Koop organised the first judging course presented by the Bulgarian Ivanka Tchakarova, and subsequently, Koop became the first RG judge in Canada.

During the 1969 World Championships in Varna, Bulgaria, gymnasts from eighteen countries competed, and Bulgarian Maria Gigova emerged as the overall winner. Bulgaria also outperformed the USSR in the group competition, as their routines received a higher rating due to difficulty (Jastrejevskaya, 1995). This World Championships marked the last instance where free routines were allowed, as they had become too theatrical. This World Championship was attended by delegates from the USA who observed the competition and participated in judges' training. Subsequently, RG advanced in the USA. The chairperson of the United States Gymnastics Federation's (USGF) Modern Rhythmic Gymnastics Committee, Mildred Prchal, promoted the sport in the USA and published a series of routines for beginner gymnasts and organized the first RG workshop for female physical education teachers in the USA. These teachers became leaders in the development of RG. Internationally, the FIG's Modern Gymnastics Commission developed judging rules, introduced a list of difficulties, and published the first official RG Code of Points in 1970 (Schmid, 1976). Additionally, the first Canadian National Competition was held in Toronto in 1970, and Hungarian rhythmic gymnast Maria Patocska who ranked 5th at the 1969 World Championships, was invited to Canada.

At the 1971 World Championships in Havana, Cuba, the competition featured four routines, introducing a new apparatus: ribbon. The ribbon originated in China, and was first used in RG by Russians. The competition also marked the first-time attendance of representatives from Central America (Cuba), Asia (Japan and Korea), Australasia (New Zealand), North America (Canada), and South America (Mexico).

However, participant numbers were low due to financial challenges associated with travel expenses for gymnasts (Schmid, 1976).

In 1972, the FIG submitted a request for RG to be included in the Olympic program, aiming to restore gymnastics as a conduit for femininity, given the p[erceived masculinization of WAG (Cervin, 2021; Schmid, 1976). However, the IOC refused, and RG had to wait until the Los Angeles Olympic Games in 1984 to make its Olympic debut. In the 1973 World Championship, clubs were introduced as a compulsory apparatus routine. In the same year, the USA staged its first RG national competition and entered its team in the World Championships (Anon., n.d.; Schmid, 1976). In the same year, RG was also introduced to Great Britain by the British Amateur Gymnastics Association (BAGA) chairperson, Jenny Bott (Anon., n.d). However, it was Evelyn Koop, a key figure in establishing RG in Canada, who played a significant role in giving the sport its international footprint.

CONCLUSION

This research primarily focuses on the organizational development of Rhythmic Gymnastics (RG), but it acknowledges the presence of underlying socio-political influences. The USSR shared similarities with the capitalist West in initially utilizing gymnastics for military training, emphasizing cohesiveness and cooperation (Cervin, 2021). While the competitive involvement of women in sports was a source of concern in the West, viewed as potentially compromising femininity, the Soviet Union embraced the participation of both women and men in sports (Cervin, 2021; Quin, 2016). By the 1940s,

gymnastics in the USSR ranked as the fourth most practiced sport among both genders. The USSR's commitment to gender equality in sports was evident, serving as a strategic approach to win medals and demonstrate sporting superiority during the Cold War (Cervin, 2021).

RG provided women gymnasts with a platform to showcase their competitiveness and other attributes associated with muscular dominance while maintaining their femininity. Scholars such as Cervin (2021) and Trangbæk (1997) argue that such displays not only empowered women, but also prompted a broader societal re-evaluation of prevailing gender ideals, questioning what was considered appropriate and acceptable for women in sport. Despite RG's original design that was aligned with traditional constructs of femininity (Quin, 2016), the sport has evolved over time, influenced by rivalries between schools of RG, such as the USSR and Bulgaria, and broader geopolitical tensions like the Cold War rivalry between the USSR and the USA. This has contributed to RG's dynamic, complex, and entertaining nature, gaining popularity worldwide (Cervin, 2021; Jastrejskaya, 1995). Innovation and creativity, inherent values in Soviet culture, have shaped RG as a sport, and it continues to evolve, exemplified by unconventional developments like Japanese Men's Rhythmic Gymnastics (MRG) challenging traditional gender norms in sport (Cervin, 2021; Jastrejskaya, 1995).

LIMITATIONS

The development of RG has still many secrets to unlock. This study has only begun to scratch the surface, yielding somewhat

ambiguous results. While RG originated within a male-dominated framework and maintained some aspects of male hegemony even at the end of the study period in 1973, women played a significant role in shaping and advancing the sport, challenging existing gender norms imposed by men. One limitation of this study is its focus on the organizational history of RG. Future research could delve into the FIG's motivations for hesitating to officially recognize the sport, exploring the philosophical foundations behind women's participation in gymnastics in the USSR, and unveiling dynamics of inclusion and exclusion. A more extensive study may be necessary to determine whether RG truly represents a domain dominated by women.

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THE ROLE OF CURIOSITY TO STUDY ENGAGEMENT OF STUDENTS IN GYMNASTICS: EXTRAPOLATING RECIPROCITY

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Original article

DOI: 10.52165/sgj.16.1.77-91

Abstract

The academic literature on the reversible association between curiosity and study engagement in elementary and high school contexts has been extensive and widespread across several countries. Regrettably, research in the field of gymnastics within the setting of higher education in the Philippines remains mostly unexplored and unknown. This study examined the reciprocal association between curiosity and study engagement in the context of gymnastics from a selected higher education institution in the Philippines. A study was conducted with 177 Bachelor of Physical Education students enrolled in Movement Education where gymnastics is part of the said course. The findings of the study revealed a noteworthy correlation between overall curiosity and study engagement in the field of gymnastics, as well as a reciprocal relationship between the two variables. Additionally, a significant and positive correlation was found between the constructs of curiosity and all three components of study engagement (vigor, dedication, and absorption), as well as a reciprocal link. The study concluded that encouraging students' natural curiosity can help them develop a healthy tolerance for ambiguity. As a result, this may have positive repercussions on students' academic performance by fostering a lifelong and sustained curiosity in expanding their knowledge and skills in gymnastics. Recommendations for teachers, replicability of the study, and future research endeavors are presented in this study.

Keywords: *curiosity, gymnastics, purposeful learning, stretch and embrace, study engagement*

INTRODUCTION

Numerous scholarly investigations have underscored the significant correlation between students' involvement in the pursuit of academic achievement and their degree of curiosity (Hulme et al., 2013; Karcher et al., 2022; Oliveira & Lathrop, 2022; von Stumm

et al., 2011). Within the realm of positive psychology within academia, considerable focus is being directed by educational psychologists and researchers towards the examination of this particular and favorable characteristic. This attribute has been found

to have a significant correlation with students' intentional acquisition of knowledge and their notable academic accomplishments. The existing body of empirical research on the correlation between study engagement and curiosity has primarily emerged from independent studies conducted in various educational institutions globally. Numerous scholarly investigations have aimed to explore the relationship between these variables. However, there is a lack of research specifically addressing the reciprocal nature of the relationship between study engagement and curiosity.

The natural propensity of individuals toward curiosity serves as a powerful driver of motivation (Mahama et al., 2023; Shah et al., 2023), forming a crucial area of investigation for psychologists and educational researchers exploring fundamental traits and personal attributes (Evans et al., 2023; Spitzer et al., 2023). However, curiosity research faces challenges arising from diverse vocabulary, operational definitions, and measuring methods, which have hindered its progress despite its widespread recognition among academic communities. In many cases, the intrinsic motivation is frequently conceptualized in manners that are congruent with the underlying principle of curiosity. Within the realm of human nature, intrinsic motivation stands out as a prominent expression of favorable characteristics. This concept represents individuals' inherent drive to actively pursue novelty, confront challenges, foster personal development, engage in exploration, and acquire knowledge (Ryff, 1989). The phenomenon known as flow, characterized by a state of deep engagement

in a demanding and pleasurable task that necessitates the utilization of one's entire skill set, has been posited as an amplified manifestation of curiosity (Fredrickson, 1998). The psychological construct known as curiosity is sometimes employed synonymously with various other terms, including interest, novelty-seeking, and openness to experience, among a multitude of others. The fundamental tenet of this conceptualization of curiosity posits that individuals must possess a perception of self-efficacy in order to proficiently navigate and comprehend the novel, ambiguous, and capricious circumstances they encounter during their venturesome endeavors. The level of confidence may fluctuate based on specific contextual factors; yet, it is probable that, as a general trend, confidence is exhibited through a readiness to accept and engage with the novel, uncertain, and unpredictable aspects of daily existence. One crucial aspect of this concept pertains to the act of embracing uncertainty, rather than succumbing to fear and evading it. Curiosity plays a multifaceted role throughout an individual's lifetime, facilitating the acquisition of knowledge, the development of skills and expertise, and the establishment of relationships, (Ernst & Burcak, 2019). Undoubtedly, individuals who engage with unforeseen stimuli inevitably encounter a certain level of unique knowledge and experiences that were previously unachievable. Hence, an additional characteristic of curiosity encompasses the inclination, and even the aspiration, to consistently gain novel skills and encounters. The concept of curiosity encompasses the innate inclination of individuals to expand

their capacities. Curiosity can be defined as a cognitive phenomenon that encompasses the processes of recognizing, accepting, and actively seeking knowledge and novel experiences (Chang et al., 2023; Jirout, 2020). The current corpus of academic literature pertaining to the advantages of curiosity is currently in its nascent phase of advancement. Curiosity is believed to exert a favorable influence on various advantageous outcomes, encompassing the augmentation of cognitive abilities, acquisition of wisdom, subjective well-being, existential fulfillment, resilience in the face of adversity, gratifying and purposeful social connections, and active involvement in educational pursuits, alongside other associated effects (Jirout et al., 2022; Karcher et al., 2022; Kashdan et al., 2020; Wang & Li, 2015). In a study conducted by Kashdan et al. (2009), two unique components of curiosity were identified using a curiosity evaluating tool devised by the researchers. The primary factor to be taken into consideration is that the concept of *stretching* may be characterized as actively engaging in the process of acquiring new knowledge and experiences (Fry et al., 2023). Conversely, the notion of embracing involves the willingness to adjust to unfamiliar, unexplored, and ambiguous aspects of daily existence (Devereux, 2022). The intersection of expanding and embracing dimensions becomes apparent when examining the interrelated elements of curiosity, as elucidated by several specialists (Berlyne, 1960; Deci, 1975; Litman, 2019).

The subject of study engagement has garnered considerable interest among researchers in education due to its potential

as a predictive indicator for academic attainment (Liu et al., 2021). Students manifest a variety of attributes, including commitment, interest, inquisitiveness, lively behavior, and enthusiasm, when exposed to information pertaining to a specific academic domain. According to Charkhabi et al. (2019), there is a positive relationship between students' level of engagement in their academic pursuits and their internal motivation to acquire knowledge and progress in their educational endeavors. This notion encompasses multiple areas, specifically *cognitive* (demonstrated through a commitment to attaining expertise and the capacity to flexibly address challenges), *affective* (indicated by a sense of recognition and a favorable attitude towards education), and *behavioral* domains (exhibited through active engagement by students and the adoption of beneficial behaviors within an educational context) (da Fonseca et al., 2023; de Toro et al., 2023). The conceptualization of study engagement has three distinct elements, specifically *Vigor* (VIG), *Dedication* (DED), and *Absorption* (ABS), derived from the three domains as proposed by Jaya and Ariyanto (2021). A student exemplifying *vigor* demonstrates unwavering enthusiasm, perseverance, optimism, and flexibility in their pursuit of success (Cortés-Denia et al., 2022; Demirbatır, 2020; Pulido-Martos et al., 2020). Despite encountering numerous academic responsibilities, these students consistently exhibit a favorable disposition towards these tasks. *Dedication* is defined as an individual's profound involvement in numerous academic obligations, characterized by a substantial level of

commitment and a strong motivation for attaining success (Listau et al., 2017; Teuber et al., 2021). According to Kassab et al. (2023), the student demonstrates a cognitive orientation marked by a constructive inclination, indicating a notable commitment to the educational processes and objectives. *Absorption*, according to Dacillo et al. (2022), is a cognitive state marked by an intensified perception of proficiency, complete concentration, and profound engagement in one's scholarly pursuits. This domain is characterized by the presence of a significantly elevated perception of competence in relation to the acquisition and comprehension of content. The investigated study engagement exhibit distinct variations while also demonstrating strong interconnections (Archambault et al., 2022; Li, 2023).

Previous research has shown that there is a strong and positive correlation between student participation in their studies and their academic achievements. Numerous inquiries have been undertaken in recent years to further examine the association between the two variables. The research conducted by Sukor et al. (2021) involved selecting a cohort of 84 students who were not majoring in food science but were enrolled in a food science course. These individuals were chosen as participants for the survey. The findings of the study revealed a statistically significant positive correlation between students' overall engagement and their academic achievement ($r = 0.312$; $p < .001$). The findings of the study indicated the existence of two distinct components in students' level of involvement, namely, emotional engagement ($r = 0.529^{**}$; $p < .001$)

and cognitive engagement ($r = 0.391$; $p < .001$). Both components had a statistically significant positive correlation with excellent academic performance. Furthermore, the research conducted by Rashid and Asghar (2016) examined the correlation between study engagement and academic achievement in the context of independent online programs. The study utilized data on module content engagement obtained from an e-learning platform. This data included many indicators, such as the quantity of content views, participation in forums, completion of activities, and consumption of videos. The findings of the analysis indicate a statistically substantial and positive correlation between study engagement and student achievement, observed at both the level of individual modules and throughout the entire cohort. Additionally, a notable association was observed between early involvement in particular subjects and general scholarly involvement, suggesting that both variables play a role in enhancing academic achievement. Lei et al. (2018) conducted a study with the aim of examining the complex association between study engagement and academic achievement. The authors' main aim was to provide conclusive evidence through a meta-analysis that incorporated 69 separate studies, with a combined sample size of 196,473 people. The research revealed a statistically significant and positive association between students' overall level of engagement and their academic performance. Moreover, a comprehensive examination of various aspects of engagement, including behavioral, emotional, and cognitive engagement, demonstrated a significant positive

correlation between these dimensions and students' academic achievement. Within this framework, there is a hypothesis suggesting that the three domains of engagement serve as reliable indicators of academic achievement. This proposal is supported by numerous scholars in recent academic literature spanning diverse fields of study (Acosta-Gonzaga, 2023; Luo et al., 2023).

Prior research has extensively investigated the correlation between curiosity and academic engagement. The literature suggests that individuals who exhibit a tendency for curiosity in acquiring new knowledge within their area of expertise, coupled with the ability to adapt to unexpected situations, are more likely to experience heightened levels of engagement, potentially resulting in improved academic performance. The study conducted by Mahama et al. (2023) aimed to scrutinize the influence of learners' intrinsic traits, including motivation, curiosity, and creativity, on their academic achievement in the fields of science and mathematics. The sample size comprised 568 participants enrolled in secondary education institutions. After conducting Multiple Multivariate analysis, the results revealed that the collective impact of students' driven behaviors, inquisitive aptitudes, and imaginative potentials explained 15.5% of the variance in science scores and 33.1% of the variance in mathematics scores. In this particular context, it becomes evident that students demonstrating curiosity, creativity, and motivation in their educational environment are more likely to elevate their level of involvement, consequently enhancing their academic performance and

achieving their educational objectives. Additionally, Mahama (2022) explored the cumulative influence of curiosity, creativity, motivation, and academic achievement in core mathematics and integrated science on a sample of 652 adolescent learners. The results of a multivariate regression analysis revealed a substantial statistical correlation between students' inquisitive behaviors, creative aptitudes, and motivation, highlighting the interdependence of these variables within the realm of academic pursuit. Consequently, the amalgamation of these attributes results in an increase in learner engagement within the educational context. In a meta-analysis by Schutte and Malouff (2022) which scrutinized the effects of interventions designed to foster curiosity 41 randomized controlled trials involving 4,496 participants were comprehensively analyzed. The results demonstrated that several interventions led to a statistically significant increase in curiosity levels. Elevated curiosity levels were associated with various positive outcomes, including heightened overall satisfaction, increased engagement in work-related activities, and enhanced academic achievements (Dubey et al., 2022; Singh & Manjaly, 2022; Whitecross & Smithson, 2023). The above-mentioned investigations were conducted on a heterogeneous sample of pupils across both elementary and high school levels, hence encompassing a varied range of countries. Given the lack of extensive reporting on the state of higher education in the Philippines, especially in the field of gymnastics, and the dearth of accessible literature addressing the reciprocal relationship between curiosity and study engagement among teacher education

students specializing in Physical Education in the Philippine context, the present study aims to fill this gap. The research endeavors to explore and understand the dynamics between curiosity and study engagement within the specific context of gymnastics classes for teacher education students in the Philippines.

This present study explored the potential impact of participation in gymnastics on purposeful learning, which in turn may contribute to greater academic achievement. The current study is focused on the following objectives:

1. Explore the relationship between curiosity and study engagement; and
2. Ascertain the association that exists between the two constructs of curiosity (stretching and embracing) and the three facets of study engagement (vigor, dedication, and absorption).

The present investigation has been guided by the research recommendations proposed by Upadyaya and Salmela-Aro (2017) as well as Widlund et al. (2021). These recommendations function as a framework for examining study engagement, with a specific emphasis on its three components and the role of curiosity. Therefore, the primary objective of this inquiry is to empirically examine and evaluate the validity of the following hypotheses:

H₁ There is a significant and positive relationship between curiosity and study engagement;

H₂ There is a positive correlation between stretching, vigour, dedication and absorption; and

H₃ There is a positive correlation between embracing, vigour, dedication and absorption.

METHODS

The respondents to the study comprise undergraduate students who are currently enrolled in the Teacher Education program at a selected higher education institution in the Philippines. *The Purposive and Convenience Sampling Technique* was employed to choose the participants, considering their characteristics and convenience in participating in the study. (Bhardwaj, 2019). Data collection took place between February and April in the year 2022. The selection criterion was formulated to ensure the collection of reliable and accurate data from survey respondents:

1. Currently enrolled in Bachelor of Physical Education;
2. Currently enrolled in the gymnastics class included in the Movement Education course;
3. Male or female;
4. Aged 19 and above.

Three distinct questionnaires were used for the study. The first part gathered demographic information such as sex and age group. The second utilized the Curiosity and Exploration Inventory-II by Kashdan et al. (2009), a 10-item self-report tool measuring individual differences in the recognition, pursuit, and integration of novel and challenging experiences and information. It comprises two constructs: *Stretching* (e.g., “I can actively seek as much information as I can in new situations.”) and *Embracing* (e.g., “I am the type of person who really enjoys the

uncertainty of everyday life.”). Responses are on a 5-point Likert Scale from 1- “very slightly or not at all” to 5- “extremely.” Lastly, the *Utrecht Work Engagement Scale for Students* (UWES-9S) by Carmona-Halty et al. (2019) was used. This particular scale is a nine-item self-report instrument that measures overall student engagement and is divided into three features: *Vigor* (e.g., “*I feel energetic and capable when I’m studying or going to class.*”), *Dedication* (e.g., “*I am proud of my studies.*”), and *Absorption* (e.g., “*I feel happy when I am studying immensely.*”). Responses are documented on a 6-point Likert Scale from 0- “never” to 6- “always.”

The research employed several statistical analyses. First, *normality* and *reliability* tests were conducted to assess the data distribution from the questionnaires. Second, a bivariate correlational analysis was utilized to examine the interrelatedness of the variables. Lastly, the Pearson correlation coefficient was employed to determine the interchangeable relationship between the studied variables. The Pearson correlation coefficient is a parametric statistical method used to quantify the degree of linear correlation between two sets of data (Schober & Schwarte, 2018). In this analysis, a composite score was computed from both the curiosity and study engagement scales. Subsequently, the two curiosity constructs

were examined in relation to the three components constituting study engagement.

The respondents were required to provide their consent by indicating their agreement to the statement included in the Google Forms. Additionally, participants were briefed on the research objectives, the tools used, and the specific factors under investigation. The online survey also outlined potential minor risks that participants might encounter. Respondents had the autonomy to withdraw from the study or request a debriefing at any point.

RESULTS AND DISCUSSION

A total of 179 students pursuing teacher education participated in the survey. After data cleaning, it was determined that all responses were considered suitable for analysis. Table 1 presents the demographic attributes of the participants. The sample (179) shows a higher proportion of female respondents compared to male respondents [$N_{\text{FEMALE}} = 112(62.6\%)$, $N_{\text{MALE}} = 67(37.4\%)$]. Additionally, a majority of the participants fall into the 19-21 age bracket, with the next highest representation in the age groups of 22-24 and 25 years and above [$N_{19-21 \text{ YEARS OLD}} = 154(86.0\%)$, $N_{22-24 \text{ YEARS OLD}} = 21(11.7\%)$, and $N_{25 \text{ YEARS OLD AND ABOVE}} = 4(2.2\%)$].

Table 1:
Demographic profile

Variables	Items	N(%)
Sex	Male	67(37.4%)
	Female	112(62.6%)
Age group	19-21	154(86.0%)
	22-24	21(11.7%)
	25 and above	4(2.2%)

Table 2:
Descriptive Statistics, Normality Estimates, and Bivariate Correlation.

Variables	1	2	3	4	5
CUR	(.95)				
ENG	.99**	(.95)			
STR	(.90)				
EMB	.91**	(.90)			
VIG	.89**	.95**	(.84)		
DED	.92**	.92**	.84**	(.89)	
ABS	.92**	.89**	.82**	.81**	(.89)
Mean ± SD	4.00 ± .83 4.10 ± .85	3.96 ± .83 3.93 ± .84	3.90 ± .87	4.17 ± .88	3.81 ± .90
Skewness	-1.393 -1.406	-1.287 -1.250	-0.969	-1.606	-0.730
Kurtosis	2.327 2.244	2.004 1.836	1.038	2.563	.484

Note: CUR-Curiosity (STR-Strength, EMB-Embrace); ENG-Study Engagement (VIG-Vigor, DED-Dedication, ABS-Absorption).

* Statistically significant at $p < .05$.

** Statistically significant at $p < .01$.

A test of normality and reliability was initially conducted on all variables under investigation. Based on the results obtained, it can be shown that the majority of the scales met the established threshold value of -2 and 2. In this context, it can be inferred that the data have normal distribution [CUR ($4.00 \pm .83$; $Skew = -1.393$ $Kurt = 2.327$), ENG ($3.96 \pm .83$; $Skew = -1.287$ $Kurt = 2.004$), Curiosity and Exploration: STR ($4.10 \pm .85$; $Skew = -1.406$ $Kurt = 2.244$), EMB ($3.93 \pm .84$; $Skew = -1.250$ $Kurt = 1.836$), Study Engagement: VIG ($3.90 \pm .87$; $Skew = -0.969$ $Kurt = 1.038$), DED ($4.17 \pm .88$; $Skew = -1.606$ $Kurt = 2.563$), and ABS ($3.81 \pm .90$; $Skew = -0.730$ $Kurt = .484$)]. Additionally, the reliability test showed that all scales obtained high to excellent reliability scores [CUR ($\alpha = .95$), ENG ($\alpha = .95$), Curiosity and Exploration: STR ($\alpha = .90$), EMB ($\alpha = .90$), Study Engagement: VIG ($\alpha = .84$), DED ($\alpha = .89$), and ABS ($\alpha = .89$)]. In the bivariate

correlation analysis, all scales and subscales indicated interrelatedness ($p < .05$).

Table 3 presents the results of the correlational analysis between overall curiosity and study engagement, as well as the sub-dimensions of CUR and ENG. The findings indicate a strong and positive relationship between curiosity and study engagement [$r(177) = .996$, $p < .05$], suggesting that as students' curiosity in gymnastics and their acceptance of life's unpredictability increase, their degree of engagement with studying also increases, and vice versa. Additionally, strong and positive relationships were also observed between stretching and vigor [$r(177) = .885$, $p < .05$], dedication [$r(177) = .915$, $p < .05$], and absorption [$r(177) = .920$, $p < .05$]. This suggests that as the level of curiosity among students in gymnastics grow, their enthusiasm, commitment, and devotion to their studies are also increase, and vice-versa. Similarly, there were strong and positive

relationships between embracing and vigor [$r(177) = .951, p < .05$], dedication [$r(177) = .924, p < .05$], and absorption [$r(177) = .890, p < .05$], indicating a positive correlation between students' level of curiosity and their liveliness, commitment, and absorption in their studies. Conversely, a decrease in curiosity may lead to a decrease in these attributes.

The analysis of the collected data reveals a robust and statistically significant correlation between curiosity and study engagement, suggesting reciprocal relationship between these two key features. This finding aligns with previous research in various academic disciplines within the field of education (Mahama, 2022; Mahama et al., 2023; Schutte & Malouff, 2022). The study also identifies a favorable correlation between the concept of curiosity and the three dimensions of academic engagement: stretching, embracing, and the overall

engagement. In the context of gymnastics, the term *stretching* refers to the proactive engagement in acquiring novel knowledge and engaging in unfamiliar activities, as discussed by Fry et al. (2023). The concept of *embracing* involves a mindset that recognizes and adapts to the uncertain, unexplored, and unpredictable aspects of daily existence (Devereux, 2022). The findings suggest that students who exhibit an inclination towards active engagement in the educational process and embrace the inherent uncertainty of life experience enhanced enthusiasm, dedication, and the ability to acquire knowledge in their academic pursuits in gymnastics. Previous research has consistently demonstrated a significant impact of curiosity on students' engagement in academic pursuits, contributing to improved academic performance. (Amerstorfer & Freiin von Münster-Kistner, 2021; Arnone et al., 2011; Hulme et al., 2013).

Table 3:
Curiosity vis-à-vis Study Engagement

		Study Engagement			
Curiosity		Correlation Coefficient	.996**		
		Sig. (2-tailed)	.000		
			Vigor	Dedication	Absorption
Pearson-r	Stretching	Correlation Coefficient	.885	.915**	.920**
		Sig. (2-tailed)	.000	.000	.000
	Embracing	Correlation Coefficient	.951**	.924**	.890**
		Sig. (2-tailed)	.000	.000	.000

Note: **. Correlation is significant at the 0.01 level (2-tailed).

The literature review highlights studies from various disciplines that have explored the relationship between curiosity and engagement. For example, the study of Saeed AlShamsi et. al. (2023) in the aviation industry found that work engagement positively influenced the curiosity and

exploration of employees in the United Arab Emirates (UAE). Young et al.'s (2018) meta-analysis revealed a significant role of curiosity in employees' engagement. Generally, it can be concluded that curiosity has a significant relationship with engagement. However, there is a noticeable

gap in research specifically considering the characteristics of curiosity and the three components of study engagement, particularly in the field of gymnastics within the context of higher education. The existing body of knowledge emphasizes the crucial role of curiosity in various aspects of individuals' lives, including knowledge acquisition, skill enhancement, social connections, and expertise development (Dubey et al., 2022; Singh & Manjaly, 2022; Whitecross & Smithson, 2023). Given the limited research in the specific context of gymnastics and higher education, the study suggests that a similar investigation would help bridge the gap and provide a more nuanced understanding of how curiosity influences study engagement in the unique setting of gymnastics education.

The current investigation aligns with the recommendations of Upadyaya and Salmela-Aro (2017) and Widlund et al. (2021), indicating that the concept of study engagement can be universally applied to younger students in both primary and secondary education settings. However, the research acknowledges that young adults, specifically college-aged individuals, may demonstrate a nuanced understanding of the three domains of study engagement. The study focuses on exploring the interconnected influence of curiosity on the three facets of study engagement within the context of gymnastics education. Further research could investigate and evaluate the potential discrepancies in its results among different demographic cohorts or provide additional arguments for its claims.

CONCLUSIONS

The study emphasizes that individuals with a natural inclination towards curiosity tend to invest a significant amount of time actively engaging in the pursuit of knowledge within the field of gymnastics. This engagement is driven by a desire to bridge the gap between their current level of knowledge and skills and the level they aspire to achieve. The motivation is not solely based on the pursuit of high academic scores but rather on a genuine interest in acquiring in-depth knowledge and competence. This study posits that the promotion of curiosity with supportive feedback among students can play a role in building an enduring acceptance of uncertainties throughout one's life. Consequently, this has the potential to generate favorable outcomes in fostering students' curiosity to acquire further knowledge in the domain of gymnastics, thereby aiding them in their academic pursuits.

The study underscores the importance of providing comprehensive training to gymnastics instructors to effectively promote the development of curiosity within the educational setting. The results suggest that such training is crucial for the professional advancement of instructors. Additionally, the study recommends that policymakers and practitioners initiate programs aimed at enhancing the proficiency of educators. This is seen as essential for improving instructors' abilities to address challenging educational difficulties throughout their entire professional careers.

The study acknowledges certain limitations of this study. The study's sample

comprises only of individuals currently enrolled in a higher education institution in the Philippines. This limits the applicability of the results to a broader student population in gymnastic classes, both in the Philippines and globally. To enhance the generalizability, future research should consider diverse institutions. Additionally, the study suggests exploring additional variables like sociodemographic characteristics. Despite these limitations, the study contributes to the understanding of the reciprocal relationship between curiosity and study engagement, addressing a gap in the existing literature, particularly in the context of gymnastics and academic achievement.

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Article received: 1. 9. 2023

Article accepted: 30. 11. 2023

VALUES DEVELOPMENT THROUGH GYMNASTIC EDUCATION IN PRESCHOOL CHILDREN

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Original article

DOI: 10.52165/sgj.16.1.93-104

Abstract

Physical education and sports are at the forefront of many schools of thought when it comes to values education since sport has the power to provide a universal framework for learning values. For this reason, the aim of this study is to examine the development of values in children aged four and five who start their gymnastics education in early childhood. In the experimentally planned study, the children's families filled the values scale as a pre-test and post-test, and the changes were examined. The population of the research group consisted of children aged four to five who attended the gymnastics course opened by a private club in the Akhisar district of Manisa during the summer period. The sample group consisted of 49 children whose consent was obtained after informing their families. The Preschool Values Scale Family Form (PVSFF), developed by Neslitürk and Çeliköz (2015), was used as a measurement tool. Although there was no significant difference between the pre-test and post-test mean scores of the Preschool Values Scale Family Form, a significant difference was found only in the responsibility sub-dimension of the scale. Therefore, it is understood that children can gain values, especially responsibility, through lifelong game-based sports. Considering that learning through game is important in early childhood, it is thought that emphasizing the concept of values in the movement or sports education programs to be structured and to inform the teachers, coaches or consultants working in this field is crucial.

Key words: *pre-school education, sports, movement education, gymnastics, values education.*

INTRODUCTION

Every society wants to transfer its culture, traditions, and customs to the individuals within it, and to pass its values on to the next generations. The best way to do this is by instilling value to children (Sümbüllü & Altınışık, 2016; Koç & Akdoğan, 2018). Values are generally

defined as a set of desirable behaviors (Gündoğan, 2019). In other words, values are explained as generalized social behavior principles that are accepted as the most correct, best, and beneficial in society. Since they are an important part of the daily life of individuals, values deeply influence

life (Ceyhan, 2022). Values vary according to what people consider important and the goals they want to pursue (Roccas et al., 2002).

Values are essential and indispensable concepts for nurturing individuals who think, feel, and act in a healthy manner, emphasizing that life itself should be the subject of lessons rather than a lesson (Öztürk et al., 2016; Kaya & Antepi, 2018). Research indicates that children's value systems are similar to those of adults in many ways before school age (Tamm & Tulviste, 2022). Hence, the preschool period is viewed as a crucial time that directly influences children's future personality structures, emotions, and thoughts. Consequently, teaching values in early childhood significantly contributes to a child's social and emotional development. As emotions are present in individuals long before school age, providing a quality education during childhood, when the acquisition of values and character is most rapid and convenient, becomes a cornerstone that people require in life (Bostan, 2014; Koç & Akdoğan, 2018). Activity-based practices implemented during the preschool period enhance a child's ability to feel a sense of belonging to a certain social group, engage in helpful interactions, establish common activities, foster harmonious relations with peers, and interact effectively with those around them (Ivanchuk et al., 2022). Physical education and sports activities designed for this purpose can instill various human values such as courtesy, sportsmanship, cooperation, honesty, endurance, and leadership, thanks to their dynamic nature. Sport, with its capacity to provide a universal framework for learning values, has been recognized as a powerful tool in this regard (UNESCO, 2017). Values that

can be imparted to children through physical education and sports include respect, responsibility, helpfulness, social relations, honesty, justice, fair play, citizenship, and more (Gil-Madrona et al., 2016; Rogers, 2020).

According to the innovative physical education curriculum at One World International School (OWIS), children are encouraged to lead a healthy and active lifestyle while instilling important values in them. In the preschool program, children embark on their physical education adventures like throwing balls at each other and playing fun games. It is evident that gymnastics, a discipline that has been recognized as an educational branch for many years, holds a central position in the physical education program (Mauldon, 2014). Gymnastics, known for its emphasis on play activities and peer collaborations, has consistently maintained this crucial role. Within gymnastics, children acquire a range of fundamental movement skills, encompassing displacement movements like running, jumping, and bouncing, as well as balancing skills such as standing on one leg, walking in balance, and turning. These movements are essential for the development of children's motor skills in daily life, providing them with opportunities to practice and enhance these skills through gymnastics practices (Mülazımoğlu Ballı, 2021). Beyond these benefits, gymnastics training contributes to improvements in physical fitness, body awareness, spatial awareness, and balance. Moreover, it fosters creativity, aesthetic appreciation, and collaboration within small groups (Kleinman, 2009). Working with peer groups improves cooperation and sensitivity, making individuals more tolerant and willing to help. This experience helps children learn responsibility and

become more reliable individuals (Pallett, 2014). Consequently, it is strongly advocated that all children, especially at the introductory level, should be participate in gymnastics training (Mitchell, Davis & Lopez, 2002). Gymnastics, as a discipline with an early starting age, is believed to offer value-oriented education to children through peer interactions and game-themed educational content. Despite the longstanding goal of promoting values through physical activity, there is limited evidence and research on values education and development in the field of physical education and sports (Wandzilak, 2012). Moreover, few studies specifically investigate the effects of play and creative drama, with positive outcomes reported in these studies (Kılıç, 2017; Mehmudoğlu & Yüce, 2020; Can & Günaydı, 2019; Doğan, 2021; Gündüz et al., 2017; Özyürek et al., 2018). In this context, there is a noticeable gap in the literature regarding the impact of disciplines such as gymnastics on values. To address this gap, this study aims to examine the development of values through basic gymnastics education during the pre-school period.

METHOD

This semi-experimental study was planned to examine the value development of four and five-year-old children.

In this study, 49 preschool children aged four and five, officially enrolled in the gymnastics program at the Akhisargücü Sports Club in the Akhisar district of Manisa, were included. Before the application, the parents of the preschool children planned to participate in the study were informed about the research. Participation was voluntary, and written and

verbal consent were obtained from both parents and children.

The research received approval from the Ege University Social and Humanities Scientific Research and Publication Ethics Committee on 29/06/2022, with the meetings/decision number 06/05 and protocol number 1520.

A personal information form, prepared by the researcher, was completed by the parents, containing various demographic information. Additionally, the parents filled out the Preschool Values Scale Family Form, developed by Neslitürk and Çeliköz (2015). The Preschool Values Scale is a 3-point Likert-type scale, assessable by both families and teachers. It comprises six sub-dimensions and a total of 30 items, covering aspects like friendship, honesty, cooperation, sharing, respect, and responsibility. During the validity studies, factor analysis and subtest correlation coefficients were computed. Items were included in the final scale based on a factor load value of at least .30 in the factor analysis. Significant relationships at the levels of .01 and .001 were observed between subtests of the teacher and family forms when examining correlation coefficients. Moreover, the reliability of the forms was established using the internal consistency coefficient, with split-half and Cronbach's alpha reliability formulas. The family form demonstrated a reliability coefficient of .84 based on the split-half method and .89 according to the Cronbach's Alpha reliability results.

The research was carried out at the Akhisargücü Sports Club over a period of 10 weeks, including both pre-test and post-test measurement weeks. In the first week, the Preschool Values Scale was completed as the pre-test. Subsequently, an 8-week experimental procedure was implemented.

Finally, in the last week, the same scale was once again filled out by the parents for the post-test evaluation.

The experimental program commenced one week after the start of the school holidays and spanned 8 weeks

throughout the summer vacation. The content of the 8-week planned training and the 10-week total program, including the 2-week measurement period, is outlined below:

Table 1
10-week program content

Weeks	Days	Duration	Program content
1.	Tuesday	Online	Parents fill in the Preschool Values Scale as a pre-test.
2.	Tuesday-Thursday	1 hour	Meet-and-greet (everyone tells their name and greets each other). Presentation of the rules to be followed in gymnastics training, such as coming to class on time; wearing an appropriate outfit for gymnastics; and packing together after the lesson (promoting the value of responsibility). Activities to be followed in order. Showing respect when a friend is unable to perform a move (promoting the respect and friendship values), cooperation and sharing tasks during games (promoting the cooperation and share value). Honesty encouraged in evaluation of gymnastic moves given as homework (promoting the honesty value). Coordination studies carried out aimed at developing skills such as group cohesion, maintaining order, following instructions, and waiting for friend.
3.	Tuesday-Thursday	1 hour	Warm-up using a game (tail snatch); teaching basic gymnastics postures (lunge, back scale, bridge, plank, side plank, reverse plank, candlestick, long sitting, straddle leg sitting, athlete sitting, eagle stance, tabletop, reverse table top, butterfly sitting).
4.	Tuesday-Thursday	1 hour	Warm-up using an animal-imitation game (bear walk, rabbit, caterpillar, snake, worm, seal, crab), repetition and control of basic gymnastics postures (lunge, back scale, bridge, plank, side plank, reverse plank, candlestick, long sitting, straddle leg sitting, athlete sitting, eagle stance, tabletop, reverse table top, butterfly sitting) through games. The animal-imitation game rules: the teacher calls out a movement, everyone performs it at the same time. Those who get it wrong are eliminated. This continues until only one person remains.
5.	Tuesday-Thursday	1 hour	Warm-up using the animal-imitation game (bear walk, rabbit, caterpillar, snake, worm, seal, crab); teaching flexibility and balance postures (seated forward fold, standing fold, split, straddle leg sitting, front balance, side balance, vertical split, bridge).

6.	Tuesday-Thursday	1 hour	Warm-up using a game, repetition of flexibility and balance postures (seated forward fold, standing fold, split, straddle leg sitting, front balance, side balance, vertical split, bridge). The game rules: the teacher calls out a movement, everyone performs it simultaneously. Anyone who makes a mistake is eliminated. This continues until only one person remains. The teacher may intentionally make a wrong to add some excitement. Teaching basic aerobic gymnastics steps (march, jog, skip, knee lift, kick, jumping jack, lunge).
7.	Tuesday-Thursday	1 hour	Warm-up on the spot, teaching jumping movements (air turn, straddle jump, tuck jump, cossack jump, pike jump, split jump, star jump); playing and repeating aerobic steps (march, jog, skip, knee lift, kick, jumping jack, lunge) using the coordination ladder.
8.	Tuesday-Thursday	1 hour	Warm-up using a game of catch; repetition of basic jumping movements (air turn, straddle jump, tuck jump, cossack jump, pike jump, split jump, star jump). The game includes jumping on the mat from different heights and performing the basic jumping movements. Jumps from from each height are different. Anyone who makes a mistake is eliminated.
9.	Tuesday-Thursday	1 hour	Parkour competition, checking each of the learned movements.
10.	Tuesday	Online	Parents to fill in the Preschool Values Scale as a post-test.

In the 8-week experimental program, with games integrated in the course content to promote the values of responsibility, respect, cooperation, friendship, sharing and honesty, emphasis was placed on the concepts of respect, cooperaton, sharing, and friendship. Additionally, at the end of each lesson, the movements learned in that lesson were given to the children to study at home as homework. In the following week, the children were always asked whether they did their homework (to promote the values of responsibility and honesty).

The pre-test and post-test data obtained from the experimental and control groups were analyzed using the SPSS Statistics 25.0 package program. Skewness-Kurtosis values and Kolmogorov-Smirnov and Shapiro-Wilk tests were used to determine the normality distribution and the analysis methods to be used in the study. Mann Whitney-U and Kruskal Wallis tests were used for group comparisons, and Wilcoxon-Signed Rank test was used for pre-test-post-test comparisons, since the number of samples (n:49) was small, and the distribution was not normal.

RESULTS

Table 2 presents participants' socio-demographic data.

When the normality distributions are examined as presented in Table 3, skewness and kurtosis values of some variables appear to deviate from the extreme points.

The total scores of the participants' preschool values scale did not differ according to gender, age, and kindergarten variables in the pre-test. (Table 4).

Table 5 shows the total scores of the participants' preschool values scale didn't differ according to the mother's and father's education level variables in the pre-test.

Table 6 presents there was a significant difference only in the sub-dimension of responsibility in the participants' pre-test and post-test scores as extracted from the preschool values scale family form.

There was no significant gender difference in the scores of the scale total score and sub-dimensions (Table 7).

As displayed in Table 8, age produced a significant difference in the total score of the scale and the difference scores of its sub-dimensions only in the friendship score.

As shown in Table 9, the averages of the friendship sub-dimension are in favor of the post-test in the 4-year-old group.

Table 2
Frequency table

Variable	Type	Frequency	Percent
Gender	Girl	38	77.6
	Boy	11	22.4
Age	Four	30	61.2
	Five	19	38.8
Preschool	Private	34	69.4
	Public	15	30.6
Mother's education level (graduate)	Primary-secondary school	2	4.1
	High school	5	10.2
	University	37	75.5
	Master's/ doctorate	5	10.2
Father's education level (graduate)	Primary-secondary school	4	8.2
	High school	11	22.4
	University	32	65.3
	Master's/ doctorate	2	4.1

Table 3
Normality distributions

	Gender	Age	Preschool (private-public)	Pretest Values Total Score
N	49	49	49	49
Mean	1.2245	1.3878	1.3061	47.8980
Standart deviation	.42157	.49229	.46566	4.77513
Skewness	1.363	.475	.868	-.676
Std. error of skewness	.340	.340	.340	.340
Kurtosis	-.151	-1.851	-1.301	1.264
Std. error of kurtosis	.668	.668	.668	.668

Table 4

Results of Mann Whitney-U test for pre-test preschool values scale total scores

Variables	Mann Whitney- U	Z	p
Gender	140,	-1.661	.097
Age	277	-.165	.869
Preschool	174	-1.765	.078

Table 5

Kruskal Wallis test results for pre-test preschool values scale total scores

Variables	Chi-Square	df	Asym. Sig.
Mother's education level (graduated)	2.174	3	.537
Father's education level (graduated)	.312	3	.958

Table 6

Pre-test post-test Wilcoxon results in relation to the participants' preschool values scale total score and sub-dimension averages

	Total Values Scale Score	Responsibility	Respect	Cooperation	Honesty	Friendship	Sharing
Z	-.801 ^b	-2.002 ^b	-1.583 ^c	-.475 ^b	-.320 ^c	-1.439 ^b	-.222 ^c
Asymp. Sig. (2-tailed)	.423	.045	.114	.635	.749	.150	.824

Table 7

Comparison of pre-test and post-test difference scores in relation to gender in preschool values scale sub-dimensions

	Responsibility	Respect	Cooperation	Honesty	Friendship	Sharing	Values Total
Kruskal Wallis	.043	.321	.157	1.511	.659	.037	1.391
df	1	1	1	1	1	1	1
Asym. Sig.	.836	.571	.692	.219	.417	.848	.238

Table 8

Comparison of pre-test and post-test difference scores in relation to age in preschool values scale sub-dimensions

	Responsibility	Respect	Cooperation	Honesty	Friendship	Sharing	Values Total
Kruskal Wallis	.105	.676	.027	.906	6.648	1.254	.880
df	1	1	1	1	1	1	1
Asym. Sig.	.746	.411	.869	.341	.010	.263	.348

Table 9

Pre-test post-test averages in the friendship sub-dimension in relation to age

	Valid	Friendship average (Pre-test)	Friendship average (Post-test)
Age 4	30	1.8200	1.9267
Age 5	19	1.9263	1.8737

DISCUSSION

In the study, preschool children who underwent 8 weeks of gymnastics training during the summer showed an increase in total scores on the values scale. However, this difference was not statistically significant, except for the responsibility sub-dimension, where a significant difference was observed. The significance of the responsibility dimension may be attributed to the fact that the movements taught in the course were assigned as homework, requiring children to take ownership of their responsibilities.

There is a lack of literature examining the development of values specifically through sports such as gymnastics. However, existing studies on values in education highlight concepts such as respect, responsibility, love, tolerance, and cooperation as essential for children's development (Akto & Akto, 2017; Arıcı & Bartan, 2019; Ogelman & Sarıkaya, 2015; Yıldız, Elibol & Ada, 2021). These concepts align with the scale and sub-dimensions used in our study. Notably, Yıldız et al. (2021) found that sharing is a challenging value to acquire, consistent with Ogelman and Sarıkaya's (2015) observation that responsibility and sharing are particularly challenging for families and teachers to instill in children. The significant difference observed in the responsibility sub-dimension in our study supports the notion that sportive activities, especially those involving game-based fun

activities like gymnastics, can serve as effective tools in facilitating the transfer of values that are often difficult to attain.

Furthermore, the study revealed that the development of values did not exhibit significant differences based on age and gender. Regarding age variables, only the difference scores in the friendship sub-dimension showed significance in favor of the 4-year-old age group. This finding aligns with Neslitürk and Çeliköz's (2015) study, which reported no difference in the family form scores of the values scale in preschool children based on gender and age. Similarly, Deniz's (2019) master's thesis results indicated no significant relationship between the family form scores related to values in preschool children and the children's gender and age variables. Upon examining sub-dimensions such as friendship, honesty, sharing, cooperation, and respect, which did not vary significantly based on age and gender, it is suggested that acquiring these values may take time. Pedagogical support and participation in a longer and more regular training program are considered potential factors that could make a difference in developing these values.

In Şahin's (2017) study, girls' value scale scores were reported to be significantly higher than boys. Similarly, Eke's (2018) study mentioned a higher mean for girls than boys, specifically in the cooperation sub-dimension. Ötgür's (2019) results indicated a significant difference favoring girls in the responsibility sub-

dimension of the value acquisition scale for children. Alamehmet's (2019) master's thesis observed higher mean scores for girls in both the preschool values scale and the honesty sub-dimension compared to boys. Yakupoğulları's (2018) master's thesis found significantly higher scores for girls in respect and cooperation than boys. Yılmaz et al. (2022) compared the value perceptions of Turkish and English children, revealing significantly higher scores for girls. Contrary to these findings in the literature, no significant difference between genders was observed in the present study. This lack of difference may be attributed to the fact that both girls and boys participated together in gymnastics activities, engaging in games and inclusive activities without gender-specific distinctions. Regarding age variables, while Şahin's (2019) and Şahin's (2017) studies found that as children's age increases, their level of value acquisition also increases, the current study did not reveal significant differences in sub-dimensions or the total scale, except for the friendship sub-dimension, based on age. To draw a clearer conclusion regarding age effects, longitudinal studies may be warranted.

Dönmez & Uyanık (2022) proposed initiating preparations for values development in the pre-school period, emphasizing the need for practical applications. The current experimental study aligns with this suggestion. Yenen & Ulucan (2021) highlighted the complexity of the value transfer process, involving multiple disciplines. Thornberg & Oğuz (2013) emphasized the integration of values with subjects like physical education, and Öztürk & Can (2020) noted the positive impact of integrating music education with movement on the social values of preschool students. Several studies support the idea

that transferring values through physical education and sports is a powerful, enjoyable, and sustainable approach (Öztürk Kuter & Kuter, 2012). The choice of gymnastics in this study, with activities conducted through entertaining games, aligns with the notion that values, being related to various disciplines, can be effectively conveyed through enjoyable physical education and sports activities.

Moreover, studies have indicated the effectiveness of creative drama (Kılıç, 2017; Mehmudoğlu & Yüce, 2020) and games (Can & Günadı, 2019; Doğan, 2021; Gündüz et al., 2017; Özyürek et al., 2018) in values development. The emphasis is on the idea that children learn more permanently when actively participating, doing, and experiencing. The practice content of this study reinforces the recommendations and findings from other literature, showcasing that gymnastics exercises, designed as game-based activities, engage children in the learning process with their peers in a fun and interactive manner.

CONCLUSION

In the study, a significant difference was observed only in the dimension of responsibility in the development of values in preschool children who participated in gymnastics training during the summer period. However, an increase was noted in the scores of all sub-dimensions. This outcome suggests that game-based sportive activities such as gymnastics in preschool children can be effective in transferring the values that families and teachers aim to instill in children.

SUGGESTIONS

The recommendation is to conduct multidisciplinary studies in various disciplines and with different samples to explore the development of values. It is also suggested to design and incorporate training plans with game content, such as gymnastics and group activities, into the preschool curriculum.

Additionally, supporting trainers who work with younger age groups in terms of communication and specific training activities for this age group is deemed important. Therefore, it is advised to include courses on working with preschool children in the curriculum of the Sports Science Faculty.

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Article received: 1. 2. 2023

Article accepted: 24. 10. 2023

ANALYSIS OF THE SCIENTIFIC LITERATURE ON ARTISTIC GYMNASTICS IN SCOPUS DATABASE

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Original article

DOI: 10.52165/sjg.16.1.105-121

Abstract

The purpose of this article is to examine the current state of scientific production, collaboration, and the effects of research publications on artistic gymnastics, as well as the most active researchers pursuing this area of study. Documents acquired from the Scopus database served as the basis for our investigation. MS Excel as well as VOS viewer were used to carry out the bibliometric analysis and network design. As a result, 430 original articles and scientific reviews in 22 Scopus subject areas were found in 167 journals. Most articles were published in Science of Gymnastics Journal (76). These articles are also most cited (294). There are 28 authors with five to fifteen articles whose citation form most of the citation network. Most of the artistic gymnastics research is published in journals that cover subjects such as medicine, health professions, and social science, with the first receiving the most citations.

Keywords: *artistic gymnastics, bibliometrics, citation network, scientific literature*

INTRODUCTION

Artistic gymnastics stands as a widely embraced competitive sport, encompassing both male and female participants on the Olympic stage. This sport comprises four events for women (vault, uneven bars, balance beam, floor) and six events for men (floor, pommel horse, rings, vault, parallel bars, floor). In accordance with the findings of Arkhaev & Suchlin (2004), artistic gymnastics involves a diverse range of routines executed on equipment with varying motor skill requirements. The significance of artistic gymnastics lies in its capacity to foster physical well-being, mental resilience, aesthetic expression, teamwork, and cultural sensitivity. It plays

a pivotal role in holistic development, exerting enduring positive impacts on individuals and society at large. The International Gymnastics Federation (FIG) serves as the global governing body for artistic gymnastics and related disciplines.

The application of scientific research holds the potential to enhance training methodologies, elevate performance standards, and establish a safer milieu for gymnasts to excel. In essence, scientific inquiry within gymnastics contributes to the evolution and advancement of the sport, simultaneously aiding athletes in unlocking their utmost capabilities while ensuring their safety and overall welfare. In our

research, the bibliometric method will be used to better understand the current state of research in artistic gymnastics. Bibliometrics is the mathematical and statistical study of scientific literature (Pritchard, 1969). It identifies papers that are focused on a certain subject and reveal the social and logical connections between the key players (authors/scientists) in each scientific field. The basis for bibliometric research are the so-called primary sources of scientific information. These are publications that most often include articles and other papers published in academic journals, monographs/books, and papers published in academic journals and book proceedings (Jokić et al., 2012).

As far as we know an attempt to globally evaluate the current state of artistic gymnastics scientific research has not been published in a scientific journal to date. The only comparable study that we could find was research of the academic production on men's artistic gymnastics conducted by Pauline Iglesias Vargas and André Mendes Capraro (2020). The goal of their study was to outline the scholarly output of publications related to men's artistic gymnastics that were indexed in the Scopus and Web of Science databases. Authors conducted a non-specific date-range search on both platforms using the terms "men's artistic gymnastics" and "male artistic gymnastics" with the objective to highlight a panorama of the distinct academic production on men's artistic gymnastics through the application of the criteria.

Several bibliometric studies focusing on various sports have been published in the field of sport science. A bibliometric analysis of sports economics research between 1956 and 2009 revealed an increase in the quantity of published articles and journals, as well as the productivity of

this field of study (Santos & García, 2011). The research on bibliometric characteristics of articles can be found in the research by Peset et al. (2013) whose goal was to detect the status of the scientific production, collaboration, as well as impact of scientific papers on judo. Research by Prieto et al. (2015) provides a bibliometric review of the scientific production in handball. The same year Pérez-Gutiérrez et al. (2015) performed a bibliometric analysis of taekwondo articles indexed in the Web of Science between 1989 and 2013. They concluded that there weren't enough academics studying this martial art, despite the fact that taekwondo had seen a significant surge in scientific research. Ho & Ho in 2015 conducted a bibliometric analysis of scientific production in the field of dance by analysing papers published in journals indexed in Web of Science database from 1994 to 2013. In 2019, Wang and Ho conducted an analysis of dance performance reviews from the years 1992 to 2016. The analysis focused on various aspects, including languages, publication outputs, authors, and journals of publication. Another bibliometric analysis was completed between 1968 and 2018 (Huertas González-Serrano et al., 2020) with the goal of providing an examination of sport entrepreneurship in the Web of Science Core Collection. The "sport sciences" literature's bibliometric analysis of all articles pertaining to summer and winter Olympic sports offers useful and practical information for researchers, practitioners, and funding stakeholders to further the Olympic-based research agenda in the rapidly expanding interdisciplinary subject of sport sciences (Millet et al., 2021). Özkadı et al. (2022) gave a summary of 2392 publications published between

1980 and 2021 thorough bibliometric analysis on swimming.

The aim of our study is to find out the current state of scientific production, collaboration, and most active researchers in artistic gymnastics. The primary achievement of this study is pinpointing significant research topics that enhance comprehension of the publishing patterns within artistic gymnastics. Utilization of bibliometric analysis offers a thorough outline of the field's progress, by concentrating on noteworthy publications, journals, authors, and connections. This serves as a valuable step towards offering essential background for upcoming research and researchers.

METHODS

We chose Scopus (Elsevier) as the data source because it took into account the caliber of the literature as well as the

requirement for the right reference format. Since 2004, prestigious academic, commercial, and governmental organizations have chosen the Scopus database. The database combines the exceptional quality and coverage of Scopus data with cutting-edge analytics and technology. We employed the Scopus database to ensure the study's thoroughness due to its scope: it covers more than 23,452 top-notch peer-reviewed journals.

The approach to the search was as follows: the term “artistic gymnastics” was searched within the Article title, Abstract, Keywords (Figure 1). The focus of the study were the years 1975 to 2022. The earliest entry in the database dates to 1975. To ensure the accuracy of the analysis, the current year, 2023, has been omitted from consideration. The only acceptable publication types were (original) articles and reviews. A total of 430 articles were under investigation.

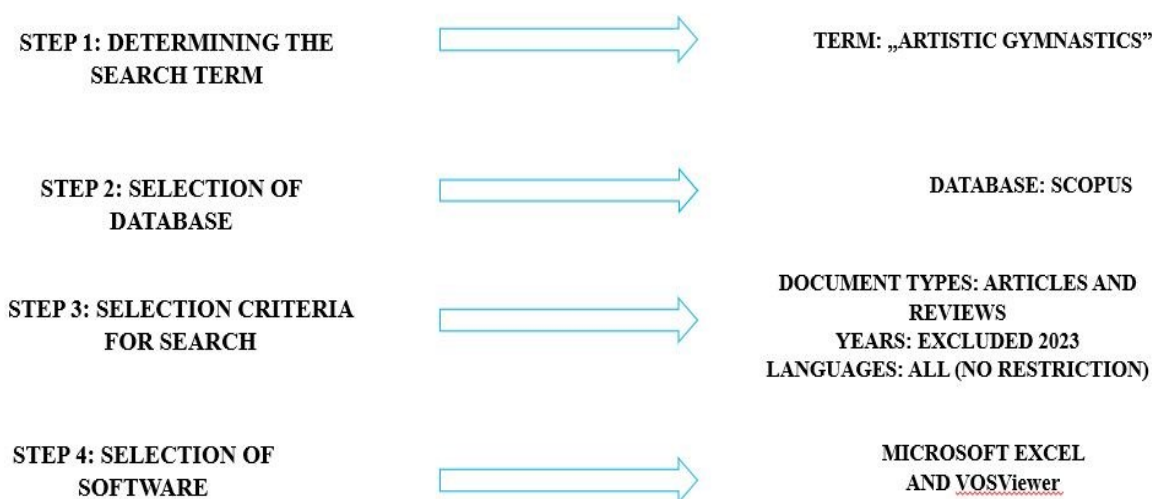


Figure 1. Scopus database selection criteria.

All results were downloaded with the record content of “Citation information”, “Bibliographical information” and “Abstract & keywords”, and exported in RIS format for further processing using Scopus's “Export Document Settings” option. A Microsoft Excel file was created and stored with a summary of the bibliographic data, which included the annual number of publications and citations, nations, institutions, authors, journals, funding agencies, research topics, keywords, and references.

The 2021 Scientific Journal Rankings served as the foundation for the SJR. Using VOSviewer 1.6.18, both qualitative and quantitative assessments were carried out. It was used in the present study to illustrate the co-authorship analysis of the authors and the co-occurrence analysis of the keywords. Graphs and descriptive statistical analyses were conducted using Microsoft Excel 2022.

The bibliometric analysis considered the following factors: document types and languages, the annual trend of articles published, the average number of authors

per article, research fields and topics, trends of publications in the most active research fields, top journals, author productivity, and country distribution of publications.

RESULTS

Figure 2 shows the analysis of document type. Reviews (N=23; 5.35%) were the second-most common form of publication after (original) articles (N=407), which accounted for 94.65% of the analyzed references.

Examining the language of publication (Figure 3), 84.88% of the 430 studied articles were written in English (N=365), significantly more than in any other publication language. Other languages included Portuguese (N=24 articles; 5.58% out of the total), Russian (N=19; 4.42%), Spanish (N=15; 3.49%), German (N=8; 1.86%), French (N=7; 1.63%), Slovenian (N=7; 1.63%), Croatian (N=4; 0.93%), Italian (N=3; 0.70%), Japanese (N=2; 0.47%), Chinese (N=1; 0.23%), Korean (N=1; 0.23%), Polish (N=1; 0.23%), and Turkish (N=1; 0.23%).

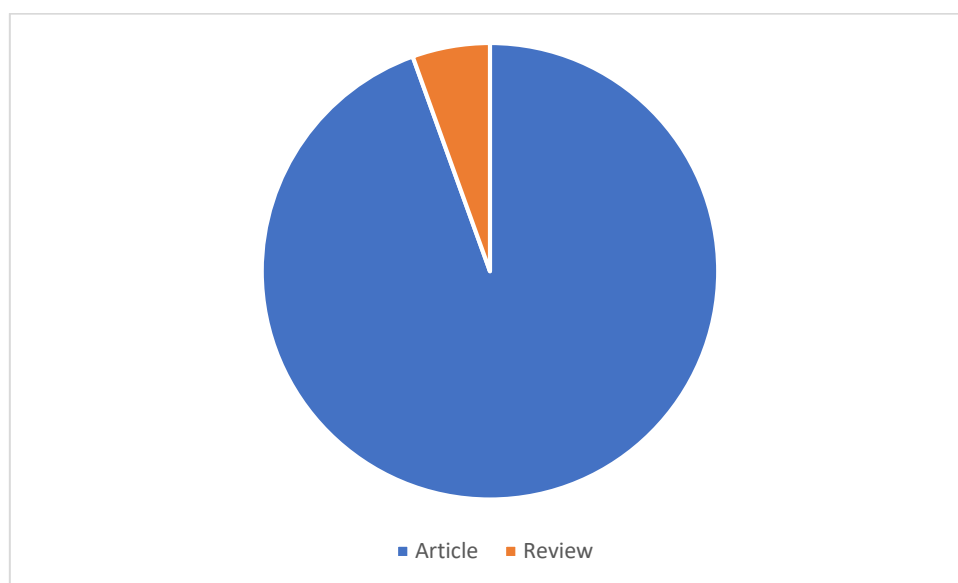


Figure 2. Total number of publications by document type

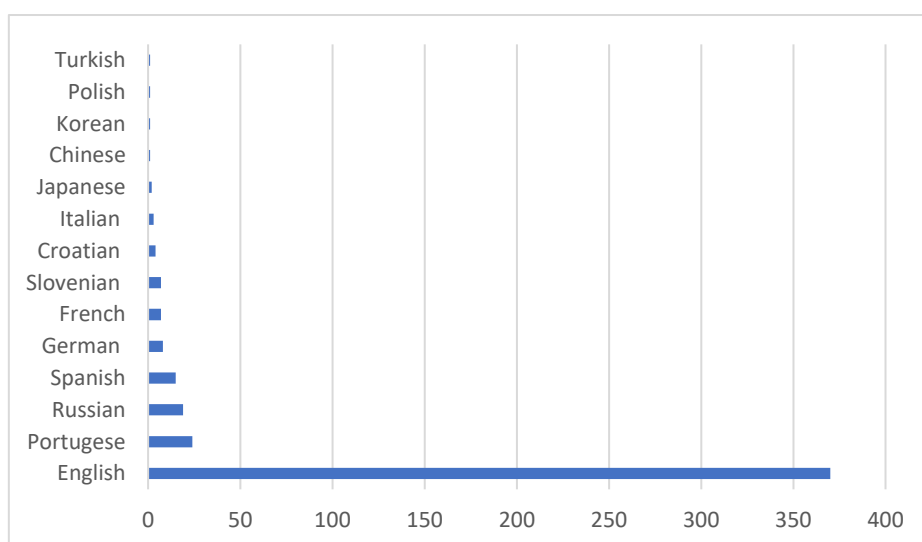


Figure 3. Total number of articles published by language.

Figure 4 displays the annual trend of articles that have been published. *Studies on the vertebral column in young female gymnasts (Wirbelsäulenuntersuchungen bei Jugendlichen Kunstturnerinnen)* was the first publication in artistic gymnastics research to be published (Meyer, 1975). From this year to 2010, the number of published articles remained in very low figures, with no more than 8 articles per year, and for several years there was only one published article per year. Since 2011,

there has been a steady rise in the number of articles, with some years (2014 and 2015) still seeing a fall in production. Nevertheless, there has been a definite upward trend, with the number of articles rising from 18 in 2012 to 41 in 2022. This pattern of publishing, particularly since 2011, when the number of published articles nearly tripled, demonstrates a significant advancement in artistic gymnastics research.

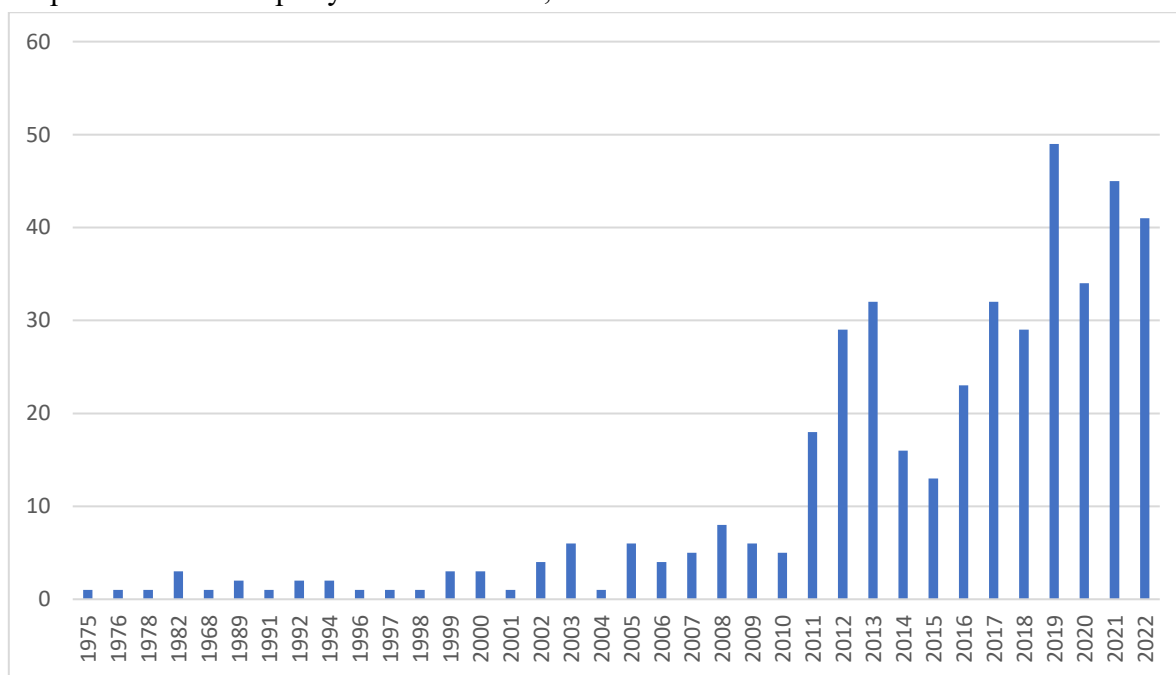


Figure 4. Number of published articles per year during 1975-2022.

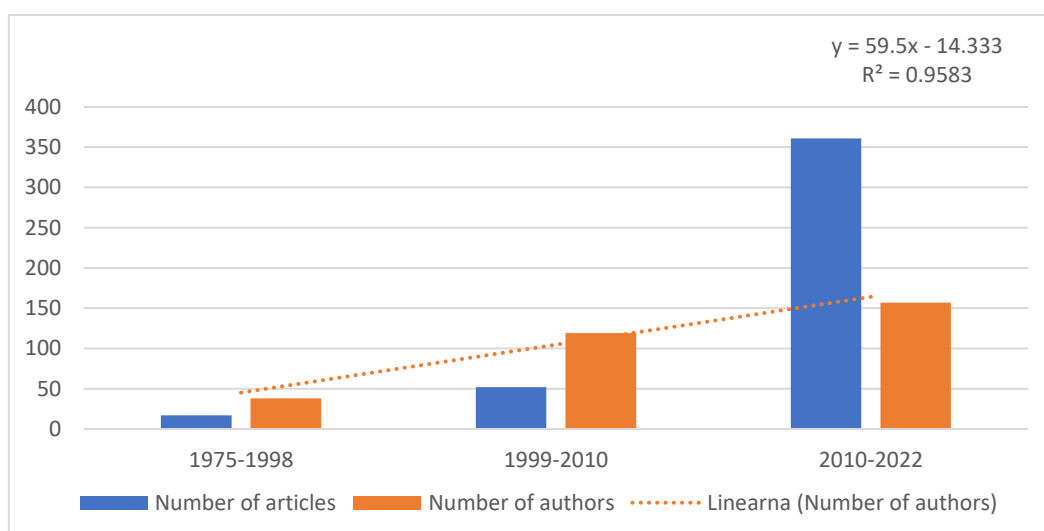


Figure 5. Average number of authors per article during 1975-2022.

Figure 5 illustrated the average number of authors per article. From 0.47 authors per article in the years 1975–1998 to 2.30 authors per article in the years 2010–2022, there was a significant rise in the average number of authors who contributed to articles. The linear trend line's R-squared value was 0.9583. The years with no articles published had a substantial impact on this number. Whatever the case, this demonstrates a significant level of cooperation in artistic gymnastics studies over time, particularly in recent years.

Table 1 shows the distribution of articles by area of study. Medicine emerged as the most productive, with the highest number of published articles (N=292, 67.91%), followed by health professions (N=250, 58.14%), social sciences (N=152, 44.71%), biochemistry, genetics, molecular biology (N=36, 8.37%), and engineering (N=24, 7.06%). Regarding article citations, medicine accumulated most citations (N=3533), followed by health professions (N=2345), social sciences (N=790), biochemistry, genetics and molecular biology (N=503), and engineering (N=148).

Regarding the 10 keywords that were most often used in the articles, (artistic)

gymnastics appeared 296 times, followed by human(s), physical education, female, adolescent, male, adult, sport, athlete, and biomechanics.

An article's title, abstract, and author-supplied keyword list are used to extract keywords from the text. The number of publications in which two keywords appear together in the title, abstract, or keyword list is known as the co-occurrence of the keywords.

Figure 6 shows the co-occurrence of keywords. According to outputs produced by the VOSviewer based on the Scopus data, the analysis of co-occurrence of all keywords (in title, abstract, or keyword list) returned 2016 results. 176 were selected based on the threshold of 5 co-occurrences. It was not surprising to find that "gymnastics" had the highest total link strength of any term. The proximity of keywords revealed a relationship between them; the further away from "gymnastics" they were, the further away the relationship or the less research was conducted on them. Gymnastics, bone strength, ankle injury, and shoulder joint, for instance, received less research.

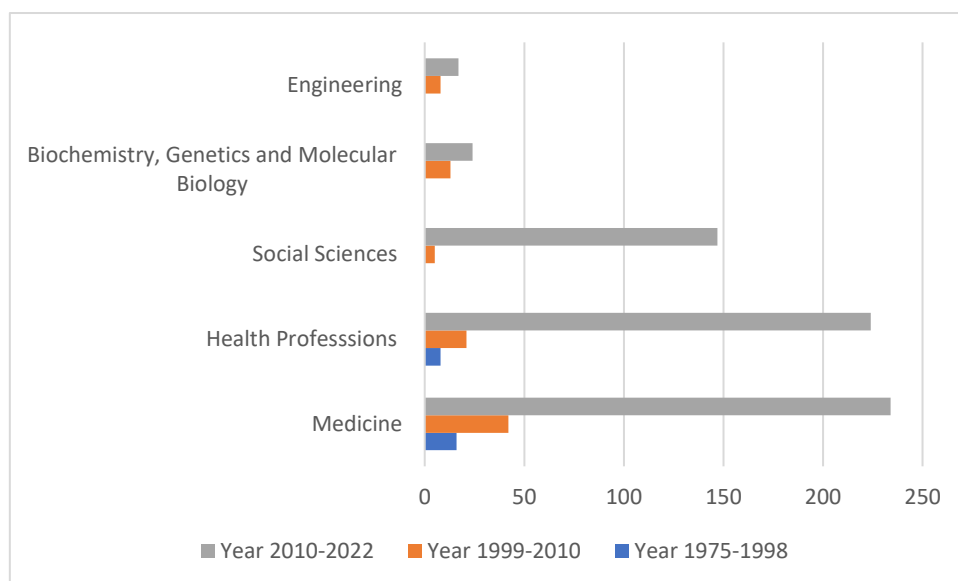


Figure 8. Number of published articles per research area.

The 430 articles under analysis were published in 167 journals overall. Table 2 lists the top 10 scientific journals for artistic gymnastics research along with statistics on the number of published articles, overall journal citations, average citations per article, and current journal rankings (SJR). Out of the 167 journals, the top 10 most active journals published a total of 175 articles, accounting for 40.70% of all articles published. *The Science of Gymnastics Journal* (76 articles; 6.43% of all published articles) and the *Journal of Physical Education and Sport* (24 articles; 5.58% of all published articles) stand out, followed by *Teorya i Praktika Fizicheskoy Kultury* with 14 articles (3.26%). The top 10 journals received 1,276 citations, or 29.98%, of the 4,256 citations that were received by all retrieved articles.

The fact that three of these journals—*Science of Gymnastics Journal*, *Journal of Sports Sciences*, and *Sports*

Biomechanics—account for 18.59% of all citations is also noteworthy. With only 7 papers published (1.63% of the total publications), the *Journal of Sports Medicine and Physical Fitness* garnered 177 citations (4.16% of the total citations), averaging 25.26 citations per article. This is primarily due to one article with 124 citations, regarded as strong evidence of its contribution (*The contribution of anthropometric characteristics to performance scores in elite female gymnasts*; Claessens, 1999). Other featured articles which were cited more than 100 times were: *The prevalence of spondylolysis in the Spanish elite athlete* (Tomása & Calderón, 2000); *In pursuit of an identity: A qualitative exploration of retirement from women's artistic gymnastics* (Lavalee & Robinson, 2007); and *Gymnastics injuries* (Caine & Nassar, 2005) with 189, 123 and 121 citations respectively.

Table 2 *Top ten most active journal.*

Journal title	Articles	Citations	Average citation per article	SJR
Science of Gymnastics Journal	76	294	3,9	0.283
Journal of Physical Education and Sport	24	60	2,5	0.393
Teorya i Praktika Fizicheskoy Kultury	14	8	0,6	0.204
Journal of Sports Sciences	12	248	20,7	1.162
Sports Biomechanics	10	249	24,9	0.783
Journal of Human Sport and Exercise	9	37	4,1	0.589
Journal of Human Kinetics	8	59	7,4	0.816
Journal of Sports Medicine and Physical Fitness	8	177	22,1	0.49
Journal of Biomechanics	7	117	16,7	0.747
Motriz Revista de Educacao Fisica	7	27	3,9	0.217

Table 3 *The ten most productive authors.*

Author	Country	Number of Articles	Leading Author Articles	Collaborated Articles	Citation Number	Average per article
Nunomura, M.	Brazil	15	5	15	101	6,73
Čuk, I.	Ljubljana	14	5	14	174	12,43
Kalinski, S. D.	Croatia	10	5	10	58	5,80
Barker-Ruchti, N.	Sweden	10	4	1	229	22,90
Atiković, A.	Bosnia and Herzegovina	9	5	8	39	4,33
Hiley, M. J.	United Kingdom	9	8	9	237	26,33
Irwin, G.	United Kingdom	9	3	9	125	13,89
Hübner, K.	Switzerland	8	0	8	31	3,88
Schärer, C.	Switzerland	8	8	8	31	3,88
Yeadon, M. R.	United Kingdom	8	1	8	229	28,63

In the observed period, articles produced by a sole author were in minority (39 articles; 9.07%). The high level of collaboration between scientists is reflected in multi-author articles, with 4 authors as the most frequent (201, 46.74%). There are

102 articles (23.72%) with two authors and 88 with 3 authors (20.47%). The 430 articles that were retrieved were signed by a total of 155 different authors. Table 3 lists the top ten authors in artistic gymnastics research in leading author publications and

collaborative publications, along with their home nations. These top-10 most productive authors contributed to 104 articles (24.19% of the total number of publications), making up 6.45% of all authors. This is consistent with findings in the majority of academic domains, where a small number of productive authors produce a sizable portion of publications. The fact that three of the top 10 writers were British highlights the significance of artistic gymnastics research in this nation.

A visual representation of research networks called co-authorship networks can show how collaborative a group of researchers are (e.g., grantees, international or industry collaborators, or faculty mentors). Vosviewer software was used to facilitate the analysis.

A cluster is a group or agglomeration that maintains a certain link, and each hue on the map denotes a cluster. Each hue represents a team of scientists who collaborate and research in the same field in this fashion. The size of the circles and the characters in the authors' names show how much writing each author has produced. Larger circles denote higher productivity. The lines between the circles show the

approximate co-authorship relationship, while the distance between them shows the relationships between the authors. Clusters near one another suggest closely connected fields (van Eck & Waltman, 2017).

In 430 publications that were examined for co-authorship, 155 collaborative authors were identified. To enhance data visualization, authors who have co-authored more than three articles were selected, resulting in a map featuring 70 results with 12 significant relations. The map reveals the presence of four clusters or groups of authors maintaining co-authorship relationships, distinguished by colors (Figure 9). Additionally, Čuk (Cuk) is notably interconnected with other authors across various clusters.

Analyzed articles were published by 50 different nations in total. Figure 10 lists ten nations with the highest levels of productivity. Brazil, the United States of America, and eight other European countries were in the top ten most productive nations. European nations contributed to 62.52% of the articles overall, showing just how important this continent is to artistic gymnastics study.

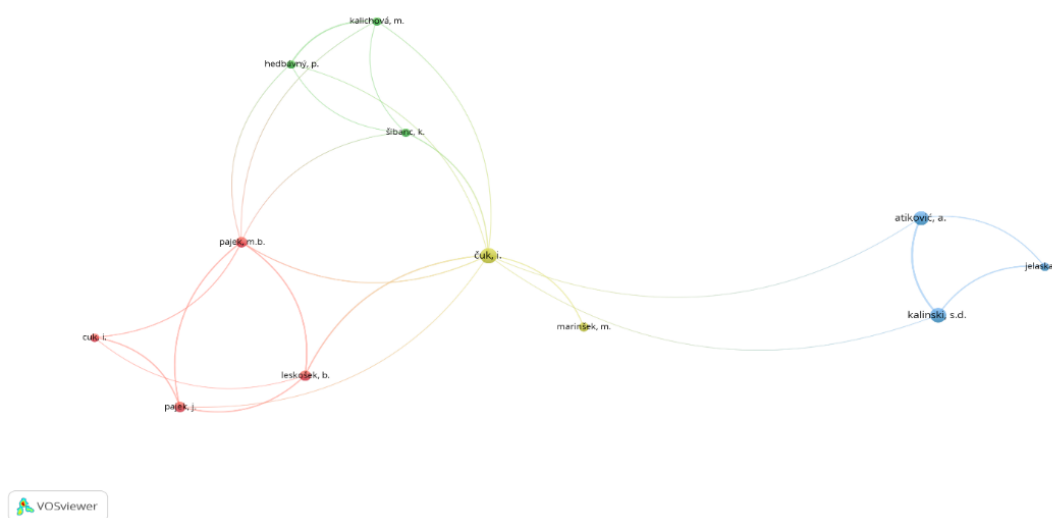


Figure 9. Map of co-authorship

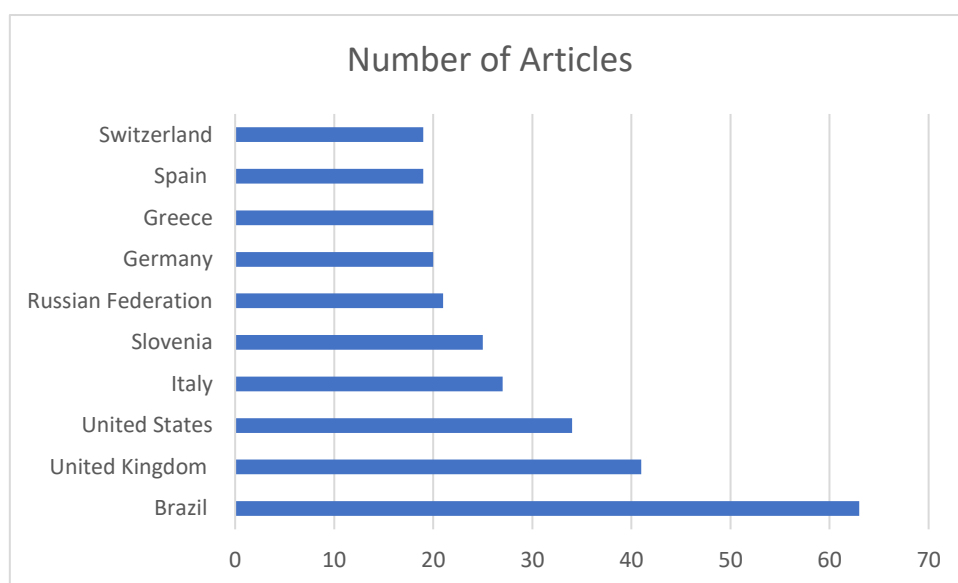


Figure 10. Top ten most productive countries.

DISCUSSION

While not as widespread as other sports, research on artistic gymnastics has expanded significantly in recent years. The goal of the current study was to conduct a bibliometric analysis of the body of research in artistic gymnastics. Publications from 1975 until 2022 were gathered from the Scopus databases. Original scientific articles were the most prevalent document type (N=407) and made up 94.65% of all publications. This demonstrates that researchers in the discipline of artistic gymnastics choose articles from scholarly journals as their primary medium for disseminating their most recent and significant results, which is consistent with most scientific research domains.

Of the 430 articles included in the research, 365 (84.88%) were written in English. Similar results can be found in the research on handball scientific production (Prieto et al., 2015). This confirms that English is the most widely used academic language and that the majority of scientific publications indexed in global academic databases are written in English. The

number of published articles from 1975, when the first scientific article on artistic gymnastics was published and indexed in Scopus, through 2010, stayed below 8 per year. Since 2010, the number of articles has gradually increased, particularly since 2017, when the number of published articles nearly tripled to reach an annual average of 30 articles. This demonstrates how artistic gymnastics has advanced significantly in recent years. The same conclusion was made by Vargas & Capraro (2020), and the reason for that was found in the global increase in academic output in tandem with the growth of search platforms.

With the evolution of collaborative research, there has been a consistent rise in the average author count per publication across all scientific fields since the 1980s (Hosseini et al., 2022). Within the examined dataset, a clear escalation in the authors per paper is evident, shifting from 0.47 authors to 2.30. According to the 2017 Taylor and Francis White paper, the rise in the number of authors could be attributed to the possibility that the nature of the research being carried out might require greater collaboration. The expansion of

interdisciplinary work, which gains advantages from diverse viewpoints, received notable emphasis. Additionally, emerging methodologies like participatory research are also exerting an impact. Knudson (2005) arrived at a similar finding through an analysis of applied biomechanics research. His conclusion aligns with the idea that there is an increasing inclination towards having a higher number of coauthors per paper. Moreover, there is an increase in the proportion of articles with six or more authors, while the percentage of articles authored by a single individual has been declining.

The scientific field with most publications was medicine, followed by the health professions, social science, biochemistry, genetics and molecular biology, engineering, and psychology. It draws attention to the fact that three of the top 10 disciplines (health profession, biochemistry, genetics and molecular biology, psychology) are in some way related to the medical sciences. This shows that artistic gymnastics is a sport with a high physical and psychological component where studies about injuries, physical capabilities, physiological components, etc., are common.

Various study areas in the field of medicine encompass topics such as eating disorders, vitamin D intake and bone density, sports injuries, strength, and motor skills, among others. The risk of spinal and other injuries is particularly high in artistic gymnastics due to its demanding nature, which increases with the level of performance. Research topics that are commonly explored include physical capabilities and conditions, physiological variable assessment, performance and success variables, male and female artistic

gymnastics, and sport technique. The predominance of the biological domain over the social domain is elucidated by Vargas & Capraro (2020). They suggest that this is not unexpected as there are generally fewer researchers and consequently fewer publications in the social aspects of sports.

The dominant trend in artistic gymnastics research publication are still articles published in the field of medicine, which has held the top spot every year throughout this period. In the same span of time, there was a considerable increase in biochemistry, genetics, and molecular biology, which emerged as the field with most articles published in 2003, 2005, and 2008. The same applies to the research area of social sciences, which had three indexed articles and 147 total publications in 2011.

VOSViewer's functionality for clustering keywords based on their co-occurrence is utilized for the analysis of keywords. Both author keywords and index keywords contribute to constructing a comprehensive overview of the diverse areas of study within the field of artistic gymnastics. The size of each node corresponds to the frequency of a particular keyword's occurrence, while the connections between nodes indicate the instances of these keywords co-occurring. A higher frequency of co-occurrence leads to a closer proximity between the associated keywords. Among the keywords exhibiting high frequencies, terms like "adolescents," "man," "adults," "women," "biomechanics," "physiology," and "performance" stand out. These frequencies suggest an increasing focus on researching the biomechanical and physiological aspects of artistic gymnastics, gender disparities, and various dimensions of artistic gymnastics concerning young individuals and adolescents. The outcomes of the keyword analysis align with the

prevailing trend of publications in the most active research domains, with medicine prominently holding the top position across different research periods.

The top three journals with the highest research activity in artistic gymnastics were *Science of Gymnastics Journal*, *Journal of Sports Sciences*, and *Sports Biomechanics*. The predominance of *Science of Gymnastics Journal* can be attributed to its specialization as an international gymnastics journal. Additionally, its affiliation with the gymnastics department of the University of Ljubljana and sponsorship by the Fédération Internationale de Gymnastique contribute to its prominence in publishing articles related to gymnastics (Vargas & Capraro, 2020).

The authorship pattern revealed that a small group of writers were responsible for a sizable portion of the publications. British authors made up three of the top ten most productive authors, demonstrating the significance of artistic gymnastics in this nation. In terms of region, European nations contributed to 22.09% of the articles. Aside from Brazil, the top 10 nations are almost predominantly European, demonstrating Europe's significant research presence in artistic gymnastics. This finding aligns with the results of the research conducted by Vargas & Capraro (2020), which also highlighted the predominance of the United Kingdom.

The top four productive authors, each with over ten published scientific papers in the field of artistic gymnastics, are Nunomura, M. (15), Čuk, I. (14), Kalinski, S. D. (10), and Barker-Ruchti, N. (10). The most cited articles are authored by Ivan Čuk, accumulating a total of 174 citations. All of these authors hold professorial positions at prestigious universities and specialize in artistic gymnastics.

Specifically, Myrian Nunomura is a professor at the School of Physical Education and Sport, University of Sao Paulo; Ivan Čuk is a professor at the Faculty of Sport, University of Ljubljana; Sunčica Delaš Kalinski is a professor at the Faculty of Kinesiology, University of Split; and Natalie Barker-Ruchti is a senior lecturer at the School of Health Sciences at Örebro University.

The co-authorship network offers insights into the structure of research within specific subjects, the progression of research networks over time, and the involvement of specific organizations or countries within these networks. Through co-authorship, we can observe the quantity of publications produced by authors and the connections between them. By employing co-authorship analysis, the prominent figure in the network was identified as Ivan Čuk. It's important to note that co-authorship data presents just one potential measure of scientific collaboration. Not all collaborative endeavors culminate in published works, and not all joint papers necessarily denote a sharing of knowledge among the authors. Nevertheless, it is generally assumed that co-authorship predominantly signifies active cooperation among partners that extends beyond mere material or information exchange.

When it comes to the overall scientific output concerning artistic gymnastics, Brazil stands out as the most productive nation. That's no surprise given that artistic gymnastics is very popular in Brazil, boasting a rich heritage and formidable global representation (Dindu, 2022). The administration of gymnastics in the country falls under the jurisdiction of the Brazilian Gymnastics Confederation (CBG), an affiliate of the International Gymnastics Federation (FIG). The nation has a track

record of accomplishments in artistic gymnastics, especially within the women's category. Among the prominent Brazilian gymnasts are individuals like Daiane dos Santos (Dindu, 2022), who secured a bronze medal during the 2004 Olympics, and Jade Barbosa, recognized for her multiple victories in the Pan American Games and various other global tournaments.

CONCLUSION

After describing the scholarly output on artistic gymnastics in journals listed in the Scopus database we came to the following conclusions: 1) the earliest article on the topic dates back to 1975, with 2019 being the year with the highest number of articles published; 2) English remains the dominant language in academic publications with 84.88% of the articles analyzed authored in English); 3) an increase in collaboration among authors was observed over time; 4) medical research comprises the majority of articles (67.91%) and also has the highest citation rate (82.64%); 5) four authors have authored more than 10 publications on this topic: one Brazilian (Nunomura, M.), one Slovenian (Čuk, I.), one Croatian (Kalinski, S. D.), and one Swedish (Barker-Ruchti, N.); 6) the *Science of Gymnastics Journal* leads in the number of articles on artistic gymnastics (17.67%), followed by the *Journal of Physical Education and Sport* (5.58%).

The purpose of this article is to encourage researchers to delve into the intricacies of artistic gymnastics and advocate for increased funding to advance scientific knowledge in this field. The information provided here can serve as a guide for researchers in deciding which journals to subscribe to and where to submit

their future articles. It can also aid new researchers in identifying key contributors and institutions in the realm of artistic gymnastics.

Acknowledging the limitations of the methodological approach, particularly in the selection of search engines and keywords, this study sought to offer an overview of the diverse academic production in artistic gymnastics within the methodological constraints. It underscores the importance of authors being meticulous in crafting the titles, keywords, and abstracts of their articles, as relevant research on this topic may have been inadvertently excluded by the search criteria employed in this study. Additionally, the preference for English-language journals is noted.

As bibliometric analysis is contingent upon the selected bibliographic sources, the findings and interpretations presented in this study are focused solely on evaluating the state of artistic gymnastics research utilizing the chosen Scopus database. We believe this research effectively serves as a comprehensive portrayal of the current landscape of artistic gymnastics research, given its primary objective of conducting an exploratory bibliometric analysis.

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Article received: 6. 4. 2023

Article accepted: 25. 9. 2023

ANALYSIS OF THE SCIENTIFIC PRODUCTION IN ARTISTIC GYMNASTICS, AND IN THE MEN'S AND WOMEN'S MODALITIES

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Original article

DOI: 10.52165/sgj.16.1.123-150

Abstract

Artistic gymnastics, as a fundamental sport forming the basis for acrobatic activities in sports, art, and recreation, is the subject of this research. The aim is to scrutinize scientific studies on artistic gymnastics, both in a general context and in terms of male and female modalities. A bibliometric analysis was conducted on journals indexed in Scopus and Web of Science, following established bibliometric principles. Analysis, processing, and graph generation were carried out using Microsoft Excel and Bibliometrix software. A total of 482 documents published between 1975 and 2023 were identified, revealing exponential growth in publications. The core set of prolific journals comprised six publications. Among 1241 authors, 33 were identified as prolific (with 5 or more publications), with 12 standing out as prominent. Brazil was the most productive, and the USA was the most cited. Keywords were grouped into four main categories: "technique analysis," "physiological aspects," "gymnastics as a fundamental sport," and "exercise evaluation and scoring." In conclusion, the research community exhibits a growing interest in artistic gymnastics. Sunčica Delaš Kalinski (Croatia) was the most prolific author, and Albrecht L. Claessens (Belgium) stood out prominently. The "Science of Gymnastics Journal" proved to be the most influential publication. Four primary research lines were identified based on keyword groupings.

Keywords: sports, acrobatics, bibliometric, review, Olympics

INTRODUCTION

Artistic gymnastics stands as a cornerstone in sports, alongside athletics and swimming (Jiménez Bermeo, 2020). From a physical standpoint, it encompasses all fundamental physical qualities, reaching exceptional levels of development, excluding aerobic endurance (Russo et al., 2021). Strength, flexibility, and speed of execution in artistic gymnastics often achieve remarkable levels not commonly

observed in other sporting events (Desai, Vance, Rosenwasser, & Ahmad, 2019; Kilijanek & Sanchez, 2020; Tayne, Bejarano-Pineda, & Hutchinson, 2021).

The physical coordinative capacities in artistic gymnastics shine prominently, particularly when executing elements of difficulty and coordinative complexity that involve rhythm, agility, orientation, coordination, and more (Abdurashidovich,

2020). These elements are integral to the "technique." The precision in linking gymnastics technical actions with the corresponding intensity in muscle contraction plays a crucial role in successful execution (Farana et al., n.d.), ultimately impacting the competition outcome (Barker-Ruchti & Schubring, 2016).

This sport comprises two distinct modalities: women's artistic gymnastics (WAG) and men's artistic gymnastics (MAG). WAG includes the floor, vault, balance beam, and uneven bars, while MAG encompasses the floor, horizontal bar, parallel bars, vault, rings, and pommel horse (FIG - Fédération Internationale de Gymnastique, 2016a, 2016b). The execution of acrobatic and aesthetic routines in various apparatuses demands cognitive and generative components more akin to the arts than traditional sports (Barker-Ruchti, 2008; Pero, Mallia, Capitani, & Scibinetti, 2022).

This discipline necessitates substantial physical and mental preparation, coupled with refined technique and precise execution (Niżnikowski & Sadowsky, 2020). Judges evaluate exercises performed on each apparatus, adhering to scoring criteria outlined in the Code of Points (CoP) for each modality (FIG - Fédération Internationale de Gymnastique, 2016a, 2016b).

Artistic gymnastics serves as the foundational basis for acrobatic activities across sports, arts, and recreation (Šalaj, Milčić, & Šimunović, 2019). The acquired movements and skills in this sport provide an excellent foundation for acrobatics in various disciplines such as dance, circus, parkour, or cheerleading, among others (Rabaglietti, Mulasso, & Arzenton, 2020).

Artistic gymnastics not only enhances muscular strength, flexibility, coordination,

balance, and physical endurance but also introduces a risk component that fosters constant challenge and the overcoming of fears. This not only contributes to cognitive, emotional, and social development by promoting values like discipline, perseverance, teamwork, and self-confidence but also significantly improves self-esteem and intrinsic motivation for sports practice. This, in turn, leads to the cultivation of healthy lifestyle habits (Menegaldo & Bortoleto, 2020; Petrovska et al., 2022).

This introduction allows us to know many of the areas and characteristic aspects that artistic gymnastics contains, and which any researcher might investigate. While the literature on artistic gymnastics is extensive, the distribution of topics and research objectives remains unclear. This lack of clarity hampers our understanding of which areas are more attractive for investigation and which areas are left unexplored. Therefore, it is deemed relevant to assess the state of scientific research in artistic gymnastics, akin to previous analyses in other sports like judo (Caravaca, Hernandez-Garcia, & Garcia-de-Alcaraz, 2018), badminton (Blanca-Torres, Ortega, Nikolaidis, & Torres-Luque, 2020), or collective sports (Mamani-Jilaja, Huayanca-Medina, Casa-Coila, Vilca-Apaza, & Romero-Carazas, 2023). Through a bibliometric analysis (Denche-Zamorano et al., 2023; Leite et al., 2023; Vargas & Capraro, 2020), this study aims to analyze the growth, size, and distribution of scientific publications related to artistic gymnastics. Additionally, it seeks to identify prolific and prominent authors, journals, countries, keywords, and highly cited documents, both in the general domain of artistic gymnastics and in its male and female modalities.

METHODS

As in other research similar to ours (Díaz, Teixidó, Gil, Cabeza, & Aras, 2021; Vargas & Capraro, 2020), the Web of Science (WoS) of Clarivate Analytics and Scopus databases were used to search for documents related to artistic gymnastics (AG). Searches related to women's artistic gymnastics (WAG) and men's artistic gymnastics (MAG) were conducted in both databases. These databases are widely used by researchers due to the extensive information they provide on documents, and the large number of journals indexed in them.

For the WOS search on artistic gymnastics (AG), the search vector "TS=("artistic gymnastics")" was utilized. The "TS" tag enables locating the searched term in the title, abstract, and keywords. The search was restricted to articles and reviews within the Core Collection Database of WoS, specifically in the editions of Science Citation Index Expanded (SCI-Expanded), Social Sciences Citation Index (SSCI), and Emerging Sources Citation Index (ESCI). This yielded 348 documents. In the Scopus search, the search vector "TITLE-ABS-KEY("artistic gymnastics") AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "re"))" was employed. The "TITLE-ABS-KEY" tag locates the searched term in the title, abstract, and keywords, while the "LIMIT-TO" tag filters the search to articles and reviews. This resulted in 421 documents.

Upon combining both searches, 237 duplicates were automatically eliminated using scripts. After a subsequent manual review by researchers, 28 additional duplicates were removed, and 12 documents unrelated to the subject matter

were excluded. Instances where there were differing opinions among authors were resolved through discussion. Ultimately, 482 documents were obtained.

The search for documents on Female Artistic Gymnastics (WAG) and Male Artistic Gymnastics (MAG) followed the same methodology as the main search. For WAG in WoS, a search was conducted in the Core Collection Database, specifically in the editions of SCI-Expanded, SSCI, and ESCI, limited to articles and reviews. The search vector "TS=("female's artistic gymnastics") OR TS=("female artistic gymnastics") OR TS=("women's artistic gymnastics") OR TS=("women artistic gymnastics")" yielded 67 documents. In Scopus, 80 documents, including only articles and reviews, were obtained using the search vector "TITLE-ABS-KEY("female's artistic gymnastics") OR TITLE-ABS-KEY("female artistic gymnastics") OR TITLE-ABS-KEY("women's artistic gymnastics") OR TITLE-ABS-KEY("women artistic gymnastics") AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "re"))". After automatically removing 48 duplicates with scripts, a total of 99 documents remained.

For the MAG modality, the same steps were followed as for WAG, but with the search vector "TS=("male's artistic gymnastics") OR TS=("male artistic gymnastics") OR TS=("men's artistic gymnastics") OR TS=("men artistic gymnastics") OR TS=("men artistic gymnastics")", yielding 46 documents in WoS. In Scopus, the search vector "TITLE-ABS-KEY("female's artistic gymnastics") OR TITLE-ABS-KEY("female artistic gymnastics") OR TITLE-ABS-KEY("women's artistic gymnastics") OR TITLE-ABS-KEY("women artistic gymnastics")" was used.

gymnastics") AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "re"))" resulted in 49 documents. After automatically eliminating 35 documents, a total of 56 documents remained in Scopus.

All searches were conducted on November 15, and the results were exported from WoS in ".xlsx" format and from Scopus in ".csv" format. Data processing was performed using Microsoft® Excel® for Microsoft Office Professional Plus 2019, RStudio 2022.7.2.576 (RStudio Team, 2020), and the Bibliometrix data package (Aria & Cuccurullo, 2017). For WoS searches, the label "TS" was used, and for Scopus searches, "TITLE-ABS-KEY" was used. These labels include the keyword plus and indexed keywords, respectively. While the use of such keywords may include many unrelated documents, the researchers made efforts to avoid omitting any potentially related documents. To address this concern, all documents were meticulously reviewed by the authors.

A descriptive bibliometric study was conducted, examining various aspects in accordance with traditional bibliometric principles. The law of exponential growth of science proposed by DeSolla Price (Dobrov, Randolph, & Rauch, 1979; Price, 1976) was utilized to determine if annual publications exhibited exponential growth. The coefficient of determination (R^2) adjusted to an exponential growth ratio was employed to interpret this trend. The WoS Analyse Reports tool facilitated a descriptive analysis of subject categories with the highest number of related publications and various associated characteristics. Bradford's law of the concentration of science (DeShazo, LaVallie, & Wolf, 2009; Goffman & Warren, 1969; Nash-Stewart, Kruesi, & Del

Mar, 2012) was applied to identify the most prolific journals. Lotka's law (Kushairi & Ahmi, 2021) was employed to highlight authors with the highest number of publications (Yie et al., 2021). The Hirsch index (h-index) was applied to identify the most relevant articles, considering those with a number equal to or greater than h citations (Hirsch, 2005; Rodrigues-Santana et al., 2022). Prominent authors were determined based on prolific authors who were among the authors of the most cited papers. Finally, Zipf's law was applied to the set of author keywords from the analysis (Zipf, 2013) to identify the most relevant keywords for authors. The Biblioshiny tool of the Bibliometrix data package (Aria & Cuccurullo, 2017) was used for visualizing relationships between co-authors, keywords, countries, and articles, as well as generating the global productivity map and productivity plots of journals and institutions.

RESULTS

After applying the exclusion criteria, we identified 482 documents published between 1975 and 2023, including articles accepted for publication in 2023. Annual publication continuity was observed from 1996, with one document, to the present, excluding the years 2022 and 2023 from the trend analysis as they were ongoing at the time of the investigation. Between 1996 and 2021, a total of 465 documents were found. No annual publication continuity was observed in the years preceding this range, with the first article found in 1975. The total number of articles between 1975 and 1995 was 16 papers.

The trend of publications between 1996 and 2021, inclusive, was analyzed, revealing that the publications follow an

exponential growth curve during this period. The goodness-of-fit index for the growth curve was 83.18% (R^2) (Figure 1). This analysis excluded the years before 1996 and the years 2022 and 2023, which were ongoing at the time of the analysis.

When specifically searching for women's artistic gymnastics (WAG), 99 articles published between 1986 and 2022 were identified. Publication continuity was

observed between 2007 and 2022, with 92 documents in this period. Similarly, in the search for male artistic gymnastics (MAG), 60 documents published between 1994 and 2022 were found, with publication continuity from 2015 onwards and a total of 38 documents in this range. Figure 2 illustrates the growth of publications in men's and women's artistic gymnastics.

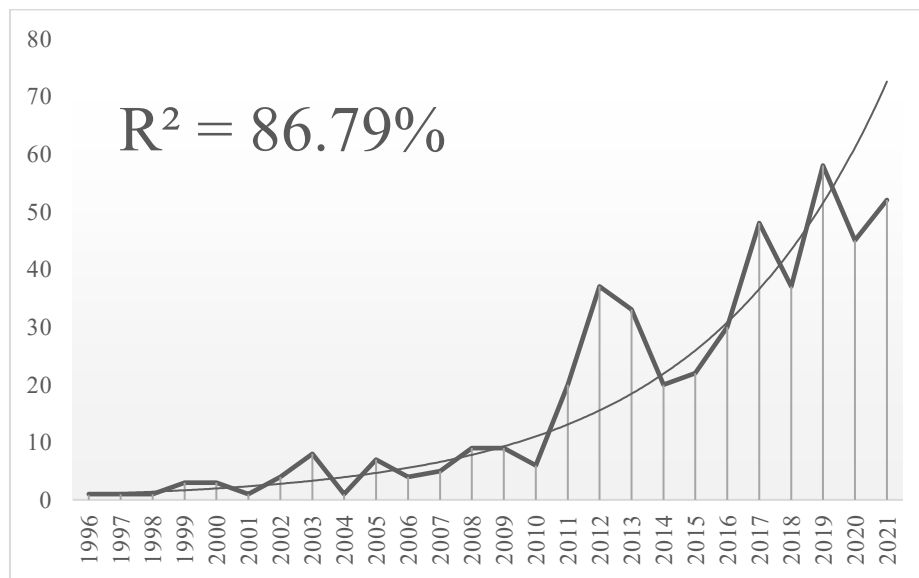


Figure 1. Annual publications trend for artistic gymnastics.

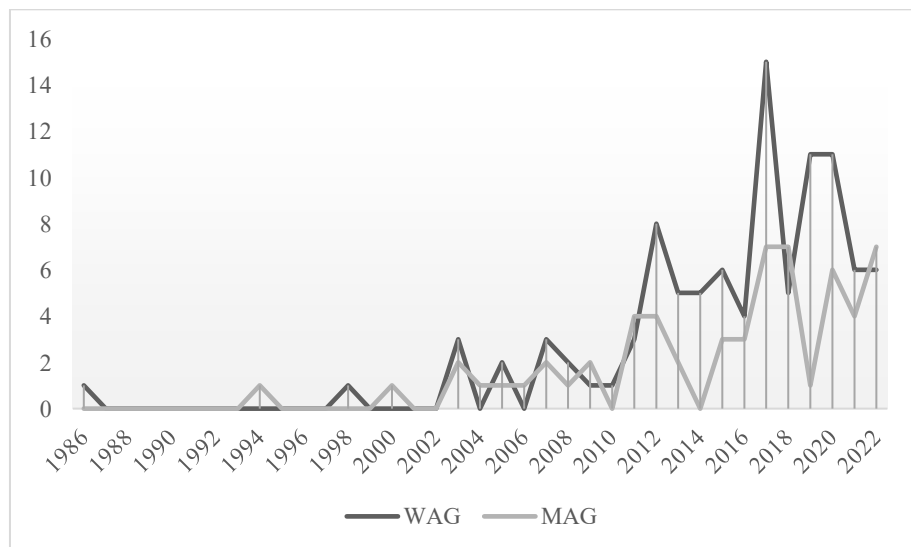


Figure 2. Annual publications trend for women's (WAG) and men's artistic gymnastics (MAG).

In the search within the WoS database, a total of 348 documents were analyzed across 56 thematic categories. The category "Sport Sciences" stands out, encompassing approximately 65% of the total publications (224 documents). Following this, "Hospitality Leisure Sport Tourism" holds 31 documents, "Engineering Biomedical" ranks third with 30 documents, and "Education Educational Research" and "Endocrinology Metabolism" each have 14 documents. Table 1 provides details on these top five categories, including the journals and publishers with the highest number of papers in each. In the specific

search for female artistic gymnastics (67 documents), the top categories were "Sport Sciences" (48 documents), "Hospitality Leisure Sport Tourism" (15 documents), "Education Educational Research" (5 documents), "History" (5 documents), and "Engineering Biomedical" (4 documents). Similar categories were identified in the search for men's artistic gymnastics, with "Sport Sciences" (37 papers), "Engineering Biomedical" (10 papers), and "Biophysics" (4 papers) being the predominant categories, while the rest of the categories contained two or fewer papers.

Table 1

Top 5 WoS thematic categories with the number of documents for which publications were indexed.

WoS Categories	Doc.	Journals (<i>Publishers</i>) most prolific	Doc.	Publishers most prolific	Doc.
Sport Sciences	224	Science Of Gymnastics Journal (<i>Univ Ljubljana, Fac Sport</i>)	67	Univ Ljubljana, Fac Sport	63
Hospitality, Leisure, Sport and Tourism	31	International Journal of the History of Sport (<i>Routledge Journals, Taylor & Francis Ltd</i>)	4	Taylor & Francis	10
		International Journal of Sports Science & Coaching (<i>Sage Publications LTD</i>)	4		
Engineering, Biomedical	30	Sports Biomechanics (<i>Routledge Journals, Taylor & Francis Ltd</i>)	12	Taylor & Francis	12
Education & Educational Research	14	Sport, Education and Society (<i>Routledge Journals, Taylor & Francis LTD</i>)	2	Taylor & Francis	5
		VIREF Revista De Educación Física (<i>Univ Antioquia, Inst Univ Educacion Fisica & Deporte</i>)	2		
Endocrinology & Metabolism	14	Osteoporosis International (<i>Springer London LTD</i>)	6	Springer Nature	6

Doc. (Number of documents)

The 494 papers in our database were distributed among a total of 186 journals, ranging from 1 to 82 publications. Bradford's law was applied to identify the most prominent journals, categorizing them into three zones: the core accumulating 32.16% (6 journals), zone I comprising

30.91% (31 journals), and zone II consisting of 36.93% (149 journals), with an error ratio of 0.5% (Table 1S). The core includes journals with a publication count ranging from 82 to 10. The most prolific journal was the "Science of Gymnastics Journal" published by "Univ Ljubljana, Fac Sport,"

positioned in the first quartile of the category "Sports Science," with a total of 82 papers. It is followed by the "Journal of Physical Education and Sport" published by "Editura Universitatea Din Pitesti" (24 papers) and "Teoriya i Praktika Fizicheskoy Kultury" published by "The Committee on Physical Culture and Sports of the Council of Ministers of the USSR" (14 papers). Table 2 displays the six journals constituting the core of the most prolific ones, along with their publisher, impact indicators (JIF, JCI, or ScoreCite2021), the quartile in their respective categories, and their open access percentage where applicable. Zone I encompasses 31 journals with publication counts ranging from 9 to 3 documents, while zone II includes 149 journals with publication counts of 2 to 1. In the analysis of the search conducted in the WAG and MAG modalities, for WAG, among a total of 46 journals, the core of prolific journals comprises 4 journals with

5 or more publications. The most prolific is "Science of Gymnastics Journal" with 24 documents and 103 total citations. It is followed by "Journal of Physical Education and Sport" with 6 documents and 18 citations. In the third and fourth positions, each with 5 publications, are "Acta Kinesiologica" with 15 total citations and "Motriz: Revista de Educação Física" with 16 total citations. In contrast, in MAG, out of a total of 28 journals, the core is represented by a single journal that accumulates 30.36% of the publications. The most prolific journal is "Science of Gymnastics Journal" with 17 papers and 65 citations. Zone I includes 7 journals, with the top three being "Journal of Biomechanics" with 4 papers and 83 citations, "Journal of Applied Biomechanics" with 3 papers and 63 citations, and "Sports Biomechanics" with 3 papers and 30 citations.

Table 2
Most prolific journals

Bradford's zone	Journals (<i>Publishers</i>)	Doc.	% Doc.	Cit.	JIF	Q.	% O.A.
Core	Science of Gymnastics Journal (<i>Univ Ljubljana, Fac Sport</i>)	82	17,01%	309	0.19*	Q4*	0.00%
	Journal of Physical Education and Sport (<i>Editura Universitatea Din Pitesti</i>)	24	4,98%	58	2.2**	n/a	n/a
	Teoriya I Praktika Fizicheskoy Kultury (<i>Committee on Physical Culture and Sports of the Council of Ministers of The USSR</i>)	14	2,90%	8	0.4**	n/a	n/a
	Sports Biomechanics (<i>Routledge Journals, Taylor & Francis LTD</i>)	13	2,70%	273	2.896	Q2	7.98%
	Journal of Sports Sciences (<i>Taylor & Francis LTD</i>)	12	2,49%	243	3.943	Q2	9.49%
	Baltic Journal of Health and Physical Activity (<i>Gdansk Univ Physical Education & Sport</i>)	10	2,07%	22	0.16*	Q4*	97.45%

Doc. (Number of documents); Cit. (Number of citations); % Doc. (Percentage of documents); JIF (Journal impact factor); % O.A. (Percentage of open access); Q. (JIF Quartile); n.a. (not application). JIF or Q. with "*" are JCI (Journal citation indicator) and JCI Quartile. JIF with "**" are CiteScore2021 by Scopus.

The analyzed publications on artistic gymnastics involve contributions from 1241 different co-authors. Notably, a majority of them, precisely 1026 authors, have only a single document in authorship (82.7%). Another 119 co-authors have contributed to 2 documents (9.6%), while 96 co-authors have been involved in at least 3 documents (7.73%), up to a maximum of 20 publications by the most prolific author. Applying Lotka's law, it was determined that the 35 most prolific authors should be highlighted. The first 33 authors, each with at least 5 publications, were selected, aligning closely with the law's recommendation. The subsequent consideration involved the top 50 authors with a minimum of 4 papers, a deviation from the number suggested by Lotka. Sunčica Delaš Kalinski, affiliated with the University of Split (Croatia), emerges as the most prolific author with a total of 20 papers. Following closely, Almir Atiković from the University of Tuzla (Bosnia and Herzegovina) takes the second position with 18 authored papers. The third author with the highest number of papers is Myriam Nunomura from the University of São Paulo (Brazil), contributing to a total of 16 papers.

Figure 3 illustrates the network of 33 prolific co-authors and their collaborations in the field of artistic gymnastics research. In this representation, nodes represent individual authors, and connecting lines depict collaborations between them. The size of each node corresponds to the author's impact or significance in the field, while the thickness of the lines indicates the frequency of collaborations. The proximity of nodes reflects the semantic or thematic relationships between authors.

The most substantial working group, highlighted in orange, consists of eight researchers, prominently featuring Myriam Nunomura. Notably, this group comprises authors from diverse countries, including Brazil, Sweden, and Australia. Additional sizable groups, highlighted in gray and pink, consist of four members each, led by Albrecht L. Claessens and Ivan Čuk, respectively. Another group in brown comprises three authors, with Sunčica Delaš Kalinski and Almir Atiković, two prolific authors, standing out. These authors also share a weak connection with Ivan Čuk, who belongs to a separate research group. The visualization further identifies four clusters of two authors and six individual authors without connections. It is essential to note that the graph exclusively showcases prolific authors, omitting groups formed by authors with fewer publications.

To identify the group of prominent authors in this research field, we cross-referenced prolific authors with those who contributed to the 31 most cited articles. The result highlighted 12 authors as prominent contributors. Albrecht L. Claessens emerges as a leading figure with 8 papers and 402 citations, affiliated with the Katholieke Universiteit Leuven (Belgium). Following closely are Gaston P. Beunen, also from the Katholieke Universiteit Leuven (Belgium), and Jeremie H. Lefevre from Hopital Saint Antoine Assistance Publique Hôpitaux de Paris (France), both with 7 papers and 395 citations each. It's noteworthy that 17 authors in total have exceeded 100 citations in the database articles. The 12 prominent authors, along with their affiliation/region, number of papers, and number of citations, are detailed in Table 3.

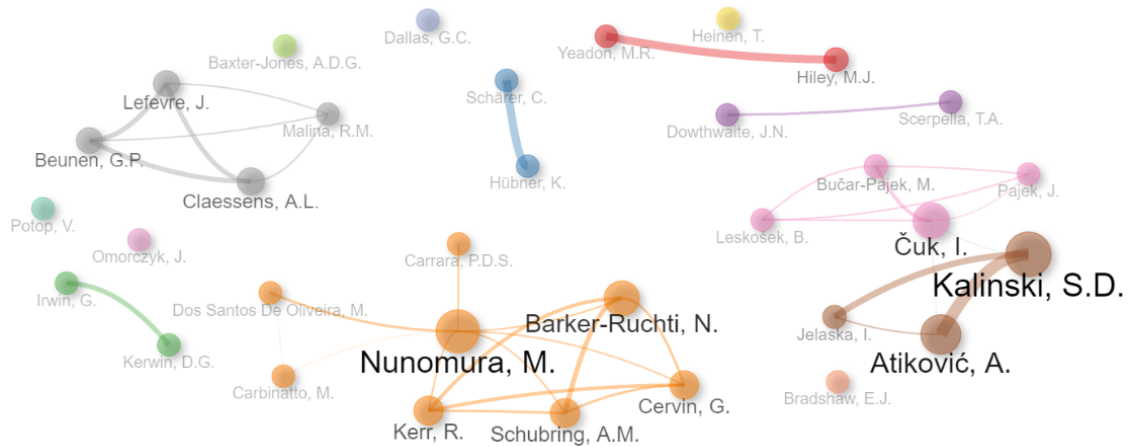


Figure 3. Graph illustrating prolific co-authors and their relationships. Bibliometrix: Analysis: Collaboration Network. Field: Authors. Network Layout: Kamada & Kawai. Clustering Algorithm: Walktrap. Normalization: Association. Number of nodes: 33. Repulsion force: 0.1. Remove isolated nodes: No. Min. number of edges: 1.

Table 3

Most prominent co-authors in artistic gymnastics.

Co-authors	Affiliation / Countries-Regions	Documents	Citations
Claessens, Albrecht L.	KU Leuven / Belgium	8	402
Beunen, Gaston P.	KU Leuven / Belgium	7	395
Lefevre, Jeremie H.	Hopital Saint Antoine Assistance Publique Hôpitaux de Paris / France	7	395
Barker-Ruchti, Natalie	University of Gothenburg / Sweden	12	261
Malina, Robert M.	University of Texas System / USA	5	259
Hiley, Michael J.	Loughborough University / England	10	238
Yeadon, Maurice R.	Loughborough University / England	9	230
Baxter-Jones, Adam D. G.	University of Saskatchewan / Canada	5	131
Schubring, Astrid M.	University of Gothenburg / Sweden	8	122
Dowthwaite, Jodi N.	State University of New York (SUNY) Binghamton / USA	5	121
Scerpella, Tamara A.	University of Wisconsin Madison / USA	5	121
Bradshaw, Elizabeth Jane	Deakin University / Australia	6	103

In the domain of MAG, we identified 145 authors associated with articles, notably recognizing Michael J. Hiley and Maurice R. Yeadon, both affiliated with Loughborough University (England), as prolific and prominent authors with 221 and 220 citations, respectively, and 9 papers each.

In WAG, a total of 199 authors were found. Notable prolific authors include

Natalie Barker-Ruchti from the University of Gothenburg (Sweden), with 12 papers and 259 citations, and Almir Atiković from the University of Tuzla (Bosnia and Herzegovina), with 11 papers and 63 citations. In the realm of WAG, the most prominent authors are once again Natalie Barker-Ruchti, followed by Roslyn Kerr with 8 papers and Astrid M. Schubring with 7 papers, both accumulating 81 citations.

Table 4 presents prolific authors with the highest citation counts in each modality, calculated using the h-index for prolific authors, along with their respective number of papers and citations. Authors highlighted

in gray stand out in both modalities, while those marked with an asterisk (*) do not appear as prolific in Figure 3, an analysis encompassing articles related to artistic gymnastics in general.

Table 4

Prolific co-authors with the highest number of citations in each modality.

Women's Artistic Gymnastics (14 authors)			Men's Artistic Gymnastics (13 authors)		
Co-authors	Documents	Citations	Co-authors	Documents	Citations
Barker-Ruchti, Natalie	12	259	Hiley, Michael J.	9	221
Kerr, Roslyn	8	81	Yeadon, Maurice R.	9	220
Schubring, Astrid M.	7	81	Čuk, Ivan	5	48
Čuk, Ivan	5	75	Atiković, Almir	5	40
Atiković, Almir	11	63	Bučar-Pajek, Maja	3	31
Cervin, Georgia	7	60	Amara, Samiha*	3	23
Nunomura, Myrian	9	51	Mkaouer, Bessem*	3	23
Jennings, Les*	4	38	Kalinski, Suncica Delas	3	20
Koh, Michael*	4	38	Coelho Bortoleto, Marco Antonio*	3	14
Kalinski, Suncica Delas	9	37	Hübner, Klaus	3	10
Schiavon, Laurita Marconi*	5	20	Schärer, Christoph	3	10
Potop, Vladimir	6	18	Capraro, Andre Mendes*	3	3
Jelaska, Igor	5	12	Vargas, Pauline Peixoto Iglesias*	3	3
dos Santos de Oliveira, M.	4	12			

The authors contributing to articles in our database represent a total of 51 different countries/regions. Brazil leads in article productivity with 74 documents, followed by the United Kingdom with 39 documents, the USA with 37 documents, and Italy with 34 documents. Concerning total citations, the USA takes the lead with 616 citations, followed by the United Kingdom with 526 citations, Belgium with 478 citations, Brazil with 249 citations, and Canada with 242 citations.

In Men's Artistic Gymnastics (MAG), Brazil is prominent with 14 documents, along with the United Kingdom (12 documents), and Slovenia and Tunisia, both contributing 5 documents each. In Women's

Artistic Gymnastics (WAG), Brazil continues to lead with 25 documents, followed by Croatia with 11 documents, and Australia, Portugal, and the USA, each contributing 8 documents.

Figure 4 illustrates the collaborative network among countries/regions, with each node representing a country. The size of the node indicates the country's importance or impact in the field, and the connecting lines depict interactions, with the thickness representing the frequency of collaborations. Isolated nodes without connections are excluded from the graph.

Brazil and Australia exhibit the highest number of connections, each interacting with five countries. Brazil notably

collaborates strongly with Spain and holds the largest node, indicating its significant impact in the research field. Seven working groups are discernible, with the largest ones highlighted in blue (comprising New Zealand, Sweden, Australia, France, and Switzerland) and red (led by the United Kingdom and the USA, accompanied by

Israel, Greece, and Italy). Another noteworthy group is highlighted in green, led by Brazil, and includes Spain, Portugal, and Colombia. There is also a group in purple, composed of Slovenia, Croatia, and Serbia. Lastly, three groups with two components each are highlighted in pink, brown, and orange.

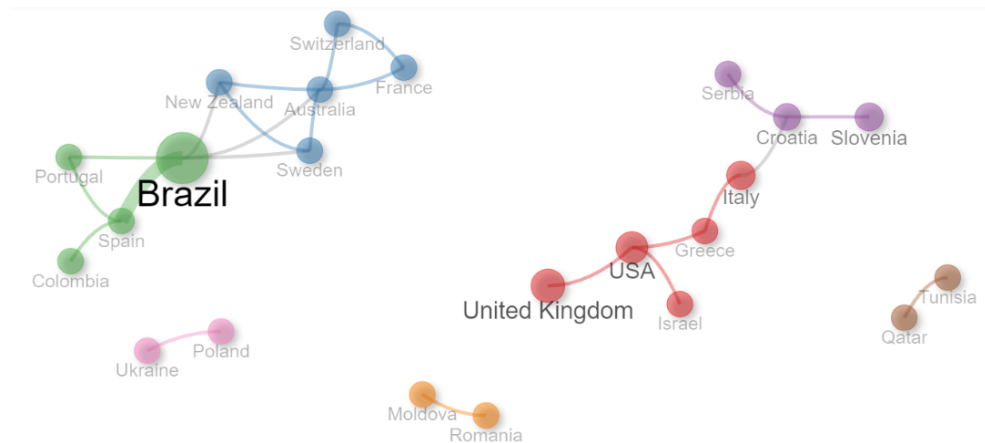


Figure 4. Collaboration networks between countries/regions. Bibliometrix: Analysis: Collaboration Network. Field: Countries. Network Layout: Automatic layout. Clustering Algorithm: Walktrap. Normalization: Association. Number of nodes: 51. Repulsion force: 0.1. Remove isolated nodes: Yes. Min. number of edges: 1.

In our database, we identified a total of 1164 unique keywords, which, after review and organization into thesauri (refer to Table 2S), were condensed to a total of 1042 keywords. To pinpoint the most pertinent keywords, Zipf's law was employed, suggesting a selection of no more than 32 words. We identified 29 words with a frequency of occurrence equal to or greater than 7, deeming them relevant. The two most frequently occurring words were "artistic gymnastics" (136 occurrences) and "gymnastics" (130 occurrences), both of which were utilized as search terms. Additionally, "women's artistic gymnastics" (18 occurrences) and "men's artistic gymnastics" (12 occurrences) were identified as relevant search terms. Other noteworthy keywords, although not

incorporated as primary search terms, included "biomechanics" (27 occurrences), "performance" (24 occurrences), "judging" (20 occurrences), "athletes" (20 occurrences), "body composition" (20 occurrences), "injuries" (19 occurrences), and "coaching" (18 occurrences). Table 6 presents the relevant author keywords, adhering to Zipf's law, for both MAG (154 keywords) and WAG (227 keywords). Keywords employed as search terms are shaded in gray.

Figure 5 displays the connections among the most relevant keywords, with node size representing the frequency of occurrences and the connection line thickness indicating the frequency of their association. The "Spinglass" clustering algorithm, recommended for extensive and

intricate bibliometric networks with an ambiguous modular structure (Lancichinetti & Fortunato, 2009), was employed. Four distinct groups are discernible, with the most extensive being those centered around the terms "Gymnastics" (highlighted in red)

and "Artistic Gymnastics" (highlighted in blue), both consisting of eight components. Following these are the green-highlighted group, composed of seven components, and finally, the purple-highlighted group, comprising five components.

Table 6
Relevant author keywords in each modality.

Woman's Artistic Gymnastics (227 keywords)		Man's Artistic Gymnastics (154 keywords)	
Keyword	Ocurrences	Keyword	Ocurrences
<i>gymnastics</i>	33	<i>gymnastics</i>	21
<i>women's artistic gymnastics</i>	19	<i>artistic gymnastics</i>	12
<i>artistic gymnastics</i>	17	<i>men's artistic gymnastics</i>	10
<i>performance</i>	11	<i>simulation</i>	8
<i>biomechanics</i>	10	<i>high bar</i>	6
<i>coaching</i>	8	<i>optimization</i>	6
<i>olympic games</i>	8	<i>still rings</i>	6
<i>judging</i>	6	<i>biomechanics</i>	4
<i>aesthetic sports</i>	4	<i>code of points</i>	4
<i>code of points</i>	4	<i>training</i>	4
<i>elite sports</i>	4		
<i>injuries</i>	4		

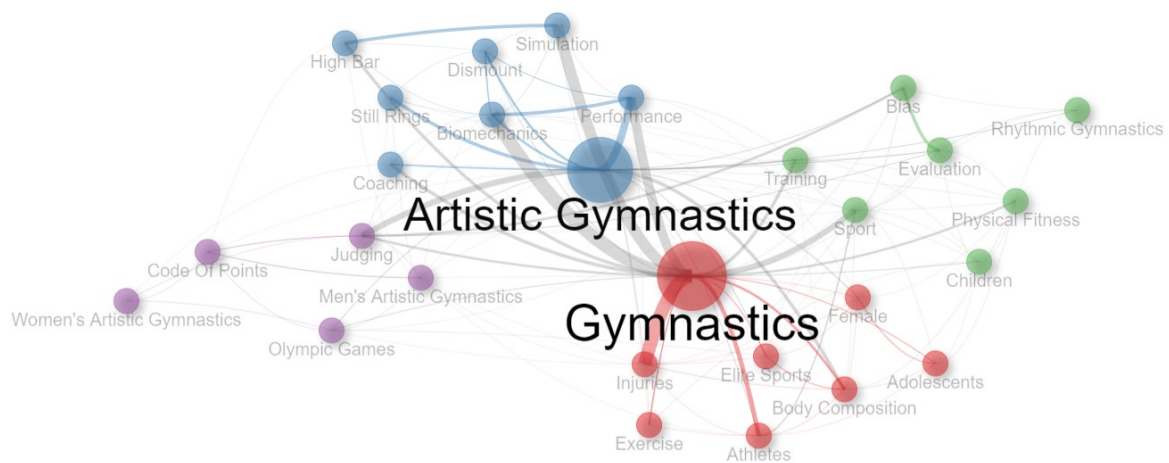


Figure 5. Most prominent author keywords and their connections. Bibliometrix: Analysis: Co-Occurrence Network. Field: Author's Keyword. Network Layout: Automatic layout. Clustering Algorithm: Spinglass. Normalization: Association. Number of nodes: 29. Repulsion force: 0.1. Remove isolated nodes: No. Min. number of edges: 1.

Table 7 highlights the 32 most relevant articles in our field based on the h-index, chosen from a total of 482 documents. The article boasting the highest citation count is

"The Prevalence of Spondylolysis in the Spanish Elite Athlete" by Soler & Calderón (2000) (Soler & Calderón, 2000) published in the "American Journal of Sports

Medicine," with a cumulative citation count of 185. This work endeavors to identify the sports associated with a higher risk of spondylolysis, pinpointing artistic gymnastics (16.96%) among those with the highest risk. Following closely is the article titled "The Contribution of Anthropometric Characteristics to Performance Scores in Elite Female Gymnasts" by Claessens et al. (1999) (Claessens, Lefevre, Beunen, & Malina, 1999), published in the "Journal of Sports Medicine and Physical Fitness," accumulating a total of 122 citations. This study aims to discern anthropometric characteristics linked to performance in WAG and predict scores based on a combination of anthropometric dimensions. Occupying the third spot is "In Pursuit of an Identity: A Qualitative Exploration of Retirement from Women's Artistic Gymnastics" by Lavallee & Robinson (2007) (Lavallee & Robinson, 2007), published in the "Psychology of Sport and Exercise," with a total of 121 citations. This article delves into factors associated with the formation of self-identity and adaptation to sport retirement in elite athletes. Figure 6

visually represents the 32 most cited articles, with connecting lines indicating collaborative or influential relationships between the documents, implying that one cites the other.

In MAG, the most cited article is "The Mechanics of the Backward Giant Circle on the High Bar" by Yeadon and Hiley (2000) (Maurice R. Yeadon & Hiley, 2000), accumulating a total of 71 citations. This article focuses on the biomechanical analysis of the backward mill on the fixed bar. Notably, the top three articles with the highest citation counts are authored by Yeadon and Hiley, with two more of their works featuring in the list of highly cited papers.

Turning to the WAG literature, the previously mentioned piece by Lavallee & Robinson (2007) (Lavallee & Robinson, 2007) holds a prominent position. Following closely is the article titled "Gymnastics Injuries" by Caine and Nassar (2005) (Caine & Nassar, 2005), securing the second spot. This work aims to review the distribution and determinants of injury rates in pediatric gymnastics.

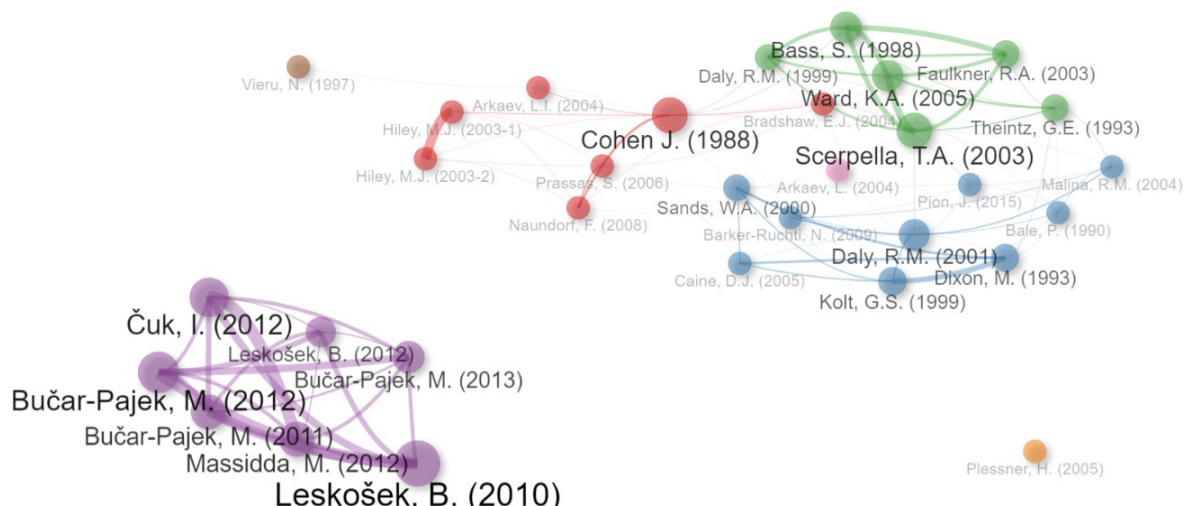


Figure 6. Graph with the most cited articles and their interrelationships. Bibliometrix: Analysis: Co-citation Network. Field: Papers. Network Layout: Kamada & Kawai. Clustering Algorithm: Walktrap. Number of nodes: 32. Repulsion force: 0. Remove isolated nodes: No. Min. number of edges: 1.

Table 7

Documents

Title. Main author (Year of publication)	Journal ISO Abbreviation	Cites
The Prevalence of Spondylolysis in the Spanish Elite Athlete. Soler & Calderón (2000)	American Journal of Sports Medicine	185
The Contribution of Anthropometric Characteristics to Performance Scores in Elite Female Gymnasts. Claessens et al. (1999)	Journal of Sports Medicine and Physical Fitness	122
In Pursuit of an Identity: A Qualitative Exploration of Retirement from Women's Artistic Gymnastics. Lavalley & Robinson (2007)	Psychology of Sport and Exercise	121
Gymnastics Injuries. Caine & Nassar (2005)	Medicine and Sport Science	115
Foucault In Leotards Corporeal Discipline in Women's Artistic Gymnastics. Barker-Ruchti & Tinning (2010)	Sociology of Sport Journal	84
Sports Disciplinary Legacy and the Challenge of Coaching Differently. Denison et al. (2017)	Sport, Education and Society	82
Anthropometric Characteristics of Outstanding Male and Female Gymnasts. Claessens et al. (1991)	Journal of Sports Sciences	79
Growth And Menarcheal Status of Elite Female Gymnasts. Claessens et al. (1992)	Medicine and Science in Sports and Exercise	79
The Mechanics of the Backward Giant Circle on the High Bar. Yeadon & Hiley (2000)	Human Movement Science	71
Initial Years of Recreational Artistic Gymnastics Training Improves Lumbar Spine Bone Mineral Accrual in 4- to 8-Year-Old Females. Laing et al. (2005)	Journal of Bone and Mineral Research	69
Gymnast Wrist an Epidemiologic Survey of Ulnar Variance and Stress Changes of The Radial Physis in Elite Female Gymnasts. De Smet et al. (1994)	The American Journal of Sports Medicine	63
Biomechanical Research in Artistic Gymnastics, A Review. Prassas et al. (2006)	Sports Biomechanics	62
A Prospective Study of Bone Mass and Body Composition in Female Adolescent Gymnasts. Laing et al. (2002)	Journal of Pediatrics	59
Energy and Nutrient Intakes of the United States National Women's Artistic Gymnastics Team. Jonnalagadda et al. (1998)	International Journal of Sport Nutrition and Exercise Metabolism	52
Biomechanical Approaches to Identify and Quantify Injury Mechanisms and Risk Factors in Women's Artistic Gymnastics. Bradshaw & Hume (2012)	Sports Biomechanics	51
Optimum Technique for Generating Angular Momentum in Accelerated Backward Giant Circles prior to a Dismount. Hiley & Yeadon (2003)	Journal of Applied Biomechanics	49
Duration of Physical and Mental Execution of Gymnastic Routines. Calmels & Fournier (2001)	Sport Psychologist	48
Higher Premenarcheal Bone Mass in Elite Gymnasts Is Maintained into Young Adulthood after Longterm Retirement from Sport. A 14-Year Followup. Erlandson et al. (2012)	Journal of Bone and Mineral Research	47
Urinary Incontinence and Other Pelvic Floor Dysfunctions in Female Athletes in Brazil A Crosssectional Study. Almeida et al. (2016)	Scandinavian Journal of Medicine & Science in Sports	44
Precompetitive and Recreational Gymnasts Have Greater Bone Density Mass and Estimated Strength at the Distal Radius in Young Childhood. Erlandson et al. (2012)	Osteoporosis International	41

Sustained Skeletal Benefit from Childhood Mechanical Loading. Scerpella et al. (2011)	Osteoporosis International	41
Reliability and Variability of Day-To-Day Vault Training Measures in Artistic Gymnastics. Elizabeth et al. (2010)	Sports Biomechanics	40
The German Young Olympic Athletes Lifestyle and Health Management Study Goal Study Design of a Mixed Method Study. Thiel et al. (2011)	Bmc Public Health	39
Ballerinas and Pixies A Genealogy of the Changing Female Gymnastics Body. Barker-Ruchti (2009)	International Journal of the History of Sport	38
The Margin for Error When Releasing the High Bar for Dismounts. Hiley & Yeadon (2003)	Journal of Biomechanics	38
Body Dissatisfaction Psychological Commitment to Exercise and Eating Behavior in Young Athletes from Aesthetic Sports. Fortes et al. (2013)	Revista Brasileira De Cineantropometria E Desempenho Humano	36
Abolished Circadian Rhythm of Salivary Cortisol in Elite Artistic Gymnasts. Georgopoulos et al. (2011)	Steroids	35
Gymnastics Injury Incidence During the 2008, 2012 and 2016 Olympic Games Analysis of Prospectively Collected Surveillance Data from 963 Registered Gymnasts during Olympic Games. Edouard et al. (2018)	British Journal of Sports Medicine	34
Postural Trials Expertise in Rhythmic Gymnastics Increases Control in Lateral Directions. Calavalle et al. (2008)	European Journal of Applied Physiology	33
Specific Injuries Induced by the Practice of Trampoline Tumbling and Acrobatic Gymnastics. Grapton et al. (2013)	Knee Surgery, Sports Traumatology, Arthroscopy	33
Evidence-Based Prerequisites and Precursors of Athletic Talent A Review. Issurin (2017)	Sports Medicine	32

DISCUSSION

The purpose of this documentary study was to examine the trajectory of scientific publications related to artistic gymnastics. The analysis aimed to identify trends in scientific output, determine the most prolific journals, recognize prolific and influential authors, highlight countries contributing significantly, identify relevant keywords, and pinpoint highly cited articles. Additionally, the study conducted separate analyses for male artistic gymnastics (MAG) and female artistic gymnastics (WAG). In the researchers' opinion, this investigation stands out as the most comprehensive and extensive to date, adhering to traditional bibliometric principles. The findings provide insights into prevalent themes, unexplored areas,

and can serve as a guiding framework for future research in artistic gymnastics (Blanca-Torres et al., 2020; Job, 2008).

In the existing literature, the researchers found three documents with a descriptive bibliographic focus on artistic gymnastics or related subjects. These studies aimed to analyze the publication landscape in Brazilian journals within the field of Physical Education (Carbinatto, Chaves, Moreira, Souza de Castro Coelho, & Rovigati Simoes, 2016; Simões et al., 2016), national scientific journals in Physical Education (Carbinatto, Moreira, Chaves, Santos, & Simoes, 2016), and graduate theses and dissertations (Oliveira, Pires, Barbosa-Rinaldi, & Pizani, 2021). Another research specifically delved into the scientific production in male artistic gymnastics (Vargas & Capraro, 2020),

while another explored acrobatic gymnastics (Leite et al., 2023). Among these documentary reviews, only Leite et al. (2023) and Carbinatto et al. (2016) applied traditional bibliometric principles, specifically utilizing Bradford's law to assess journal distribution.

The initial document discovered in the search dates back to 1975 and is available in the Scopus database. Titled "Studies on the Vertebral Column in Young Female Gymnast" (Meyer, 1975), the author is Ed. Meyer, and the study investigates the condition of the spine in a sample of women's artistic gymnasts. The oldest article found in the Web of Science database is from 1988 (Pristavkina, 1988).

While modern gymnastics has its roots in 1811 with Friedrich Ludwig Jahn and was introduced to the Olympics in 1896 (Dorado García, 2003), the absence of older documents in this search may be attributed to the fact that until around 1961, when rhythmic gymnastics was officially recognized by the FIG (International Gymnastics Federation), the only recognized discipline was "Olympic gymnastics" (Dorado García, 2003; Nunomura, Nista-Piccolo, & Eunegi, 2004). Olympic gymnastics served as the precursor to artistic gymnastics, and the latter only acquired its current name after the inclusion of additional disciplines (Nunomura et al., 2004). It's suggested that searching under the name "Olympic gymnastics" might yield older documents.

Concerning the specific discipline of Women's Artistic Gymnastics (WAG), the oldest document found is from 1986, titled "Efficacy Expectations, Training Performance, and Competitive Performance in Women's Artistic Gymnastics" (Lee, 1986) by C. Lee. For Men's Artistic Gymnastics (MAG), the earliest document

is from 1994, titled "Twisting Techniques Used in Dismounts from The Rings" (M. Yeadon, 1994) by M. Yeadon.

The increase in the number and frequency of publications on artistic gymnastics in recent years, as evidenced by the 83.18% (R²) goodness-of-fit index for exponential growth between 1996 and 2021, reflects a growing interest and investment in this field. The noticeable growth observed between 2010 and 2012, presented in Figures 1 and 2, can be attributed to several factors. Firstly, the proliferation of the internet and social media platforms has facilitated greater access to information about artistic gymnastics, thereby increasing public interest in this sport. This heightened visibility likely contributes to a growing curiosity and engagement from various researches. Additionally, advancements in technology, such as improved biomechanical analysis tools and high-speed recording systems, have enabled researchers to conduct more sophisticated analyses of gymnastic performances. These technological innovations provide researchers with the means to delve deeper into the intricacies of artistic gymnastics, leading to a richer understanding of the sport's mechanics and techniques.

When reviewing the current literature, exponential growth was also found in publications related to artistic gymnastics in Brazilian newspapers, as reported by Carbinatto et al. (2016) (Carbinatto, Moreira, et al., 2016) in their Graph 4. For the MAG modality, Vargas & Capraro (2020) (Vargas & Capraro, 2020) also present a graph which illustrates the growth in the frequency of publications over the years. Something similar is found in the acrobatic gymnastics modality by Leite et al. (2023) (Leite et al., 2023), where we also

observe a growth in the trend of publications, although much slower than in artistic gymnastics (global annual growth rate of scientific production is 26%). In comparing the research activity between men's and women's artistic gymnastics, it's evident that WAG attracts more scholarly attention (99 papers since 1986) compared to MAG (60 papers since 1994). Leite (Leite et al., 2023) speculates that this difference may be attributed to the greater participation of female gymnasts compared to their male counterparts, making it easier to find a consistent sample for an investigation.

When examining the thematic categories in WoS with the highest number of associated documents, "Sport Sciences" emerges as the leader, boasting seven times more associations than the second-ranking category, "Hospitality, Leisure, Sport and Tourism." These categories are particularly significant due to the inherently athletic nature of artistic gymnastics, a sport with a rich historical background. In third position, we encounter "Engineering, Biomedical," which features a comparable number of documents to the second-ranked category. Within this category, the focus predominantly revolves around biomechanical or kinematic analyses of gymnastics techniques. Some documents also explore methodologies for learning techniques through biomechanical resources (Fujihara, n.d.). Following these categories are "Education & Educational Research" and "Endocrinology & Metabolism." The former encompasses the majority of papers investigating training methodologies, the personal benefits of learning gymnastics, and the pedagogical aspects of gymnastics training. Conversely, the latter category hosts papers related to the physiology of gymnasts or the evolution of

their bodies throughout the training process, including research on the impact on bones and injuries.

In terms of notable journals, "Science of Gymnastics Journal" emerges as the leader in the number of published documents, surpassing the second-ranking journal, "Journal of Physical Education And Sport," by threefold. Within the core of prolific journals, "Science of Gymnastics Journal" stands out as the sole publication dedicated specifically to the subject. In contrast, the remaining journals encompass documents across various sports disciplines, with some journals focusing on specific perspectives such as education or biomechanics. Despite its specificity, "Science of Gymnastics Journal" maintains a relatively low scientific impact, with "Journal of Sports Sciences" holding the highest impact. The most cited paper published in "Science of Gymnastics Journal" is "Parents' Support on the Sports Career of Young Gymnasts" (Nunomura & Oliveira, 2013) by Nunomura and Oliveira, emphasizing the crucial role of parental support in the development of gymnasts as athletes. Meanwhile, the most cited paper in "Journal of Sports Sciences" is "Anthropometric Characteristics of Outstanding Male and Female Gymnasts" (Claessens et al., 1991) by Claessens et al., which establishes "gymnastics-specific" anthropometric reference values after analyzing a significant sample of gymnasts. Notably, some Brazilian national journals identified as prolific by Carbinatto et al. (2016) appear in our database. However, the top-ranked journal reported in Carbinatto et al. (2016) is not indexed in our databases and is therefore absent from our analysis. The second-ranked journal, "Revista Brasileira De Ciências Do Esporte," occupies position 36 in our analysis, placing

it within Zone I according to Bradford's distribution. Discrepancies with the findings of Carbinatto et al. (2016) may stem from differences in the databases used for document searches, as well as variations in the timeframe analyzed, spanning from 2000 to 2015.

When comparing our findings on prolific journals in the MAG modality with those reported by Vargas and Capraro (2020), we observe a significant degree of overlap, particularly in the top three positions. In both analyses, "Science of Gymnastics Journal," "Journal of Biomechanics," and "Journal of Applied Biomechanics" occupy these positions. While we did not encounter other studies analyzing journals in the WAG modality, a comparison with our MAG results reveals a notable difference. In WAG, journals related to biomechanical aspects do not appear until the sixth position, where "Journal of Biomechanics" emerges. In contrast, in MAG, biomechanical aspects are represented in at least four of the top six prolific journals. This suggests that kinematic analysis of technique is more prevalent in men's artistic gymnastics than in women's artistic gymnastics. Furthermore, when comparing the journals comprising the core of prolific journals in artistic gymnastics with those in acrobatic gymnastics (Leite et al., 2023), we find overlap in "Science of Gymnastics Journal" and "Sports Biomechanics." However, their rankings differ, with the former in second position with 14 documents and the latter in sixth position with 2 documents, respectively.

The most influential author in this research field is Albrecht L. Claessens from Belgium, whose work predominantly focuses on female gymnasts, except for one study that also involves male gymnasts

(Claessens et al., 1991). His most cited paper, "The Contribution Of Anthropometric Characteristics To Performance Scores In Elite Female Gymnasts" (Claessens et al., 1999), aimed to identify anthropometric variables related to performance in WAG and predict performance scores based on a combination of anthropometric dimensions. Following Claessens, Gaston P. Beunen and Jeremie H. Lefevre are notable authors, often collaborating with Claessens and contributing to many of his publications. Simões et al. (2016) analyzed authors of papers on gymnastics published in national journals indexed in the area of Physical Education by CAPES between 2000 and June 2015. They highlighted authors with three or more publications on the subject, with Myrian Nunomura being the most prolific, followed by Mauricio dos Santos de Oliveira. In our analysis, these authors are identified as prolific according to Lotka's law but not as prominent because they lack papers in the most cited category. In the realm of male artistic gymnastics, other noteworthy authors include Maurice R. Yeadon and Michael J. Hiley for the period between 1994 and 2019, as reported by Vargas and Capraro (2020). This aligns with our findings, placing them in first position. Vargas and Capraro (2020) also identify Marco Antonio Bortoleto and Ivan Čuk in third and fourth place, respectively. In our analysis, Ivan Čuk is highlighted once again, while Almir Atiković replaces Marco Antonio Bortoleto. M. A. Bortoleto's lower ranking in our study may be attributed to our search limitations, which focused on WoS Core to include only documents indexed in quality journals. This process may have resulted in a lower number of documents for that author. As for prolific authors in acrobatic gymnastics (Leite et al.,

2023), no coincidences were found in our analysis.

While the Soviet Union, United States, Japan, China, Romania, and Russia top the list of countries with the most medals in the Olympics, Brazil, the United Kingdom, and the USA lead in scientific publications, with Brazil notably producing nearly twice as many publications as the UK and USA combined. Interestingly, the USA is the only country prominent in both arenas, possibly due to its large pool of gymnasts and researchers, fostering excellence in both sports and academia. Moreover, athletic scholarships for students in the USA could fuel interest among student athletes to delve into research in their sport. Despite Brazil's prolific output, it does not match Olympic achievements in artistic gymnastics. Countries excelling in artistic gymnastics may prefer to keep research and technological advances within their organizations, limiting access to such information by other sporting powers. This could explain why, despite their athletic successes, they do not lead in research. The growing popularity of artistic gymnastics in countries like Brazil may justify their high volume of publications.

The group led by the term "Artistic Gymnastics," highlighted in blue, predominantly comprises terms related to biomechanical analysis of technique, such as "biomechanics," "simulation," or "performance." Notably, keywords related to specific apparatuses, like the horizontal bar and rings, predominantly from the MAG modality, indicate a prevalent focus on kinematic parameters analysis, especially evident in dismounts from the high bar and strength elements in the rings. Authors such as M. Hiley, M. Yeadon, C. Schärer, and K. Hübner have contributed significantly in these areas.

The following group, highlighted in red under "Gymnastics," primarily encompasses terms associated with physiological aspects like body composition or injuries, often focusing on elite and female athletes.

The green-highlighted group lacks significant keyword associations, suggesting disparate topics possibly related to gymnastics in children or non-competitive gymnastics.

Lastly, the purple-highlighted group covers aspects of evaluating gymnast performance, including terms like "judging" and "code of points," alongside references to both modalities of artistic gymnastics and the Olympics. These findings align with Carbinatto et al.'s (2016) observations on gymnastics publications in Brazilian journals, which highlight three main themes: biomechanics, psychology, and physiology.

In practical terms, this analysis offers valuable insights into the structure of publications in artistic gymnastics, including authors and keywords, among other elements. Understanding the key authors and their research areas can facilitate collaboration and help identify experts in specific topics. Moreover, it sheds light on existing collaborations among authors, providing a comprehensive overview of the research landscape.

Researchers can leverage this analysis to pinpoint prevalent research fields, emerging trends, and areas ripe for further exploration. By identifying gaps in current research, scholars can focus their efforts on unexplored or under-researched areas, thereby contributing to the advancement of knowledge in the field.

Notably, biomechanical analyses are prevalent in disciplines such as the high bar and still rings, with limited research on

apparatuses like the pommel horse. Additionally, research related to health tends to be more gender-specific, often focusing on female athletes, highlighting a potential gap in research on male athletes.

However, it's important to acknowledge the limitations of this analysis. By focusing solely on papers indexed in WoS Core and Scopus, relevant research published in smaller journals or lacking specific keywords in their titles, abstracts, or keywords may have been overlooked. Future researchers are encouraged to adopt the keywords identified in this study to enhance document identification.

Moreover, the databases used in this analysis may inherently favor content in Biological Sciences over Human Sciences and prioritize English-language publications, potentially excluding relevant research published in other languages. Therefore, researchers should remain mindful of these limitations and adopt a comprehensive approach to literature review.

CONCLUSIONS

Based on our analysis of scientific production in artistic gymnastics across the Web of Science (WoS) and Scopus platforms, several key conclusions can be drawn:

1. There is a noticeable uptrend in research interest within the scientific community. The earliest article dates back to 1975, with 2019 marking the most prolific year. A consistent interval of research activity spans from 1996 to 2022. Notably, the oldest document in the Women's Artistic Gymnastics (WAG) category dates to 1986, while in Men's

Artistic Gymnastics (MAG), it dates to 1994.

2. Among prolific authors, Sunčica Delaš Kalinski (Croatia), Almir Atiković (Bosnia and Herzegovina), and Myrian Nunomura (Brazil) emerge prominently. Noteworthy figures in the field include Albrecht L. Claessens (Belgium), followed by Gaston P. Beunen (Belgium) and Jeremie H. Lefevre (France). In WAG, Natalie Barker-Ruchti (Sweden) stands out, while in MAG, Michael J. Hiley and Maurice R. Yeadon (both British) make significant contributions.

3. The journal "Science of Gymnastics Journal" leads in terms of publication volume, accounting for 17.01% of publications, followed by "Journal of Physical Education and Sport" (4.98%), "Teoriya i Praktika Fizicheskoy Kultury" (2.9%), and "Sports Biomechanics" (2.7%). Notably, "Science of Gymnastics Journal" maintains its prominence in both WAG (24.24%) and MAG (30.36%) categories.

4. Analysis of keyword clusters reveals four primary themes: "analysis of technique," "training (physiological aspects)," "gymnastics as a basic sport," and "evaluation and scoring of exercises."

DECLARATION OF INTEREST STATEMENT

The authors declare no conflict of interest.

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SUPPLEMENTARY MATERIAL

Table 1S. Bradford's zones and their number of journals, according to number of articles.

Zone	N° journals (%)	Number articles (%)	Acc. n° journals (%)	Acc. n° articles (%)	Bradford multipliers	Journals (theoretical serie)
CORE	6 (3,2%)	155 (32,2%)	6 (3,2%)	155 (32,2%)		n0 6
Zone 1	31 (16,7%)	149 (30,9%)	37 (19,9%)	304 (63%)	5,17	n1 30
Zone 2	149 (80,1%)	178 (36,9%)	186 (100%)	482 (100%)	4,81	n2 149
Total	186 100%	482 100%			Mean 4,99	185
						% Error 0,5%

N° (Number); % (Percentage); Acc (Accumulated);

Table 2S. Thesauruses created with keywords.

olympic games, 2012-2016 olympic games, olympic games 1, olympics, youth olympic games	dismount, dismounts, dismounts skill
maximum strength, absolute strength	dxa, dual-energy x-ray absorptiometry, dual-energy x-ray absorptiometry (dxa)
muscular strength, muscle strength	emotion, emotions
isometric contraction, static strength	epidemiology, épidémiologie
injuries, ankle injury, athletic injuries, head injury, injury, muscle injury, muscular and skeletal injuries, musculoskeletal injuries, sporting injuries, sports injuries, wounds and injuries, wrist injury	exercise, exercises
injury prevention, injury risk analysis	artistic gymnastics, artistic gymnastic, artistic gymnasts, key two: artistic gymnastics
female gymnasts, female gymnast, female sporting gymnastics, women's gymnastics	women's artistic gymnastics, female artistic gymnastics, woman artistic gymnastics, women artistic gymnastics, women's artistic gymnastic, women's artistic gymnastics
gymnastics, gymnast, gymnastic, gymnastic sports, gymnastique, gymnasts, sports gymnastics	men's artistic gymnastics, male artistic gymnastics, male artistic gymnasts, man artistic gymnastics, men artistic gymnastics, men's artistic gymnastics, men's artistic
rhythmic gymnastics, rhythmic gymnasts	gender participation, gender-participation

children, childhood	handstand, handstand skill
aesthetic sports, aesthetic sport, aesthetics of sport	high performance, high performance athletes, high-level
elite sports, elite sport, elite, elite athlete, elite athletes, elite-level	high bar, horizontal bar
physical and sports education, physical education and sport	jump, jumping
sport, sports	landing, learning
sport results, resultados deportivos, sports result, sports results	long-term planning, long term programs of learning, long-term plan
coaching, coach, coaches, sport coaching, sports coaching	measurement system, measurement systems
judging, judge, judges, judging bias, judging system, panel judging, sports judges, sports judging	men, males
training, training process, sport training, sports training	modeling, modelling
youth sport, youth sports	motion capture, motion capturing
youth, youths	optimization, optimisation
coaches opinion, coaches' perception, opinions of gymnastic coaches	pediatric, pediatrics
acrobatics, acrobatic	peripheral quantitative computed tomography, peripheral quantitative computed tomography (pqct), pqct
adolescents, adolescence, adolescent	range of motion, range of movement, rom
body composition, anthropometrics, anthropometry	social goal orientation, social goal orientations
athletes, athlete, atletas	somersault, somersaults
athlete development, athletes' development	still rings, rings
athletic performance, athletic performances	stretching, stretch
bibliometric, bibliometrics	test, tests
bone, bones, bone and bones	trampoline, trampolining
bone mineral content, bone mineral content (bmc)	trend, trends
code of points, code of points (fig)	upper limbs, upper extremities, upper limb
coronavirus, covid-19	world championship, world championships
discipline, disciplines	

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Article received: 14. 6. 2023

Article accepted: 24. 10. 2023

SHORT HISTORICAL NOTES XXIX

Anton Gajdoš, Bratislava, Slovakia

Ivan Čuk, Ljubljana, Slovenia

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.



12th World Championship 1950 in Basel

The first World Championship (WC) in gymnastics after WWII was held in Basel (Switzerland) in 1950. Switzerland was determined as WC organizer already for year 1942, but war begun and all competitions were canceled. After the WWII it took quite a lot of time to start activities again, so it took 12 years from Prague in 1938 to Basel 1950.

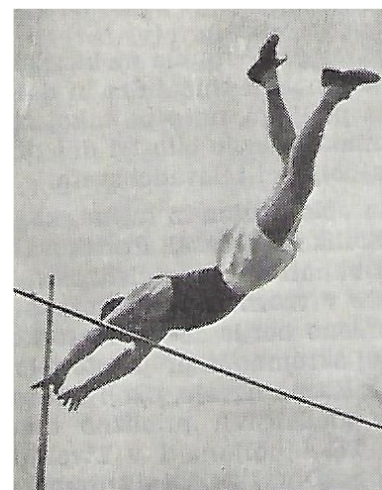
What was so exceptional with this world championship?

The Basel WC was the last championship where other activities, disciplines besides artistic gymnastics were involved.

On the first day of competition at stadium, where 20.000 spectators were present, track and field disciplines were held for men:

- pole jump, 300 cm of height for 10 points,
- high jump, 160 cm of height for 10 points
- 100 m run, 12.2 s for 10 points.

Photo on right: Esa Seeste (FIN) was excellent in track and field disciplines



Gymnasts next day competed in compulsory exercises on apparatus on free exercise, pommel horse, rings, vault, parallel bars and horizontal bar and on the third day on same apparatus in optional exercises.

MEN RESULTS

Teams (all disciplines included):

1. Switzerland 852.25
2. Finland
3. France
4. Italy
5. Yugoslavia
6. Egypt

All around (all disciplines included)

1. Lehmann (SUI)
2. Adatte (SUI)
3. Rove (FIN)

Free exercise:

1. Gebedinger, Stalder (both SUI)
2. Dot (FRA)
3. Rove, Lampinen (FIN)

Pommel horse:

1. Stalder (SUI)
2. Adatte (SUI)
3. Lehmann (SUI)

Rings:

1. Lehmann (SUI)
2. Rove (FIN)
3. Eugster (SUI)

Vault:

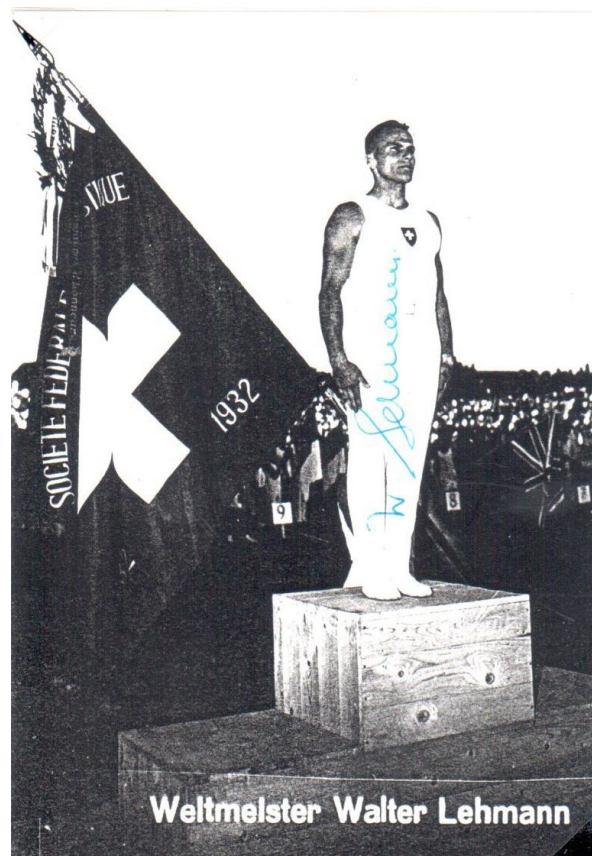
1. Gebedinger (SUI)
2. Rove (FIN)
3. Lehmann (SUI)

Parallel bars:

1. Eugster (SUI)
2. Rove (FIN)
3. Dot (FRA)

Horizontal bar:

1. Aaltonen (FIN)
2. Stalder, Lehman (both SUI)



The best gymnast in Basel Walther Lehmann (SUI)

WOMEN RESULTS

Women had compulsory and optional exercise on beam, vault, free exercise, uneven bars or swinging rings and group free exercise.

Teams

1. Sweden
2. France
3. Italy
4. Yugoslavia
5. Poland
6. Austria
7. Belgium

All around:

1. Rakoczy (POL)
2. Petersson (SWE)
3. Kolar (AUT)

Beam:

1. Rakoczy (POL)
2. Nuti (ITA)
3. Machini (ITA)

Vault:

1. Rakoczy (POL)
2. Kolar (AUT)
3. Lemoien (FRA)

Free exercise:

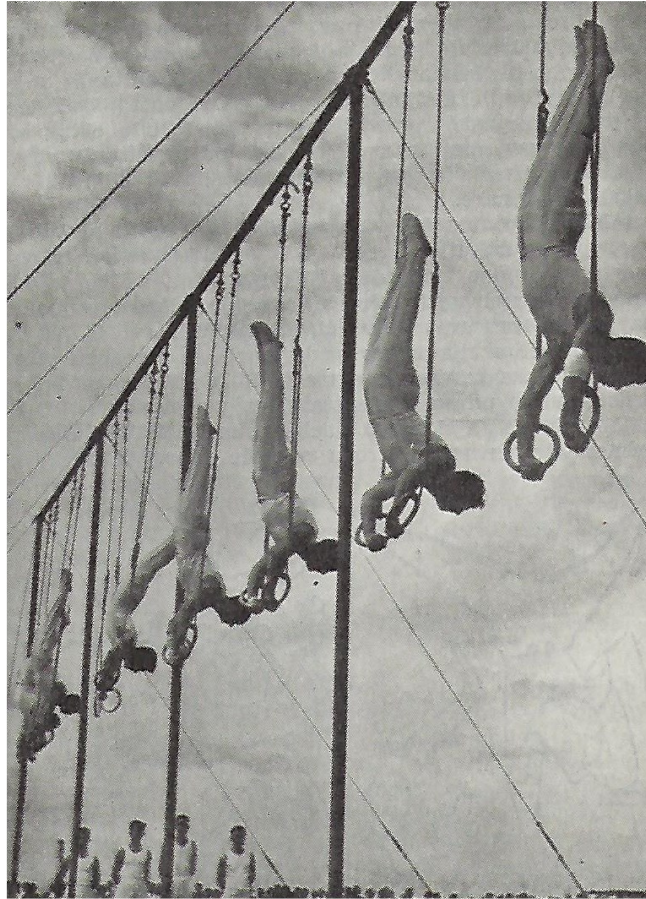
1. Rakoczy (POL)
2. Kočiš (YUG)
3. Reindlova (POL)

Swinging rings or uneven bars:

1. Kolar (AUT), Petersson (SWE)
2. Rakoczy (POL)
3. Sandahl (SWE)



The best gymnast in Basel Helena Rakoczy (POL)



During WC Switzerland had also country canton gymnastics festival, where simultaneous exercises were present.

Slovenski izvlečki / Slovene Abstracts

Masaharu Matsushima

RAZLIKA MED MIŠIČNIMI DEJAVNOSTMI PRI SKOKIH NA VELIKI PROŽNI PONJAVI MED LETOM NAVZGOR IN NAVZDOL

Odrivi na veliki prožni ponjavi se izvajajo na pravokotni ponjavi, ki je napeta čez jeklen okvir z vzmetmi. Gibanje v skoku je razdeljeno na spuščanje ponjave, to je od doskoka do največje globine, in dviganje ponjave, od največje globine do odriva. Večina raziskav o mišični dejavnosti med skokom je raziskovala mišično dejavnost v istem delu med skupinami ali med doskokom in odrivom; vendar nobena študija ni raziskovala mišične dejavnosti med deli. Zato je bil namen te raziskave preveriti mišično dejavnost med dvigovanjem in padanjem pri letu. Merjenci so izvedli 15 zaporednih skokov na ponjavi iz stoje na nogah, čim višje, naravnost navzgor na sredini ponjave. Mišične dejavnosti štiriglave stegenske mišice, prednje golenične mišice in dvoglave mečne mišice so pokazale znatno povečanje in večje velikosti učinka v padanju kot v dviganju ($p < 0,01$). Mišične dejavnosti obračalka glave, trapezaste mišice in dvoglave stegenske mišice so pokazale znatno povečanje in srednje velike učinke v padanju v nasprotju z dviganjem ($p < 0,01$). Mišična dejavnost nog je najbolj prisotna pri potiskanju ponjave navzdol ter nato telo ohrani pokončno držo ter izkoristi silo odriva iz ponjave. To nakazuje, da sta bili obračalka glave in trapezasta mišica precej dejavni pri nadzoru položaja glave. Visok skok stegneno dosežemo tako, da ponjavo potisnemo navzdol čim globlje in ohranimo pokončno držo na največji globini. Prožna ponjava je podobna odprti kinetični verigi med spuščanjem, ker se obremenitev postopno povečuje, in zaprti kinetični verigi med dviganjem, ker se obremenitev začne pri najnižji točki spusta. Ločevanje odriva in doskoka je potrebno in pomembno pri načrtovanju vadbe.

Ključne besede: velika prožna ponjava, ponjava, elektromiogram, odprta kinetična veriga, zaprta kinetična veriga.

Paulo Daniel Sabino Carrara, Gareth Irwin, Timothy Exell, Julio Cerca Serrão, Alberto Carlos Amadio, Luis Mochizuki

KINEMATIČNA RAZČLENITEV RAZPORE NA VADBENIH IN TEKMOVALNIH KROGIH: PRIMERJAVA MED VRHUNSKIMI TELOVADCI IN TELOVADCI MEDNARODNEGA RAZREDA

Za urjenje telovadnih spretnosti se uporabljajo pomožna orodja. Na podlagi načel posebnosti vadbe je bila ta raziskava namenjena raziskovanju učinkovitosti vadbenega orodja za držo razpore na krogih za moško orodno telovadbo s pomočjo kinematične razčlenitve. Dvanajst telovadcev je bilo glede na tekmovalne rezultate razdeljenih v dve skupini: odlična skupina (starost: $21,8 \pm 3,2$ leta) in zelo dobra skupina (starost: $19,3 \pm 3,3$ leta) je razpore izvedla trikrat v obeh pogojih: standardni tekmovalni pogoji ter vadbeneh krogih. Videoposnetki so bili digitalizirani in razčlenjeni kot v ramenu, trupu in rokah. Spremenljivke so vključevale desni in levi ramenski kot v čelni ravnini ter morebitno nesomernost teh kotov. Izvedena je bila dvosmerna ANOVA in t-test. Obe skupini sta izvedli razpore na vadbeneh krogih s povečanjem primikanja na desni ($p < 0,001$) in levi ($p < 0,001$) rami in zmanjšano nesomernostjo ($p = 0,01$) kot na tekmovalnih krogih. Te kinematične izboljšave bi pomenile izboljšave rezultatov tekmovanjih za 0,1 do 0,3 točke in izboljšano stabilnost ramenskega sklepa. Zato vadbeni krogi učinkovito posnemajo določene kote v sklepih in se držijo kinematičnih načel posebnosti vadbe za držo razpore na krogih, kar koristi vsem telovadcem.

Ključne besede: telovadba, trenerji, ramenski kot, video razčlenitev, razčlenitev somernosti, vadba moči.

Megan Benzie

PRETRGANJE AHILOVE TETIVE IN VRNITEV K TELOVADBI: PREGLED

Raztrganine Ahilove tetive pri študentski orodni telovadbi so se v zadnjih nekaj letih znatno povečale, z 20 pretrganinami samo v prvih treh tednih tekmovanja leta 2020 glede na Bonanno et al., 2022. Telovadke imajo desetkrat večjo verjetnost, da si bodo strgale Ahilovo tetivo kot kateri koli drugi univerzitetni športniki, s pojavnostjo 16,73/100.000. Moška košarka ima naslednjo največjo pojavnost 4,26/100.000 (Bonanno et al., 2022). Dejavniki, ki prispevajo k povečanju strganin, niso dobro raziskani ali razumljeni. V tem članku je predstavljena ustrezna literatura o dejavniki tveganja za poškodbo in vrnitev k vadbi. Gre za pregled zgodnjega zdravljenja, osredotočeno predvsem na vrnitev k meritvam in napredovanje v telovadbi z vidika fizioterapije. Raziskane so teme, o katerih se je razpravljalo v pogovorih s številnimi športnimi fizioterapevti z bogatimi izkušnjami z orodno telovadbo ali univerzitetnim športom. Orodna telovadba je zelo tehničen šport, kjer ima vsak športnik svoje sposobnosti z različnimi biomehanskimi zahtevami; zato se potrebe med športniki razlikujejo. Namen tega prispevka je obravnavati prehodno fazo med časom, ko kirurški postopki omogočajo vrnitev k športu, in dejansko vrnitvijo k zmogljivosti med okrevanjem. Na tem določenem področju obstaja stalna potreba po presečnih in večletnih študijah za raziskovanje merjenja in meritev rezultatov, prilagojenih orodni telovadbi. Te raziskave lahko igrajo ključno vlogo pri usmerjanju športnikov, vaditeljev in fizioterapevtov pri omogočanju varne in učinkovite vrnitve k tekmovalnim nastopom po operaciji.

Ključne besede: telovadba, pretrganje ahilove tetive, vrnitev k vadbi, fizioterapija.

Tamer Çankaya, Numan Yener and Muhammet Fatih Uysal

ALI OBSTAJA VPLIV RESNOSTI GIBLJIVOSTI PLOSKEGA STOPALA NA SPOSOBNOST OHRANJANJA RAVNOTEŽJA PRI VRHUNSKIH TELOVADCIH?

Gibljivost je pomembna gibalna sposobnost pri vadbi telovadcev, saj lahko njena nezadostna razvitost pomembno oteži proces oblikovanja določenih veščin in skladnosti gibanja ter omeji možnost nadzora in povečevanja moči in hitrostnih sposobnosti (Dejneko in Vilenjka, 2021). Namen te študije je bil razčleniti vpliv resnosti gibljivosti ploskega stopala (FPP) na ravnotežje v različnih ravninah (čelni, vodoravni in bočni) v turški mladinski vrsti. Ta raziskava je presečna raziskava, izvedena na oddelku za fizioterapijo in zdravljenje po poškodbah univerze Bolu Abant İzzet Baysal. Postopek vrednotenja je sestavljen iz dveh glavnih delov: prvi je meritev položajev ali kotov sklepov (položaj skočnega sklepa, kot skočnega sklepa, kot iztegnitve prvega sklepa palca na nogi (MTP) in meritev golensko stegenskega kota), druga pa meritev ravnotežja. V to raziskavo je bilo vključenih 20 udeležencev, starih od 13 do 18 let, moških in žensk, iz turškega državne mladinske vrste. Izvedena je bila linearna regresijska razčlenitev, da bi ugotovili, ali obstaja učinek resnosti FPP na zmogljivost ravnotežja. Ni jasnega vpliva resnosti FPP na uspešnost ravnotežja v mladinski orodni telovadbi na državni ravni. Vendar pa nekatere ocene kažejo pomembne povezave v čelni ravnini glede na razmerje srednje zunanega ravnotežja. Nobena od ocen ni pokazala pomembne povezave z razmerjem sprednje zadnjega stabilnosti.

Ključne besede: vrhunski telovadci, plosko stopalo, ohranjanje ravnotežja.

Gokhan Deliceoglu, Guler Atalay and Banu Kabak

VPLIV TOGOSTI NOG NA HITROST, HITROST SPREMEMBE SMERI IN IZVEDBO SKOKOV PRI TELOVADCIH

Pri pregledu virov smo se odločili, da izvedemo to raziskavo zaradi pomanjkanja raziskav, ki bi preučevale vpliv togosti nog na zmogljivost, kot so hitra sprememba smeri, moč skoka in hitrost pri telovadcih. Namen te študije je raziskati učinke togosti nog telovadcev na zmogljivosti, kot so hitra sprememba smeri, skok in hitrost. V ta namen je bilo v raziskavo vključenih 65 telovadcev, starih od 12 do 22 let. Za oceno skoka je bil uporabljen skok v globino (z merilno napravo Optojump), za oceno togosti nog pa vskok (merilna naprava Optojump), za oceno hitrosti pa test teka na kratke proge na 20 m (z merilno napravo Witty). Meritve hitrosti spremembe smeri so bile izvedene s SpeedCourt™. Kot rezultat naše raziskave smo ugotovili zmerno pozitivno povezavo med vrednostmi togosti nog in vrednostmi razmerja reaktivne moči (RSI), pridobljenimi iz testov skokov telovadcev. Poleg tega smo ugotovili negativno povezavo na nizki ravni med hitrostjo in hitrostjo spremembe smeri z vrednostmi togosti nog. Sklenemo lahko, da večja togost nog telovadcev pozitivno prispeva k moči skoka, hitrosti in hitrosti spremembi smeri. V tem primeru je priporočljivo vključiti »pliometrične« vaje v vadbo za izboljšanje togosti nog akrobatov na ponjavah, ritmičark in orodnih telovadcev.

Ključne besede: telovadba, skoki, togost nog, hitrost spremembe smeri, hitrost.

Una T. Visser and Francois J. Cleophas

KORENINE, IZVORI IN RAZVOJ RITMIKE: ZGODOVINSKI POGLED

Ritmika je šport, ki je bil zasnovan kot bolj ženska sestrška panoga ženske orodne telovadbe. Njene korenine pa so vgrajene v moško nadvlado evropske zgodovine, ki je vključevala prvine plesa, fiziologije in pedagogike. Ključne vloge so imeli François Delsarte, Émile Jaques-Dalcroze, Isadora Duncan in George Demeny, ki so močno vplivali na razvoj ritmike. Ti posamezniki so razširili prejšnje delo prejšnjih začetnikov telovadbe – Johana Gutsa Muthsa, Ludwiga Jahna in Pera Linga. Od svojih začetkov kot tekmovalnega športa v nekdanji Zvezi sovjetskih socialističnih republik v 40. letih 20. stoletja se je ritmika zelo razširila, dokler je leta 1962 ni uradno priznala Mednarodna telovadna zveza (FIG). Leta 1963 je bilo prvo svetovno prvenstvo in šport je pridobil večji mednarodni pomen. Namen te študije je raziskati družbene in politične dejavnike, ki so prispevali k razvoju ritmike, od njenih začetkov v evropskih državah do njenega priznanja kot samostojnega športa leta 1973. Članek zaključujemo s predpostavko, da šport ni neposredno izzival moške nadvlade, ampak da so ženske v tem športu začele spreminjati spolna pričakovanja in norme.

Ključne besede: evropske države, ritmika, moška nadvlada, ženstvenost.

Joseph Lobo

VLOGA RADOVEDNOSTI PRI ŠTUDIJSKI ZAVZETOSTI ŠTUDENTOV V TELOVADBI: NAPOVEDOVANJE VZAJEMNOSTI

Sodobni viri o ponovljivosti povezav med radovednostjo in študijsko zavzetostjo v osnovnošolskem in srednješolskem obdobju so obsežni in razširjeni v več državah. Na žalost so raziskave na področju telovadbe v okviru visokega šolstva na Filipinih večinoma neraziskane in neznane. Ta raziskava je preučevala vzajemno povezavo med radovednostjo in študijsko radovednost v sklopu telovadbe na izbrani visokošolski ustanovi na Filipinih. Izvedena je bila raziskava s 177 študenti dodiplomskega študija športne vzgoje, vpisanih na Gibalno vzgojo, kjer je telovadba del omenjenega predmeta. Ugotovitve študije so razkrile omembe vredno povezavo med splošno radovednostjo in študijsko zavzetostjo na področju telovadbe ter vzajemno razmerje med obema spremenljivkama. Poleg tega je bila ugotovljena pomembna in pozitivna povezanost med dejavniki radovednosti in vsemi tremi dejavniki študijske zavzetosti (živčnost, predanost in sprejemanje), pa tudi vzajemna povezava. Zaključili smo, da lahko spodbujanje naravne radovednosti učencev pomaga razviti zdravo strpnost do dvoumnosti. Posledično ima lahko to pozitivne posledice na akademsko uspešnost učencev s spodbujanjem vseživljenjske in trajne radovednosti pri širjenju njihovega znanja in spretnosti v telovadbi. V tej študiji so predstavljena priporočila za učitelje, ponovljivost študije in prihodnja raziskovalna prizadevanja.

Ključne besede: radovednost, telovadba, namensko učenje, pomisli in odloči, zavzetost učenju.

Sinem Yürük, Sibel Sönmez and Feride Zişan Kazak

RAZVOJ VREDNOT S TELOVADNO VZGOJO PRI PREDŠOLSKIH OTROKIH

Pri telesni vzgoji je v ospredju mnogih šol mišljenje, ko gre za vzgojo vrednot, da ima šport moč zagotoviti temeljni okvir za učenje vrednot. Zato je cilj te raziskave proučiti razvoj vrednot pri otrocih, starih štiri in pet let, ki začnejo s telovadnim izobraževanjem že v zgodnjem otroštvu. V poskusno načrtovani raziskavi so družine otrok izpolnjevale lestvico vrednot pred meritvami in po meritvah ter preverjale spremembe. Raziskovalno skupino so sestavljali otroci stari štiri do pet let, ki so poleti obiskovali tečaj telovadbe, ki ga je odprlo zasebno društvo v okrožju Akhisar v Manisi. Vzorčno skupino je sestavljalo 49 otrok, katerih soglasje je bilo pridobljeno po obvestilu njihovih družin. Kot merilno orodje je bila uporabljena družinska oblika lestvice predšolskih vrednot (PVSFF), ki sta jo razvila Neslitürk in Çeliköz (2015). Čeprav ni bilo pomembne razlike med povprečnimi rezultati pred in po testu na lestvici Družinskega obrazca predšolskih vrednot, je bila pomembna razlika ugotovljena le v podzvrsteh odgovornosti na lestvici. Zato se razume, da lahko otroci pridobijo vrednote, zlasti odgovornost, skozi vseživljenjsko telesno vzgojo, ki vključuje tudi šport, ki temelji na igri. Glede na to, da je učenje skozi igro pomembno v zgodnjem otroštvu, se zdi ključnega pomena poudarjanje zasnove vrednot pri vadbi telesne vzgoje, ki jih je treba strukturirati in o tem obveščati učitelje, vaditelje ali svetovalce, ki delajo na tem področju.

Ključne besede: predšolska vzgoja, šport, gibalna izobrazba, telovadba, razvoj vrednot

Ivan Čolakovac, Iva Barković, Lucija Milčič in Marijo Možnik

RAZČLENITEV ZNANSTVENE LITERATURE O ORODNI TELOVADBI V PODATKOVNI BAZI SCOPUS

Namen prispevka je preučiti trenutno stanje znanstvenega udejstvovanja, sodelovanja in vplive raziskovalnih objav na orodno telovadbo ter najdejavnejše raziskovalce, ki se ukvarjajo s tem področjem. Za osnovo naše raziskave so bili članki pridobljeni iz baze Scopus. Za izvedbo bibliometrične razčlenitve in načrtovanja omrežja sta bila uporabljena MS Excel in VOS viewer. Tako je bilo v 167 revijah najdenih 430 izvirnih člankov in znanstvenih ocen z 22 tematskimi področji Scopusa. Največ člankov je bilo objavljenih v *Science of Gymnastics Journal* (76). Ti članki so tudi največkrat navedeni viri (294). Avtorjev je 28 s pet do petnajstimi članki, katerih navedbe tvorijo večino mreže navajanja virov. Večina raziskav orodne telovadbe je objavljenih v revijah, ki pokrivajo teme, kot so medicina, zdravstveni poklici in družboslovje, pri čemer prva prejme največ navedb.

Ključne besede: orodna telovadba, bibliometrija, omrežje navajanja virov, znanstvena literatura.

Yeray Rodriguez-Redondo and Kiko Leon

RAZČLENITEV ZNANSTVENIH OBJAV V MOŠKI IN ŽENSKI ORODNI TELOVADBI

Orodna telovadba kot temeljna gibalna dejavnost, ki predstavlja osnovo za akrobatske dejavnosti v športu, umetnosti in sprostivni, je predmet raziskave. Cilj je natančno preučiti znanstvene vire o orodni telovadbi, tako v telesni vzgoji kot v smislu tekmovalne moške in ženske orodne telovadbe. Opravljena je bila bibliometrična razčlenitev revij, uvrščenih v Scopus in Web of Science, po uveljavljenih bibliometričnih načelih. Razčlenitev, obdelava in izdelava grafov je potekala s programoma Microsoft Excel in Bibliometrix. Prepoznanih je bilo skupno 482 virov, objavljenih med letoma 1975 in 2023, kar je razkrilo naraščujočo rast objav. Osrednji nabor izdatnih revij je obsegal šest objav. Med 1241 avtorji je bilo 33 prepoznanih kot plodnih (s 5 ali več objavami), 12 pa jih je izstopalo kot vidnih. Najbolj delavna je bila Brazilija, najbolj citirane pa ZDA. Ključne besede so bile razvrščene v štiri glavne kategorije: »razčlenitev tehnike gibanja«, »fiziološke obremenitve«, »telovadba kot temeljna gibalna dejavnost« in »vrednotenje in točkovanje vadbe«. Skratka, raziskovalna skupnost kaže vse večje zanimanje za orodno telovadbo. Izstopala sta Sunčica Delaš Kalinski (Hrvaška) in Albrecht L. Claessens (Belgija). Kot najvplivnejša revija se je izkazala "*Science of Gymnastics Journal*". Na podlagi skupin ključnih besed so bile določene štiri osnovne raziskovalne smernice.

Ključne besede: šport, akrobatika, bibliometrija, pregled, Olimpijada.

INNOVATION OF THE SUBJECT OF ARTISTIC GYMNASTICS AT UNIVERSITIES WITH A SPORTS FOCUS - SAFE GYMNASTICS 4ALL (Erasmus+ project)

Authors are Petr Hedbávný, Miriam Kalichová, Ivan Čuk, Maja Pajek, Marijo Možnik and Lucija Milčić.

The evolution of contemporary education with its current trends, which include the use of digital technologies, is gradually affecting all areas and levels of education. Due to the nature of physical education, where practical learning is key, the potential of innovative approaches to support contact learning has not been fully exploited in this area.

In cooperation of the Faculty of Sports Studies of Masaryk University, The Faculty of Sport of the University of Ljubljana and the Faculty of Kinesiology of the University of Zagreb, new multimedia materials called „Safe gymnastics 4all“ were created to support the teaching of artistic gymnastics within the international Erasmus+ project "Innovation of the subject of artistic gymnastics at universities with a sports focus".

The content of these materials aligns with the academic standards set for students studying sports at universities. Nevertheless, they are also highly versatile and suitable for coaches, gymnasts, physical education teachers, and anyone with an interest in artistic gymnastics education.

The educational materials are available to the general public in OPEN ACCESS mode in Czech, Slovenian, Croatian and English. The materials contain textual and audiovisual support for selected about 80 basic gymnastic elements from all disciplines. You can access it at:

https://is.muni.cz/do/fsp/e-learning/safe_gymnastics_4all/index_cs.html

Each element is briefly introduced through commented videos, showcasing the execution from various angles. These videos are valuable for observational learning, a common practice in gymnastics instruction. In the more advanced stages of motor learning, a less frequently utilized method is ideomotor training, which, nonetheless, offers significant benefits. To facilitate this, we've created video recordings from the trainee's perspective, aiding practitioners in visualizing spatial perception and the timing of movements during ideomotor training.

Comprehending the biomechanical principles of these elements is crucial for instructors and coaches, but it can also be beneficial for practitioners who favor a systematic approach to mastering these skills. To serve this purpose, we have developed audiovisual sequences featuring animations that analyze the biomechanical foundations of all the selected elements.

In accordance with the principles and regulations of motor learning, a specific level of motor abilities, limiting the acquisition of a particular motor skill, is considered a prerequisite. Therefore, the materials outline the necessary physical prerequisites for mastering a specific element and provide corresponding exercises to enhance these capabilities. Furthermore, an additional benefit is the inclusion of exercises that can primarily be conducted outside of the gym, facilitating preparation for actual training within a home environment.

Selecting the right methodology for practicing each element is one of the prerequisites for successfully attaining the desired outcome, namely, mastering the skill correctly. For each element, a series of individual steps and drills are suggested, following the established

principles of didactics and motor learning, such as progressing from the close to the distant, from the simple to the complex, from the easy to the difficult, from the known to the unknown.

An integral component of motor learning in gymnastics is spotting, clearly demonstrated in the videos with accompanying text. Additionally, the videos include a listing of the most common errors in the execution of each element, serving as a valuable resource for teachers and coaches in diagnosing their students' mistakes.

The produced audiovisual materials enable students to prepare both theoretically and physically for their gymnastics lessons in advance, which is expected to accelerate the motor learning process during gym sessions. To assess their theoretical readiness, there are accompanying worksheets that teachers can utilize when instructing students. Furthermore, tests have been developed to evaluate specific theoretical knowledge that students should acquire through the study of these materials.

Placing gymnastics within a broader context provides us with a comprehensive understanding of the discipline. Consequently, in addition to supporting the training of specific gymnastic elements, we have also included concise theoretical chapters covering topics such as the Characteristics of Artistic Gymnastics, its History, and General Didactic Principles."

We are confident that we have developed materials that will not only support in-person gymnastics instruction but also assist students in preparing for practical lessons, both theoretically and physically, in their own homes. We believe that this will enhance the training of gymnastic skills and make gymnastics accessible and enjoyable to a broader audience of sports enthusiasts.

MUNI P CZ HR SL IS

Safe gymnastics 4all

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CHAPTERS

-  Characteristics of artistic gymnastics
-  Short History of Gymnastics
-  General didactic guidelines
-  Disciplines of artistic gymnastics
-  Tests

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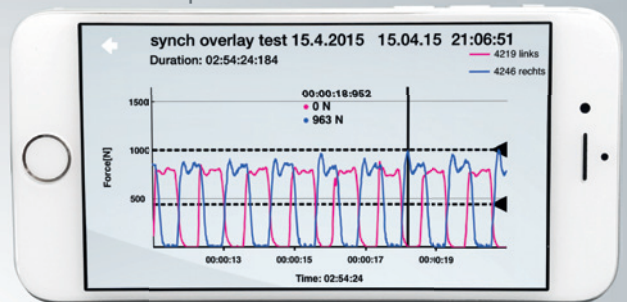
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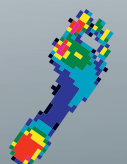
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Science of Gymnastics Journal (ScGYM®)

(e-ISSN 1855-7171)

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ScGYM® (ISSN 1855-7171) is an international
online journal published three times a year
(February, June, October).

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Front page design: Sandi Radovan, Slovenia.

Published by: University of Ljubljana Press (Založba Univerze v Ljubljani)

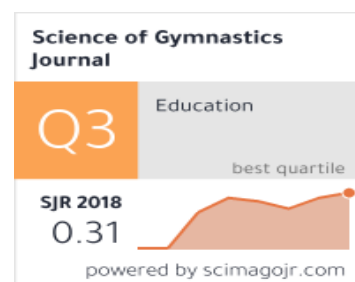
For the Publisher: Gregor Majdič, Rector of the University of Ljubljana

Issued by: University of Ljubljana, Faculty of Sport, Department of Gymnastics

For the Issuer: Damir Karpljuk, the Dean of the Faculty of Sport UL

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E-mail: scgym@fsp.uni-lj.si
Home page: <http://www.scienceofgymnastics.com> & <https://journals.uni-lj.si/sgj/>



Publication is free of charge.

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

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