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

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EDITORIAL

Dear friends,

We hoped COVID-19 would leave us without any serious consequences; however, ScholarOne, the manager of the editorial program we used for many years, has increased their prices so much that we can no longer afford them. In an effort to find a more cost-effective solution, we moved to a new open-source editorial software that is managed by the Ljubljana University. This move required a huge amount of work and means a NEW ADDRESS as well as some delays on the way. We apologise for any inconvenience and hope to get everything running smoothly again by the end of the year.

Our journal can now be found at this new address:

https://journals.uni-lj.si/sgj

The first article - a case study from Brazil - is about an Olympic champion on rings and his preparation strategy to achieve his goals. Very interesting reading! Even though it provides no scientific evidence to explain why he won at the OG, we decided to publish the article. In our view, such outstanding results are closely related to athlete's personal characteristics and abilities which are difficult to quantify. What we also want to emphasise with this article is planning. Many coaches work without proper planning, whereas here we have an example of good planing. Once we have more knowledge about how gymnasts won their titles, meta analyses will probably help us determine the data that define success. Let us just say this is the first step on this path.

Other contributing authors in this issue come from Germany, Serbia, Poland, Slovakia, China, USA, South Korea, Spain and Greece. Again, many different aspects of gymnastics are presented.

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

Anton Gajdoš drafted the 24rd short historical note introducing Aljaž Pegan from Slovenia.

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

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

Ivan Čuk
Editor-in-Chief

TOWARDS THE OLYMPIC GOLD: THE TRAINING PLAN ON THE GYMNASTICS RINGS

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Abstract

The objective of this article was to describe the training plan and the strategies developed with an Olympic champion gymnast on the rings in Men's Artistic Gymnastics. In London 2012, our athlete became the first Brazilian to stand on the podium in the history of Gymnastics at Olympic Games, and the first Latin American to win an Olympic gold medal in Gymnastics. At the 2016 Rio Olympic Games, the gymnast again stood on the podium and won the silver medal. However, we have not yet seen studies that would highlight the preparation process of an athlete that culminated in such unprecedented achievements for Gymnastics at the continental level. We present the structure of the periodization of this gymnast for the period cycle that included the Olympic Games. In order to detail the training process, we looked at the training sheets with strength tests, the macrocycle, and the physical and technical preparation distributed among the three stages of the macrocycle. The periodization planned and applied by the coaches led the gymnast to increase the complexity of the technical elements of his routine, which made it possible to increase the final score. The main factors that facilitated the Olympic result were the training periodization in three stages and the competitive tactics in the preparatory evaluations.

Keywords: *artistic gymnastic, resistance training, muscle strength, athletic performance.*

INTRODUCTION

Men's Artistic Gymnastics (MAG) comprises competitions on six apparatus, including the rings. This apparatus requires varied technical elements of swing, strength and hold in approximately equal parts (FIG, 2018). Thus, various forms of muscular strength manifestation (isometric, endurance and power) are required; they are presented in specific ways in MAG routines, with the execution quality of gymnastics technical elements (FIG, 2018).

The motor capacities required in gymnastics are primarily determined by the need to manipulate gymnasts' own body mass (Arkaev & Suchilin, 2004; Smolevskiy & Gaverdovskiy, 1996). The rings event demands predominantly upper limbs strength (FIG, 2018; Smolevskiy & Gaverdovskiy, 1996). Considering that the main motor task is to lift and support one's own body weight, relative strength is very important for the event (Arkaev & Suchilin, 2004; Jemni, Sands, Friemel, Stone, & Cooke, 2006), as well as endurance strength that requires a relatively long duration of muscle tension with minimal decrease in its efficiency. Its manifestation can occur dynamically or statically (Siff & Verkhoshansky, 2004).

The physical training process must respect a series of biological principles that aim at best results, such as biological individuality, specificity, overload, and reversibility (Bompa, 1999; Issurin, 2010). The periodization is applied to improve the physical training process, which is a comprehensive and detailed way of planning the development of performance for a certain period of time by observing the principles of sports training (Gomes, 2009). The purpose of periodization is to facilitate the best possible performance and, concomitantly, to preserve the integrity of athletes through a coherent distribution of content and appropriate handling of training loads by specific stages, distributed throughout the entire sports career (Lacordia, Miranda, & Dantas, 2006; Weineck, 1999). Periodization is a training subdivision that aims to improve the athletes' performance to peak at competitions, that is, the competition calendar that the coach prepares by planning the cycles and defining the milestones to reach the set objectives (Bompa, 1999; Verkhoshanski, 2001; Weineck, 1999).

One of the challenges in MAG is to plan the training program in such a way that progressive and balanced demands are met to achieve the objectives, but at the same time to maintain the integrity and prolong the gymnast's career (Tricoli & Serrão, 2005). The double periodization, used in the present study, occurs over two periods of competitions in a year, and is indicated for high performance athletes and sports disciplines that run competitions for extensive periods of the year (Bompa, 1999; Weineck, 1999).

The block periodization system is an efficient alternative to the traditional model (Issurin, 2016), as it also seems to be superior to the traditional periodization for athletes who participate in sports disciplines characterized by fast muscular contractions of the upper limbs (Bartolomei, Hoffman, Merni, & Stout, 2014) as occurs in most MAG competitions.

Given the goals set by the coaches and the challenge to achieve results, which periodization model should be followed? In the current context, the question is very relevant for many coaches. In the literature, studies were found for Women's Artistic Gymnastics (Lacordia et al., 2006) in Brazil or for MAG in other countries (Chu, 1994; James, 1987), which means that there are limited materials that can be used for our scientific basis.

There are some international models offered, including suggestions from the *Fédération Internationale de Gymnastique* (Fink & Hofmann, 2015). However, high performance coaching is very individualized, therefore, specific to each athlete. Nevertheless, models are valuable as support materials for less experienced coaches as they provide comparisons and diverse reflections, and help coaches update and share their experiences.

Thus, a scientific paper describing and clarifying how the training of an Olympic Champion was thought out, planned, and executed is of great importance, since it would support other coaches and would be a useful guidance for their athletes when designing their training. Therefore, the objective of this work was to describe the training periodization of the gymnast who won the gold medal on the rings event at the London Olympic Games.

METHODS

In the present study, this gymnast is responsible for the greatest achievement in the history of Brazilian AG. It occurred at the London Olympic Games (2012) when he won the ring event and was awarded the unprecedented gold medal. At that time, the gymnast belonged to the senior category, was 22 years old and had had 13 years of sport practice, always in the same institution and with the same coaches. The project gained approval from the State University of Campinas Research Ethics

Committee, CAAE:16529219.8.0000.5404, and followed all the ethical precepts for studies involving human beings.

The weekly training frequency involved ten sessions lasting approximately 25 to 30 hours. Both the systematic preparation and the training plan progression were developed through direct observation (Borresen & Lambert, 2009) of the gymnast's training needs by the head coach, who at the time had accumulated more than 20 years of experience in MAG coaching. The training sessions included preventive exercises with physiotherapist, general and specific warm-ups, technical preparation with elements on the apparatus, combinations of elements or complete routines, and finally, physical preparation with specific exercises on weight-training apparatus, or on competition rings with adaptations.

In order to guide the load values for strength training, dynamic concentric strength tests (Planche Support, Hirondelle, Azarian, Inverted cross, Triceps, Dorsal Leg, Cross, Front Raise, ESG, cross on pulley) of one maximum repetition (1MR) were performed (Kraemer & Ratamess, 2004). After the warm-up, the gymnast performed the movements with the maximum possible load using adjustable dumbbells, without technical faults in execution, with two minutes of rest between them (McArdle, Katch, & Katch, 2008). The tests used to quantify training loads were proposed by the International Gymnastics Federation (FIG, 2018; Fink & Hofmann, 2015) and adjusted by the coaches according to the specifics of the gymnast and the training venue.

For this type of test, in addition to the methodological issues that must be considered, it should be noted that the values obtained vary depending on the subject, the level of strength, the experience, and the number of maximum contractions performed (Häkkinen, Alén, & Komi, 1985; Hartmann, Bob, Wirth, & Schmidtbleicher, 2009).

Furthermore, the tests were based on the specific intended technical elements that would be part of the target routine to be presented at the Olympic Games. The routine presented at the Games, which has theD-score of 6.8 points, contained the following technical elements: roll backward slowly to planche support (2s) (E value 0.5); descent to back lever (2s) (A value, not counted); press to hirondelle (2s) (F value 0.6); uprise backward to support scale (2s) (D value 0.4); double salto forward piked (D value 0.4); uprise backward to support scale straddled (2s) (C value 0.3); roll backward slowly to hirondelle (2s) (F value 0.6), through hanging scale rearways with straight arms pull to cross (2s) (D value 0.4); salto forward direct to cross (2s) (D value 0.4); uprise backward swing to handstand with straight arms (C value 0.3); double salto backward stretched with full twist (D value 0.4); plus 2.5 points for five groups of elements.

Descriptive statistics were used to analyze the data. The load amount in the maximum strength tests and exercise weight/body weight ratios for calculating the relative strength for cycle distribution were calculated in Microsoft Excel software.

RESULTS

Table 1 presents the competitions that the gymnast participated in during each macrocycle, with dates, results and final scores for difficulty and execution. Table 2 shows the results of the 1MR strength test. Even though at the beginning of the macrocycle the relative strength values were already close to one for the basic exercises when performing technical elements as part of the routines, such as the planche support, hirondelle and cross.

Table 1
Competition calendar and competitive performance.

Competition	Date	Result	Final Score (Dif + Exec)
World Cup – Cottbus / Germany	22 - 25 / Mar	2nd	15.600 (6.5 + 9.100)
International Meeting – SBC / Brazil	13 - 15 / April	1st	15.825 (6.8 + 9.025)
World Cup – Osijek / Croatia	27 - 29 / April	1st	15.875 (6.8 + 9.075)
Challenge cup – Maribor / Slovenia	01 - 03 / June	1st	15.575 (6.8 + 8.775)
World Cup – Ghent / Belgium	09 - 10 / June	1st	15.925 (6.8 + 9.125)
Olympic Games – London / England	27 - 31 / July	1st	15.900 (6.8 + 9.100)

Legend: Dif = Difficulty, Exec= Execution

Table 2
Maximum Dynamic Strength Test 1MR.

		Weight	Relative strength
Gymnast		59.5	-
Exercises	Support planche	58	0.97
	Hirondelle	61	1.03
	Azarian	30	0.50
	Inverted cross	51	0.86
	Triceps	35	0.60
	Dorsal Leg	42	0.71
	Cross	60	1.01
	Frontal Raise	32	0.54
	ESG	45	0.76
	Pulley cross	47	0.79

Legend: ESG= erector spinae group, weight in Kg, relative strength = exercise weight/body weight.

The double periodization model was used in the planning with the first macrocycle of 28 weeks between January and July (date of the Olympic Games), divided into three distinct blocks: A (Basic), B (pre-competitive) and C (competitive), but correlated (Siff & Verkhoshansky, 2004; Verkhoshanski, 2001), with the main characteristic of concentrated and distributed loads throughout the training cycle. The worksheet of the first macrocycle is shown in Table 3; the second macrocycle is not addressed in this study.

The basic stage (Block A) contained the largest training volume of the entire season. Its objective was to destabilize previous performance levels, aiming to increase strength gains, with greater emphasis on the total volume of repetitions to obtain greater adaptation of the neuromuscular complex to be used (Verkhoshanski, 2001). The central objective was the elevation in the motor potential of the athlete, ensured by a high volume of means and special training methods with emphasis on strength.

The pre-competitive stage (Block B) developed the increase in strength and speed capacity (explosive strength), decreased the volume and increased the intensity of training, to intensify the muscle tension index and activate the neuromuscular system (Verkhoshanski, 2001). Thus, the volume was reduced, and specific loads were accentuated, especially the more intense ones, supported by the foundation created by the morphological and functional changes in the system.

Finally, in the competitive stage (Block C) of the macrocycle, the main objective was training with low volume and greater intensity so that training became more specific to the sport. It was characterized by a greater incidence of competitive loads which aimed to consolidate the athlete's readiness at the highest level and coincided with major competitions.

Table 4 presents the distribution of the physical preparation variables (means, method, sets, repetitions, load and rest) between the training Blocks. Comparing the variables in the Blocks, an adjustment of values and items from a general training organization to a specific organization of the routine on the apparatus can be observed: a decrease of sets and repetitions, a load increase until close to the maximum relative strength, and a rest increase.

Table 5 presents the distribution of the technical preparation between the days of the week in accordance with the training Blocks. Comparing the days in each Block, a few modifications in the combination of movements are notable, adapted to the gymnast's individual needs. However, when considering the distribution during the week, there is a variation in the movements and methods. As for the apparatus, there is the construction of the routine to be presented, with the refinement of movements and combinations of technical elements acquired and new combinations, in line with the gymnast's partial results and scoring needs.

DISCUSSION

The objective of this paper was to describe the training plan of the Olympic champion in the rings event. The objectives and methods of strength training vary according to sports characteristics, the athlete and the competitive calendar (Bompa, 1999). The increase in the number of competitions (Gomes, 2009), the development of the sport and the need for success were determinant factors in the search for new training systems to ensure an increase and prolongation of the sport performance in the athlete at the highest competitive level (Platonov, 2008). Considering the sequence of competitions presented in the calendar, and the need to be present at a competitive level on the international scene, the coach's choice to devise an extended competitive block of 12 weeks was justified. In order to understand the periodization planning, we started by analyzing the competition calendar for the Olympic year (Table 1), in an attempt to coincide the performance peaks with target events (Bompa, 1999; Verkhoshanski, 2001; Weineck, 1999).

Due to competition distribution in this calendar, the double annual periodization (Weineck, 1999) with two competitive periods or macrocycles was used in the planning, using three blocks in the two macrocycles (Siff & Verkhoshansky, 2004; Verkhoshanski, 2001). In a year composed of two macrocycles, the first cycle presents approximately seven months and comprises a preparatory period (Block A and B in the present study) and another competitive period (Platonov, 2008) (Block C in the present study).

In the case of the present study, the training loads, normally considered for the basic stage, were developed already with technical elements of a high contemporary competitive level. This was possible due to the relative strength values already found close to the body weight (reason one) in the basic exercises. Additionally, it was considered that the gymnast had many years of preparation and international results, such as world championships, already behind him.

This physical-technical basis allows for more complex technical elements to be developed more quickly (Siff & Verkhoshansky, 2004; Smolevskiy & Gaverdovskiy, 1996). We emphasize the importance of a long-term training plan (Bompa, 1999). In the case of gymnasts in different technical conditions, it would be interesting to observe the development of relative strength for the consolidation of technical elements and their inclusion in the routine (Smolevskiy & Gaverdovskiy, 1996).

Table 3
Macrocycle worksheet.

MONTHS		**JAN**			**FEB**					**MAR**				**APR**				**MAY**					**JUNE**			**JULY**		
WEEKS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
BLOCKS					BLOCK A								BLOCK B										BLOCK C					
STAGES		A1			A2			RA			B1			B2		RB							C1					
Duration (weeks)		3			4			1			4			3		1							12					
Controls		A		A						C		A	C		C		A			C	C		A		A			C
Volume Control					▲								►										▼					
Intensity Control					▲								▲										▲					
Methodologic Variation					▲								►										►					
Dynamic Maximum Strength					XXX								XX										XX					
Explosive Strength					XX								XX										XXX					
Isometric Maximum Strength					X								XXX										XX					
Static Resistance Strength					X								XX										XXX					
Dynamic Endurance Strength					X								X										XX					
Anaerobic endurance					X								XX										X					
Speed					X								X										X					
Flexibility					XX								X										X					

Legend: AR=Block A Regenerative BR= Block B Regenerative E=Evaluations, C=Competitions, Importance of the capabilities: X=not very important, XX=important, XXX=very important, ▲=increased, ►=maintenance, ▼=decreased.

Table 4
Distribution of physical preparation in the training blocks.

	BLOCK A			BLOCK B			BLOCK C
STAGE	**A1**	**A2**	**A Regenerative**	**B1**	**B2**	**B Regenerative**	**C1**
VARIABLES							
Main Capacity	Maximum Strength			Explosive Strength			Explosive Strength
Means	Weight training			Weight training		i) Specific exercises on the apparatus ii) Weight-training[d]	Technical elements of the test
Method	Multiple sets			Multiple sets	Contrast	Multiple repetitions	Multiple repetitions
Series	3 to 4	3 to 4	3 to 4	3 to 4	i) 3 to 4 ii) 3+1+1+1+1+1 iii) 1+1+1+1+1+1	i) 1 ii) 1	1 to 2
Repetitions	Maximum	4 to 6	6 to 8	6 to 8	i) 4 to 6 ii) 2+3+1+3+1+3 iii) 3+2+2+2+1+3[c]	i) 1 ii) 2 to 3[e]	1 to 2
Load (%)	75[a]	85[b]	85	90	i) 70 ii) 90+50+90+50+80+40 iii) 85+60+90+40+80+40	i) additional load on the body up to 103 ii) 85 to 95[d]	- body weight - additional loads
Rest	90 s	120 s	180 s	180 s	i) 120 s ii) 180 s to 240 s iii) 180 s to 240 s	180 s to 300 s	180 s to 300 s

Legend: a=load referring to the last test of the previous year, b=load referring to the new test of the current year, c=at the end of high loads performs isometric of 2-3 seconds, d= Weight work only 2 x per week, e= isometrics of 3 seconds at the end of each exercise.

Table 5
Distribution of technical preparation in the training blocks.

	BLOCK A			BLOCK B			BLOCK C
Day	**ME A1**	**ME A2**	**A Regenerative**	**ME B1**	**ME B2**	**B Regenerative**	**ME C1**
Monday	Hirondelle, ESG, Elevation, Inverted Cross			Hirondelle, ESG, Elevation, Inverted Cross	Hirondelle, ESG, Inverted Cross Azarian, Dorsal legs, Cross	Hirondelle, ESG, Elevation, Inverted Cross	Rest
Tuesday	Specific: cross with rubber and in the cart, Hirondelle in the cart and sequence in the rings with pulleys			Specific: cross with rubber and in the cart, Hirondelle in the cart and sequence in the rings with pulleys			*
Wednesday	Azarian, Triceps, Dorsal Leg and Cross.			Azarian, Triceps, Dorsal Leg and Cross.	Elevation, Azarian, Triceps, Dorsal Leg and Cross.	Azarian, Triceps, Dorsal Leg and Cross.	*
Thursday	Specifics: Hirondelle and extended ascent in the parallel bars, inverted cross on the cart and sequence in the rubber rings			Specifics: Hirondelle and extended ascent in the parallel bars, inverted cross on the cart and sequence in the rubber rings			*
Friday	Elevation, Inverted Cross, ESG, Hirondelle.			Elevation, Inverted Cross, ESG, Hirondelle.	Triceps, Elevation, Inverted Cross, ESG, Hirondelle.	Elevation, Inverted Cross, ESG, Hirondelle.	*
Saturday	Cross, Triceps, Dorsal Leg, Azarian.			Cross, Triceps, Dorsal Leg, Azarian.	Varied Specifics from 3rd to 5th	Cross, Triceps, Dorsal Leg, Azarian.	*
Official Apparatus	- new elements - maintenance and improvement of the elements already acquired.	- linking elements and sequences - new elements - combinations.	- 3part routines - new combinations of technical elements	- 2-part routines - sequences and combinations of technical elements	- full routines - new combinations of technical elements	- full routines - new combinations of technical elements	- full routines - combinations

*Legend: MS= Micro Stage, ESG= erector spinae group *= Test Specific Test Exercises.*

The organization of training in blocks (Verkhoshansky, 1990) is based on the premise that high performance athletes have an extremely high level of special preparation and that the use of complex and non-specific loads may cause negative changes in physiological functions. Thus, when high performance athletes have their competitive capacity increased, training conditions must simulate the competitive demands (Verkhoshansky, 1990).

In Table 3, the disposition of a higher loads volume is aimed at training localized anaerobic muscular endurance and maximum strength. In Block A it is justified by the need to create a solid muscular and joints structural basis with the purpose of ensuring a simultaneous development of specific loads with technical quality. The duration of Block A was between six and 12 weeks, the same as Block B (Issurin, 2016).

Block C with 12 weeks seems long, which allows us to speculate about stabilization or adaptation to this training block. The competitive period is characterized by the high volume of competitive loads, that is, where the main competitions of the year are concentrated (Platonov, 2008). Thus, this period is characterized by a noticeable decrease in volume and a considerable increase in intensity combined with complete rests (Platonov, 2008). However, when considering the number of competitions in this block, it contributes to the destabilization of the training routine (Kraemer & Ratamess, 2004). Competitions, especially international ones, involve trips of approximately 24 hours due to the distance from Brazil to the competition venues, as well as acclimatization to another time zone and adaptation to a different training and competition environment, another gymnasium and apparatuses.

In Table 4, for considerable improvement in the sport, it is necessary to create a "power reserve" of the locomotor potential, that is, the development of motor skills to a desirable level to perform new motor tasks. This ensures that new movements can be learned within the limits of the locomotor potential (Siff & Verkhoshansky, 2004). Thus, to improve the gymnast's performance, it was necessary to develop his strength capacity to levels that would allow him to improve the execution technique and to include some element of higher difficulty.

Regarding Table 5, the routine presented at the Olympics was already outlined from the beginning of the periodization planning. In the World Championships held the previous year, the coach observed that the best gymnasts scored 6.8 points for Difficulty on rings. Thus, the new objective was to adjust the Brazilian gymnast’s Difficulty score by replacing some technical elements for others of higher difficulty. This is an example of annual planning in AG (Arkaev & Suchilin, 2004; Smolevskiy & Gaverdovskiy, 1996).

A noteworthy point of this tactical strategy was the coach’s visualization about the gymnast characteristics, that is, his condition and needs, weaknesses and strengths.

This anticipated planning provided the physical-technical basis to fulfill the sequence of technical elements with quality execution, and allowed the goal to be reached, with higher difficulty and thus routine value. Currently, the value of execution penalties influences how coaches compose the routines, which is determined by the relation between the highest difficulties a gymnast can perform over the lowest penalty (Carrara & Mochizuki, 2011).

The gymnast’s technical ability is measured by competition results, in addition to control test results in the technical preparation (Gomes, 2009). To measure the competitive performance, the difficulty and execution scores during the competitions in the macrocycle were used (Smolevskiy & Gaverdovskiy, 1996). When comparing the scores of the first competition of the year - 15.533 (6.5 of difficulty plus 9.033 of execution) and the Olympic final - 15.900 (6.8 of difficulty plus 9.100 of execution), we have an increase in both the Difficulty score and the Execution score, which indicate that the planning using the MAG performance parameters at the Olympic level was appropriate.

The investigations aimed to intensify the training process have suggested that competitive activity should be simulated under training conditions (Verkhoshansky, 1990). Thus, the use of the means of special physical preparation on a large scale is indicated to ensure that similar stimuli to those found in competitions contribute to the simultaneous resolution of tasks related to technical, tactical, physical and psychological aspects (Verkhoshansky, 1990).

The concentrated loads training strategy is suitable for sports that require one main fitness component, or are based on some targeted abilities (Issurin, 2016). It was well adapted to the present work for the rings event in MAG, with similar movements among the ten valid skills.

In the pre-competitive stage B1, the gymnast was already prepared to present the routine with higher difficulty, but the coach understood that it would be better to present it at the end of the B2 stage, to maintain the quality of the presentation, seen by the execution score identical to the first competition of the year with lower difficulty.

The goal of the Brazilian gymnast was to win one of the first three places in all competitions in the year of the Olympic Games. At the World Cup in Cottbus, the gymnast qualified in the first place with a difference of 0.10 points over the second place, won by the Chinese gymnast. However, the Brazilian coach chose not to compete with new routines with 6.8 points Difficulty score, so that the Chinese gymnast would not have enough time to overcome it for the Olympics. Thus, in this World Cup final, the Brazilian gymnast lost the first place to the Chinese gymnast by 0.10 points. This was the only competition before the Olympics in which they faced each other. This is an interesting point as it is crucial to know how to apply information assertively to the individuality and specificity of the athlete and the objective that is being sought.

Therefore, to accomplish the Olympic result, the participation of the Brazilian gymnast was planned technically and tactically, so he would get to the podium and be seen by the judges as a potential champion in the Olympic Games. For this reason, all coaches should be concerned with defining long-term objectives in competitive sports, to establish and facilitate long and realistic sports career plans with training conditions adapted to the characteristics of their gymnasts (Araújo, 1998).

After this Cup in Cottbus, the Brazilian gymnast began to compete with a new routine with 6.8 points difficulty. The first test was a meeting in Brazil. There were still three more World Cup stages before the Olympics, and the goal in this phase was to win these events. In addition, the gymnast who wins familiarises himself with being on the podium, and this would induce his desire to focus on training and keep him motivated to continue this cycle (Nunomura, Okade, & Carrara, 2012).

The strategy at the Olympics was to compete in the qualifying competition with a difficulty score of 6.5 points, which placed the Brazilian gymnast in the fourth place. This was planned so that in the draw for the finals the gymnast would not qualify in the first place. If this happened, he would be the first to perform in the finals and would be a reference for other finalists. This situation would not be favourable, because the next gymnasts could try to raise the value of their routines to overcome the Brazilian gymnast.

The coaches observed that there was usually constancy in the deduction for execution errors from the qualifying to the final phase in the rings event in former Olympics editions. This was also expected for the Brazilian gymnast, due to little variability in the execution of technical elements, which is typical at this high-level (Carrara, Amadio, Serrão, Irwin, & Mochizuki, 2016). Thus, by raising the difficulty score to 6.8 points, his final score would also increase proportionally, and would lead to the coach and gymnast becoming champions. After testing combinations of technical elements during all the Blocks of the macrocycle, it is important to point out that it is a must for the coach to know the Code of Points in depth, and to use this knowledge for the benefit of his gymnast.

In summary, the Block periodization would have greater effectiveness in the development of maximum and fast strength compared to the traditional periodization system for the upper limbs, but not for the lower limbs (Bartolomei et al., 2014), in which the weekly undulating model would be more effective (Bartolomei, Stout, Fukuda, Hoffman, & Merni, 2015). Therefore, studies are needed to verify the applicability of this Block periodization in other MAG events, such as in floor exercises, where the demand for strength in the lower limbs is predominant for the execution of technical elements (FIG, 2018).

Moreover, the general concept of concentrated loads postulates the selective development of one main skill (strength, in the case of the present work) and is, therefore, basically indicated for sports that demand small numbers of target skills (Issurin, 2010, 2016). Thus, more research on block periodization with other MAG events would be needed, such as preparing generalist gymnasts, i.e., those who compete in all MAG events at a high level and consequently perform a greater number of skills to participate in the six apparatuses.

Given the training principles of biological individuality, specificity, overload, and reversibility, probably every preparation model in MAG should consider adjustments and adaptations to suit each gymnast individually.

CONCLUSION

The division of physical preparation into three Blocks favoured the development of the gymnast, as it allowed for controlling the training in greater detail, as well as by being better adapted to the annual calendar of competitions. The complex system of Blocks used for the MAG contemplated the programming based on the competition calendar, the organization according to the technical elements to be included in the routine of the competition, and control in accordance with the results of the competitions in the macrocycle.

The Block periodization presented in this paper for the high-level gymnast specialized in the rings event contributed to the improvement of competitive performance during the competitions of the macrocycle, through the strategy of raising both the Difficulty and the Execution scores. The practical and detailed application of this model added important knowledge to the limited existing specific literature on the subject, and may support other coaches in the development of their athletes, as long as they consider factors such as the physical condition and the technical level of their athletes, hence, their individuality.

We must also consider that the coach in this study dedicated a lot of time to studies, believed in science, integrated a multidisciplinary team, and relied on the discipline and commitment of the gymnast. These are complementary factors, whether in the scope of the training or not, that need attention for the coach and gymnast to achieve the desired result.

The competitive results obtained lead to the conclusion that the proposed periodization was adequate to provide the optimal physical and technical condition to increase gymnast's competitiveness in the proposed macrocycle.

We conclude that, with the achievement of the Olympic gold medal, this periodization model made it possible to accomplish the goal and the final result of the referred gymnast. However, it would not be possible to affirm that other gymnasts would obtain the same success in the application of the same method, because it would depend on the training conditions available, the gymnast's individuality and the coach himself, and the general support provisions for the whole preparation process.

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AESTHETIC RATIOS OF FLIGHT - HOW OBSERVER EXPERTISE AND AESTHETIC PERCEPTION ARE RELATED TO WEBSTER FREERUNNING SKILL FLIGHT KINEMATICS

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Abstract

The perception of (motion) aesthetics is related to the circumstances of the object, the observer, and the given context. The central question of this study is whether the perception of motion aesthetics is related to a motor skill's ratio of flight kinematics and the observer's sensory-motor experiences. Motor skills, perceived as more aesthetic, are hypothesized to show kinematic flight ratios near the golden ratio. Motor skills, perceived as less aesthetic, are hypothesized to show kinematic flight ratios farther away from the golden ratio. Furthermore, this relationship is hypothesized to be related to the observer's sensory-motor experience. Therefore, 36 participants (12 freerunning experts, 12 freerunning novices, and 12 laypeople) were asked to indicate their perception of motion aesthetics when watching video sequences of different freerunning performances. The results indicate that kinematic flight ratios and the observer's sensory-motor experience are related to the aesthetic perception of the freerunning skill. As hypothesized, kinematic ratios of Webster performances perceived as more aesthetic are closer to the golden ratio, and Webster performances perceived as less aesthetic are farther away from the golden ratio; this is significant for expert and novice freerunners, but not for laypeople. Thus, we conclude that the aesthetic perception of complex motor skills is related to kinematic flight ratios and the observer's sensory-motor expertise. Future work should incorporate such knowledge about kinematic ratios and how to address them during motor skill performances to create and perform aesthetically pleasing complex motor skills.

Keywords: *empirical aesthetics, motion perception, Likert-scale, golden ratio, videography.*

INTRODUCTION

Imagine somebody drawing the properties and ratios of an athlete's complex motor skill performance comparable to the da Vinci's drawing of the Vitruvian Man (cf. Iosa, Morone, & Paolucci, 2018). They illustrate, for example, aspects of the athlete's proportions, aspects of the skills' kinematic proportions in space and time, and each in relation to an observer and a given context. Would drawings of skillful motor skill performances reveal more aesthetically pleasing ratios and proportions compared to drawings of mediocre motor skill performances? And may such drawings be related to an observer's perception of more versus less aesthetically pleasing motor skill performances?

The central question of this study is to address whether the perception of motion aesthetics is related to the (golden) ratio of the flight kinematics of a motor skill and the observer's sensory-motor experiences.

The perception of (motion) aesthetics is related to the specific circumstances of the object, the observer, and the given context (Brielmann & Pelli, 2018; Christensen & Calvo-Merino, 2013; Vinken & Heinen, 2020). Therefore, aspects such as the properties and features of aesthetic objects, the observer's resulting response mechanisms to such objects, and the resulting interplay between the object and the observer in a given context are key topics in the study of (empirical) aesthetics (Brielmann & Pelli, 2018; Chatterjee & Vartanian, 2014; Leder & Nadal, 2014; Pelowski, Markey, Forster, Gerger, & Leder, 2017).

The golden ratio (Livio, 2003) is defined as the ratio of a shorter, minor segment to a longer, major segment, where this ratio is the same as the ratio between the longer segment to the sum of both segments, namely, the short segment plus the long segment (Iosa et al. 2018). Several mathematical and theoretical estimations reveal the number 1.618 as the so-called golden ratio between the shorter minor segment and the longer major segment. This ratio occurs, for example, in mathematical calculations, in historical observations, and in biological and evolutionary appearances (cf. Leonardo da Vinci's Vitruvian Man and the human gait cycle; Brielmann & Pelli, 2018; Iosa et al., 2018).

The question comes to mind whether the aesthetic rules of non-motion objects, such as the golden ratio, are transferable to aesthetically perceived objects in motion. For example, golden ratios are found in (human) anthropometrics (Di Dio, Macaluso, & Rizzolatti, 2007) and human gait (Iosa, De Bartolo, Morone, et al., 2019). The question arises whether those results are transferable to complex whole-body movements where the central aim is not only to achieve efficient and ecological motor performance but also to perform the motor skill so that it is perceived as skillful and aesthetic. For instance, motor skills perceived as more aesthetic may result from kinematic ratios closer to the golden ratio, whereas motor skills perceived as less aesthetic may result from kinematic ratios farther away from the golden ratio.

Research on (empirical) aesthetics either focuses on biological or nonbiological objects observed as either static or moving stimuli. For example, when observing static graphic patterns varying in complexity, symmetry, and familiarity, it is argued that symmetry and complexity are related to the observer's aesthetic perception. At the same time, familiarization with such stimuli seems to decrease the observer's aesthetic perception (Tinio & Leder, 2009). For example, static stick-figures and polygons derived from original ballet dance postures are perceived as more aesthetic by naïve dance observers when they are more vertical (Daprati, Iosa, & Haggard, 2009).

Interestingly, when trained dance teachers (Torrents, Castañer, Reverter, Morey, & Jofre, 2015), as well as naïve dance observers (Torrents, Castañer, Jofre, Morey, & Reverter, 2013), were asked to aesthetically judge stick-figure sequences of original dance skills, the authors found that specific, skill-dependent kinematic parameters were related to the observer's aesthetic perception. While dance teachers and naïve dance observers related similar kinematic parameters to the aesthetic perception of dance skills, experienced dance observers' aesthetic perception was related to more differentiated kinematic parameters (Torrents et al., 2013; Torrents et al., 2015). Consequently, we argue that research on the aesthetic perception of biological motion stimuli has to address the observer's sensory-motor experience to such stimuli observations, as well as the stimuli's properties, thus aiming to investigate the fundamental, motion-related aesthetics (Christensen & Calvo-Merino, 2013; Kirsch, Urgesi, & Cross, 2016; Orgs, Calvo-Merino, & Cross, 2018). However, such aesthetic fundamentals are less widely studied in moving biological stimuli, such as video sequences of original complex motor skill performances.

The following temporal and spatial - directly measurable or derived - parameters were found to be related to a motor stimuli's aesthetic perception: acceleration, amplitude, (body) angles, duration, frequency, height, jerk, length, position, smoothness, speed, symmetry, timing/rhythm, and (turning) velocity (Bronner & Shippen, 2015; Daprati et al., 2009; Orlandi, Cross, & Orgs, 2020; Zamparo, Carrara, & Cesari, 2017; Torrents et al., 2013). For example, dance sequences performed with uniform movement timing are perceived as less aesthetically pleasing than those performed with varied movement timing (Orlandi et al., 2020). Additionally, larger elevation angles of the gesture leg in dance poses (Daprati et al., 2009), greater motion smoothness of specific ballet skills (Bronner & Shippen, 2015), and larger amplitudes in specific dance skills (Torrents et al., 2013) are positively related to the aesthetic perception of motor skill performances. However, such parameters are hard to compare in different motion stimuli and thus partly inhibit the derivation of overall aesthetic features, which may boost and increase the aesthetic perception of a motion stimulus.

In dance and the performing arts, aesthetic features such as an extreme degree of flexibility, elongation of the limbs, and extreme turn-out positions are summarized to increase aesthetic motion perception (Christensen & Calo-Merino, 2013). Furthermore, smooth and fluent dance moves are preferred aesthetically (Orgs et al., 2018). However, it remains open which kinematic parameters describe such smooth and fluent (dance) moves and how, for example, different ratios between such parameters drive aesthetic motion perception. On the other hand, complex motor skill performances are based upon and restricted to the laws of physics. For example, motor skills containing a flight phase must be performed in specific variations of kinematic parameters (Schmidt, Lee, Winstein, Wulf, & Zelaznik, 2018). However, (expert) performers can use kinematic and perceptual possibilities, as well as the constraints of their motor skill performance, to their full potential. This could, for example, be achieved by increasing flight height at the cost of flight width or vice-versa. It is thus of special interest whether one or the other, and their resulting kinematic ratios, are related to an observer's aesthetic perception of motor skill performance.

In sport and human movement science, researchers and practitioners aim to find, address, and train kinematic properties to optimize movement quality, performance outcome, and motor economy (Schmidt et al., 2018). In technical and aesthetic sports, this is of additional importance, especially when motor skill performances are estimated, judged, and perceived by an observing audience (Bar-Eli, Plessner, & Raab, 2011). In the Code of Points for gymnastics, parkour, and artistic performances (cf. *Laban score* as an estimate of time, space, weight, and flow performance; Newlove & Dalby, 2004), the quality and execution of complex motor skills are determined by observations of, for example, the E-Score as an estimate of execution and artistry of performance (*Fédération Internationale de Gymnastique* [FIG], 2016), or as an estimate of flow, mastery, and amplitude of skill performance (FIG, 2019). However, such codes of points and score systems lack specific kinematic measures, ratios, and calculations but rely on the judge's perceptual abilities when observing and evaluating motor skill performances.

Taken together, the research suggests a relationship between sensory-motor experience and aspects, such as perception, cognition, and action (Gibbs, 2005). Furthermore, a so-called embodied relationship between a person's sensory-motor experience and the perception, cognition, and performance of this person's perception and behavior of motor skills is discussed (Kirsch, Drommelschmidt, & Cross, 2013; Vinken, Stirling, & Heinen, in press). We also suggest that the aesthetic perception of (golden) kinematic ratios may be related to the observer's sensory-motor experiences. Aspects of *knowledge* *meaning*, such as familiarity with the perceived stimuli, are related to the aesthetic perception of observers with different sensory-motor experience (Chatterjee & Vartanian, 2014; Orgs et al., 2018; Pelowski et al., 2017; Tinio & Leder, 2009). However, it remains to be investigated whether the kinematic parameters of motor skill performances rely on golden ratio proportions and whether these ratios could be related to the observer's sensory-motor experience. Addressing this question provides an insight in the question of whether the (golden) kinematic ratios of complex motor skills are related to the aesthetic perception of motor stimuli, in general, or in relationship to observer-specific sensory-motor experiences, in more detail. Furthermore, it should be addressed whether kinematic ratios of complex motor skill performances could be implemented to optimize motor skill performances as being (more) aesthetically relevant and pleasing.

We thus hypothesize that motor skills that are perceived as more aesthetic show kinematic flight ratios near the golden ratio, and the kinematic flight ratios of motor skill performances that are perceived as less aesthetic are farther away from the golden ratio. Furthermore, we hypothesize that this relationship is related to the observers' sensory-motor experience.

METHODS

We recruited N = 36 participants (30 males, five females, one other), and they were assigned to one of three groups: 1) n_{ExpObs} = 12 freerunning experts (24 ± 3 years) with a reported average freerunning experience of 8 ± 2 years, 2) n_{NovObs} = 12 freerunning novices (22 ± 10 years) with a reported average freerunning experience of 2 ± 1 years, and 3) n_{LayObs} = 12 laypeople (28 ± 9 years) who reported having no freerunning experience. Freerunning experience was totaled from leisure, sport, and championship activities. We asked participants to indicate their perception of motion aesthetics when watching video sequences of the Webster freerunning skill.

Additionally, we recruited another sample of N_{Perf} = 7 freerunners (six male, one female; 21 ± 5 years) with the aim of generating stimuli video sequences. These freerunners reported having an average freerunning experience of 6 ± 3 years and a weekly training of 9 ± 5 hours. They were included when they were able to perform and execute the Webster skill successfully, stably (Schmidt et al., 2018), and according to the experimental settings of this study (cf. Fig. 1).

All participants were recruited in Germany, participated voluntarily in this study, and signed an informed consent form prior to the beginning of the study. The study was conducted according to the local university's ethics guidelines.

The procedure to generate stimuli was similar to that followed by Vinken and colleagues (in press). The relevant steps are summarized in this paragraph for the sake of completeness and to be able to replicate this study.

First, video stimuli generation was done by inviting the freerunners of the stimuli sample to perform the Webster skills in the given experimental setting (cf. Fig. 1) and after an individual warm-up phase. We instructed each freerunner to perform variations of the Webster freerunning skill by focusing on different accentuations of flight width, flight height, and body posture(s). After successfully performing the Webster skills and their possible variations, each freerunner was debriefed. Freerunners performed the Webster skills in a prepared area of 10 x 20 meters, and their performances were video-taped. The implemented digital camera (Panasonic Lumix G7) operates at 50 Hz (1920 x 1080 pixels), was positioned ten meters away and orthogonal to take-off and landing area, and recorded each Webster freerunning skill. Sixteen video sequences with sufficient movement quality and without background irritations or emotional expressions were captured from the performing freerunners and transferred into grayscale color to reduce contextual visual biases.

Second, we determined the width of flight and height of flight of each performed Webster skill and calculated a ratio implementing the following equation (cf. Iosa et al., 2018):

Kinematic ratio = 0.5 x width of flight / height of flight

The width of flight and height of flight were determined and measured using video analysis software (*Tracker*, version 5.1.5, 2020). The width of flight was measured as the distance between the freerunner's center of mass position during take-off and the freerunner's center of mass position during landing. Height of flight was measured as the distance between the freerunner's center of mass position during take-off and the freerunner's highest center of mass position during the flight phase. We calculated the freerunner's center of mass during take-off, highest flight position and landing based on a segmental analysis of the human body (Enoka, 2015).

Figure 1 illustrates the determination of the width and height of flight and the resulting calculation of the ratios within an exemplary Webster performance.

We used an online questionnaire (*SoSci Survey*; version 3.0.00, 2018) for the presentation and evaluation of Webster video sequences to measure participants' perception of motion aesthetics when observing video sequences of different Webster performances.

Within the questionnaire, each video sequence was presented randomly and in the middle of the screen. A seven-point Likert-scale labeled "aesthetic" ranging from -3 via 0 to +3 (Palmer, Schloss, & Sammartino, 2013) was positioned below each video sequence. We asked the participants to indicate their individual perception of motion aesthetics of each freerunning skill with the help of the Likert scale. The instruction was "please indicate how aesthetic you perceive the video sequence to be by ticking the number representing your subjective perception. There is no right or wrong answer, and we are interested solely in your individual aesthetic perception". The self-paced survey containing the presentation and evaluation of the video stimuli took approximately ten minutes per participant. There was no instruction of the terms "aesthetics" and "aesthetic(ally)" to leave their meaning solely to the participants and as unbiased as possible (cf. Jacobsen, Buchta, Köhler, & Schröger, 2004).

Sixteen responses were recorded by each observing participant, leading to a total of N = 36 participants x 16 responses = 576 separate values for data analysis.

The study was conducted in the following phases. First, we invited the participants via e-mail and sent them a link to the online questionnaire. When following the invitation link, the participants were informed about the general purpose of this study, had to agree to signing an informed consent form and were asked questions about their freerunning experience. The participants' task was to indicate their perception of motion aesthetics when watching different video sequences of the Webster freerunning skill using a Likert scale. The video sequences of different Webster performances were randomly presented to each participant in the original tempo. The observing participants were instructed to indicate their response spontaneously but without time pressure. After successfully finishing the evaluation of the video sequences, the participants were debriefed and received contact details if they were interested in future studies and research. Second, the answers given by the observing participants were recorded online and used for later data analysis with the help of a spreadsheet and statistical software. Third, we calculated the median splits of the Likert-scale ratings of each observer group (experts, novices, and laypeople) to differentiate Webster performances perceived as more aesthetic from those that were perceived as less aesthetic.

Additionally, we determined the width and height of flight of each Webster performance and calculated the kinematic ratio of each Webster performance with the help of the following formula:

Kinematic ratio = 0.5 x width of flight / height of flight

An *a* = 5% significance level was used for all results reported. Separate two-sample *t*-Tests (Websters perceived as more vs. less aesthetic) were calculated to compare the corresponding means of the Webster ratios for each of the two samples in expert freerunners, novice freerunners, and laypeople. *Cohen's d* was calculated as an effect size for all significant results.

RESULTS

Figure 2 illustrates the means and standard errors of the kinematic ratios of the Webster performances perceived as more vs. less aesthetic by expert freerunners, novice freerunners, and laypeople. In general, the ratios of Webster performances that are perceived as more aesthetic are closer to 1.618 (dashed line), and the ratios of Webster performances that are perceived as less aesthetic are farther away from 1.618 (dashed line). More precisely, expert freerunners perceive Webster performances with a ratio closer to the golden ratio as significantly more aesthetic compared to Webster performances with a ratio farther away from the golden ratio ($t(14) = 2.243$, $p = .021$, *Cohen's d* = 1.121). Furthermore, the relationship between the kinematic ratios and the motion aesthetics of the Webster skills perceived by the novice freerunners revealed the same pattern of results ($t(14) = 1.800$, $p = .047$, *Cohen's d* = 0.900), whereas this was not significant among the laypeople.

The double periodization model was used in the planning with the first macrocycle of 28 weeks between January and July (date of the Olympic Games), divided into three distinct blocks: A (Basic), B (pre-competitive) and C (competitive), but correlated (Siff & Verkhoshansky, 2004; Verkhoshanski, 2001), with the main characteristic of concentrated and distributed loads throughout the training cycle. The worksheet of the first macrocycle is shown in Figure 1; the second macrocycle is not addressed in this study.

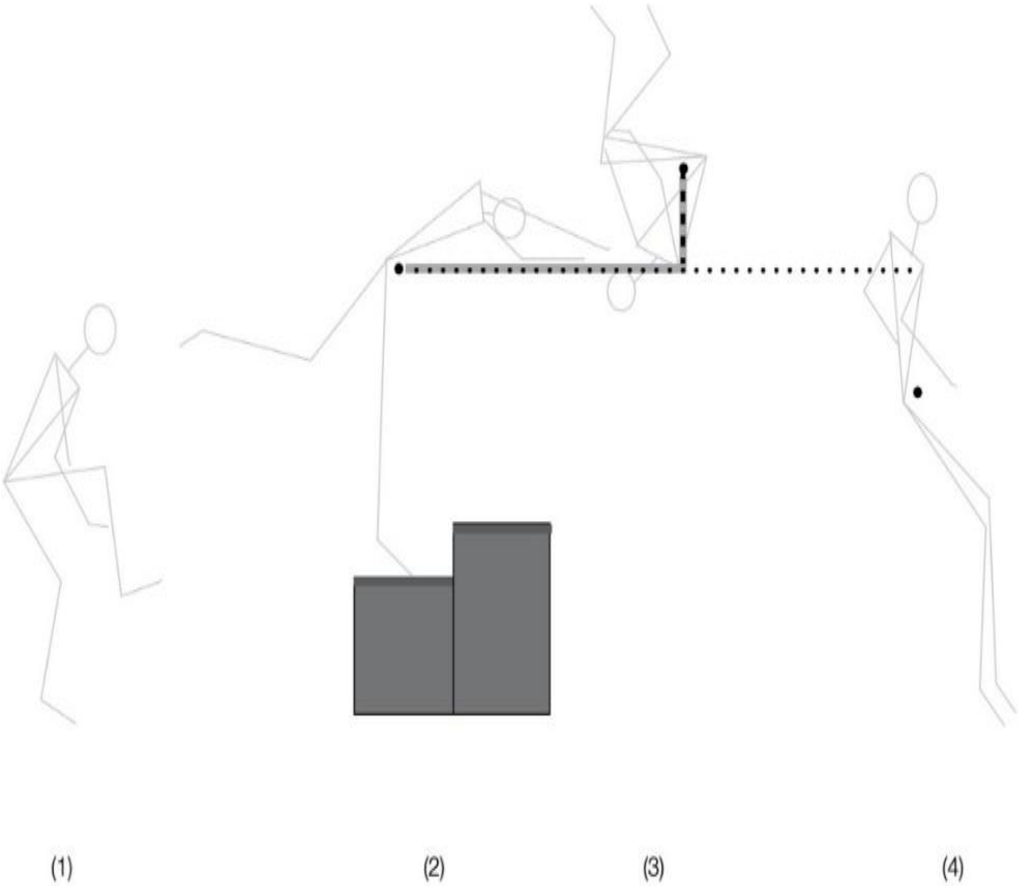

Figure 1. Webster freeerunning skill, performance setup, and calculation of kinematic ratio. Stick-figure sequence of an exemplarily Webster performance illustrating the following four movement phases: (1) approach of the obstacle, (2) take-off, (3) maximum height of flight, and (4) landing, the calculation of width and height of flight, and the calculation of the kinematic ratio.

The black dots represent the performer’s center of mass position during take-off, maximum height of flight, and landing. The dotted line represents the width of flight as the horizontal distance between the center of mass position during take-off and the center of mass position during landing. The dashed line represents the height of flight as the vertical distance between the center of mass position during take-off and the center of mass position during maximum height of flight. The bold, grey line functions as the illustrated indication of the calculated kinematic ratio = 0.5 x width of flight / height of flight.

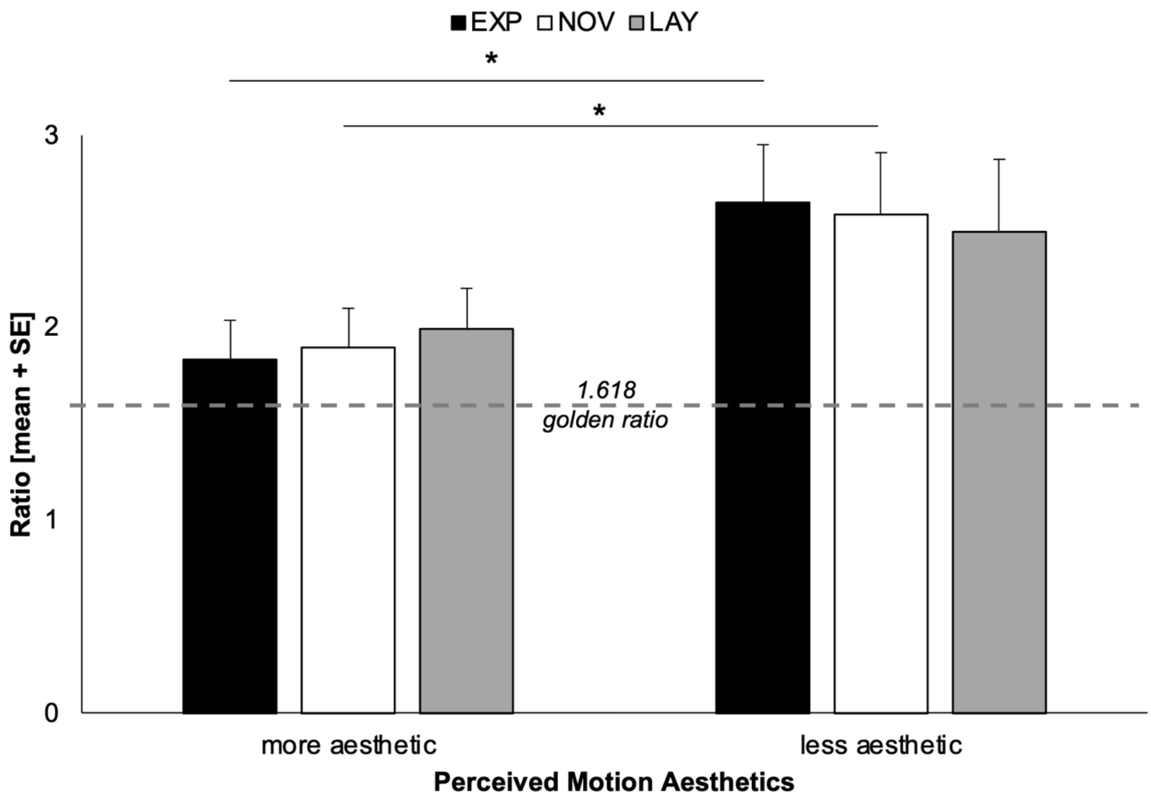

Figure 2. Kinematic ratios of Webster performances and observer's perceived motion aesthetics. Illustration of kinematic ratios of Webster performances perceived as more vs. less aesthetic from expert freerunners, novice freerunners, and laypeople. The dashed grey line indicates the golden ratio of 1.618. * denotes $p \leq 0.5$.

The basic stage (Block A) contained the largest training volume of the entire season. Its objective was to destabilize previous performance levels, aiming to increase strength gains, with greater emphasis on the total volume of repetitions to obtain greater adaptation of the neuromuscular complex to be used (Verkhoshanski, 2001). The central objective was the elevation in the motor potential of the athlete, ensured by a high volume of means and special training methods with emphasis on strength.

The pre-competitive stage (Block B) developed the increase in strength and speed capacity (explosive strength), decreased the volume and increased the intensity of training, to intensify the muscle tension index and activate the neuromuscular system (Verkhoshanski, 2001). Thus, the volume was reduced, and specific loads were accentuated, especially the more intense ones, supported by the foundation created by the morphological and functional changes in the system.

Finally, in the competitive stage (Block C) of the macrocycle, the main objective was training with low volume and greater intensity so that training became more specific to the sport. It was characterized by a greater incidence of competitive loads which aimed to consolidate the athlete's readiness at the highest level and coincided with major competitions.

Figure 2 presents the distribution of the physical preparation variables (means, method, sets, repetitions, load and rest) between the training Blocks. Comparing the variables in the Blocks, an adjustment of values and items from a general training organization to a specific organization of the routine on the apparatus can be observed: a decrease of sets and repetitions, a load increase until close to the maximum relative strength, and a rest increase.

Figure 3 presents the distribution of the technical preparation between the days of the week in accordance with the training Blocks. Comparing the days in each Block, a few modifications in the combination of movements are notable, adapted to the gymnast's individual needs. However, when considering the distribution during the week, there is a variation in the movements and methods. As for the apparatus, there is the construction of the routine to be presented, with the refinement of movements and combinations of technical elements acquired and new combinations, in line with the gymnast's partial results and scoring needs.

DISCUSSION

In this study, we aimed to investigate whether the perception of motion aesthetics is related to the (golden) ratio of flight kinematics of a motor skill. We hypothesized that the motor skills that are perceived as more aesthetic would have kinematic flight ratios closer to the golden ratio, and motor skills that are perceived as less aesthetic to have kinematic flight ratios would be farther away from the golden ratio. Additionally, we hypothesized that this finding would be related to the observers' sensory-motor experience. To calculate the kinematic ratio of the Webster performances, we used the following formula: *Kinematic ratio = 0.5 x width of flight / height of flight.*

As hypothesized, the kinematic ratios of the Webster performances perceived as more aesthetic were closer to the golden ratio (1.618, cf. Iosa et al., 2018; Livio, 2003) and the Webster performances perceived as less aesthetic were farther away from the golden ratio (1.618). Furthermore, expert and novice freerunners perceived the Webster performances with a ratio closer to the golden ratio as significantly more aesthetic than the Webster performances with a ratio farther away from the golden ratio. Laypeople's aesthetic perception was not significantly related to the kinematic ratios of the Webster performances.

Interestingly, the ratio of width and height of flight in the Webster performances is related to the aesthetic perception of those Webster performances, and the Webster performances with kinematic ratios closer to the golden ratio are perceived as being more aesthetic. While this relationship can be observed in all three observer groups, it is significant for expert and novice freerunning observers, and is not significant in laypeople. Therefore, the observer's sensory-motor experience seems to be related to the kinematic and aesthetic perception of complex motor skills, such as the Webster freerunning skill. In complex motor skills, where a flight phase with or without a salto or twist rotation is performed, flight kinematics are restricted to the laws of physics, and variations in those flight phases require the athlete's ability and expertise to vary skill performance while still achieving sufficient technical, secure, and high-quality performance. A *golden* kinematic ratio of width and height of flight during Webster performances either requires increased width of flight at the cost of height of flight, or increased height of flight at the cost of width of flight. A technical requirement that can only be addressed when considering the laws of physics and mechanics (Schmidt et al., 2018). For example, an increased width of flight requires a given amount of height of flight. Future studies may address and expand our finding in such a way that mathematical calculations and manipulations of a motor skill's flight kinematics are performed and then again related to the observer's perception of motion aesthetics to investigate aesthetically optimized flight kinematics within a given complex motor skill.

Previous research has revealed golden ratios in sculpture proportions, gait kinematics, and locomotor skills (Di Dio et al., 2007; Iosa et al., 2019). The results of our study now add that such golden kinematic ratios can also be found in complex motor skills requiring a flight phase, such as the Webster freerunning skill. We thus expect similar findings for motor skill performances that are technically and mechanically similar to Webster skills. We suggest, for example, that salto performances in artistic gymnastic routines or *grand jeté* jumps performed in classical ballet will be perceived as more aesthetically pleasing for observers, judges, and the audience when having flight kinematics of width and height of flight that are closer to the golden ratio and thus fulfill technical, qualitative, and aesthetically pleasing requirements.

In addition, the results of our study confirm that complex motor skills, such as the Webster freerunning skills, are perceived as being more aesthetic when possessing kinematic flight ratios closer to the golden ratio and that this finding is especially true when experienced observers aesthetically perceive and estimate complex motor skills. We suggest that naïve observers may already be aesthetically impressed by the complexity of the motor skill performance per se (cf. *which* movements are performed matters, Orlandi et al., 2020). In contrast, experienced observers may value the art of complexity, ability, and quality of motor skill performance (cf. *how* movements are performed matters, Orlandi et al., 2020). Taken together, when aiming to aesthetically impress experienced observers, the art of motor skill performance seems to aesthetically impress more when kinematic flight ratios are closer to the golden ratio.

However, when interpreting the results of our study, the following three limitations should be considered. First, we assessed the kinematic ratios and observers' aesthetic perception of the Webster freerunning skill on the basis of original video stimuli of experienced freerunning performers. Whether motor skill performances at different levels of expertise, ratios with different kinematic parameters, or different motor stimuli would reveal comparable results should be investigated further. Furthermore, we propose that the results of our study are transferable to other motor skills that include a flight phase and similar technical and mechanical structures (cf. closed skills with take-off phase, flight phase with or without a salto and twist rotation, landing phase; Schmidt et al., 2018) such as the Webster freerunning skill.

Second, we assessed the original stimuli of the freerunning motor skill performances. Future studies should investigate whether, for example, the manipulation of kinematic parameters within artificial or designed motor stimuli would reveal similar results. Additionally, one may derive suggestions about which direction the observer's aesthetic perception can be shifted in terms of over- or underachieving kinematic golden ratios within complex motor skill performances, for instance, by implementing eye-tracking methodologies.

Third, we behaviorally assessed the aesthetic perception of observers with different sensory-motor experiences in freerunning and calculated the kinematic parameters of flight width and height based upon videography. This was done to capture observers' perceptions of motion aesthetics as unbiased, natural, and economic as possible (Jacobsen et al., 2004; Palmer et al., 2013; Schmidt et al., 2018). However, additional parameters that can be assessed and potentially be related to the aesthetics of a motor skill performance are, for example, performers' rates of exhaustion and/or satisfaction during a motor skill performance, as well as the (golden) ratios of the contextual circumstances within a motor skill performance, such as body proportions, ornamentations, and configuration of the performing scenery. Finally, the sociocultural influences within the observer groups and contexts may be worth investigating.

The practical implications our study can reveal for coaches and practitioners are how and why to optimize the width and height of flight when aiming to perform Webster skills that are aesthetically pleasing. Therefore, given the formula mentioned above, the freerunner should be instructed to perform the aesthetically pleasing Webster skill by achieving a width of flight that is close to three times the height of the flight (1.618 = 0.5 x width of flight / height of flight ⇔ 3.236 x height of flight = width of flight). The practical implications for researchers in empirical aesthetics as well as in sport and human movement science are that the observer's sensory-motor experience is related to the perception of motion aesthetics and motor performance. Therefore, the technical and kinematic properties of motor stimuli are related to the subjective aesthetic perception of such motor skills and can be objectified and calculated.

CONCLUSION

Kinematic flight ratios of a complex motor stimulus seem to be related to the observer's aesthetic perception. When perceiving and evaluating the aesthetic perception of different variations of a freerunning skill, namely, the Webster skill, expert freerunners, novice freerunners, and laypeople differ in their aesthetic perception of motor skills with different kinematic flight ratios. We suggest that naïve observers may already be aesthetically impressed by the complexity of the motor skill performance per se, whereas (more) experienced observers may value the art of complexity, ability, and quality of motor skill performance. Thus, we conclude that when aiming to create and perform complex motor skills that should aesthetically impress an audience, this is more challenging when creating and performing for a (more) experienced audience. Furthermore, knowledge about kinematic ratios and how to address them during motor skill performances may help researchers, practitioners, and choreographers create aesthetically pleasing complex motor skills and stimuli. Future studies should investigate whether this is transferrable to different motor stimuli, different observer groups, and different contexts in which aesthetic motion perception occurs, thus providing fruitful and promising outcomes, especially when researchers and practitioners join their aesthetic perceptions and experiences.

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THE INFLUENCE OF STRENGTH ON THE GYMNASTS' SUCCESS IN PERFORMING VAULT

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Abstract

The aim of the study was to determine the influence of absolute and relative strength of the muscles of the legs, upper arms and shoulder girdle on the success of performing vault with gymnasts aged 13 to 16 who have been training gymnastics from five to 12 years. The Japanese digital dynamometer IMADAZ2H-1100 with WinWedge 3.4 software was used to estimate the absolute strength of the leg, upper arm and shoulder girdle muscles. The values shown on the digital meter represented the absolute value of the maximum force, and when the absolute value of the force was divided by the weight of the participant, the value of the relative force was obtained. Regression analysis was used to determine the influence of absolute and relative strength of leg muscles, upper arm and shoulder girdle on the success of performing vault. The results showed that although there is an influence of the above muscles, it is not statistically significant. Specifically, for a successful performance on the vault, the muscles of the shoulder girdle have the greatest influence (without statistical significance). The reason for the results obtained in this way lies in the fact that the phase of flight and landing depends on the support phase and the repulsion from the vault. As there are few research studies on the subject of this paper, regardless of the obtained results, this research represents a good foundation and basis for some future research of absolute and relative strength in artistic gymnastics.

Keywords: *vault, gymnasts, absolute strength, relative stregnth.*

INTRODUCTION

In addition to swimming and athletics, artistic gymnastics is one of the basic sports and represents a type of sports competition that reaches the highest level of artistic achievement (Petkovic, Velickovic, Petkovic, Hadzi – Ilic, i Mekic, 2013). Under the generic name "gymnastics", FIG (Federation International Gymnastics) with regulations regulate a large part of activities based on training, education and activities that will emphasize the physical and mental characteristics of the athlete regardless of race, religion, age, his or her social status.

Due to the existence of several types of gymnastics, gymnastics today must be used with a prefix in order for the term to be clearly defined (Petkovic, 2011). "Under artistic gymnastics, the widest audience experiences sports, conceptually defined as a competitive discipline, with polystructural content (exercises are performed in all three planes of movement and around all three axes of rotation) of acyclic type and strictly defined rules as a convention in practice". These exercises are usually performed in anaerobic conditions, with the aim of showing the form of movement and making a visual impression (Petkovic, Velickovic, Petkovic, Hadzi – Ilic, i Mekic, 2013, pg. 12).

The vault, present in both men and women gymnastics, is one of the more attractive apparatuses. Gymnasts start vaulting from a calm position, with their legs joined at a maximum distance of 25 meters from the apparatus, where the first step or jump is counted as the beginning of performing a vault. It consists of two phases: the first phase is the flight from the springboard to the support on the vault, and the second phase includes the flight phase, from pushing from the vault to landing on both feet (FIG, 2017). The gymnast is obliged to perform one vault. But in qualifications for finals and in the finals on the vault, two vaults are performed from two different groups and with a different second phase of the flight. Each vault can have one or more rotations around both axes of the body, or it can be performed without rotation (Petkovic, Velickovic, Petkovic, Hadzi – Ilic, i Mekic, 2013).

There are a number of definitions of motor abilities. Findak (1999) and Prskalo (2004) similarly defined motor abilities as latent motor structures responsible for an infinite number of manifest reactions, which can be measured and described. Milanovic (2009) defined motor abilities as the ability of the body to realise all types of movements. Malacko and Popovic (2001, pg. 26) state that "motor abilities are latent, they cannot be measured directly but indirectly, which means that only motor reactions, i.e., manifestations of different units of measurement, can be measured directly". Milanovic (2009) states that according to Meinel (1977), it is a complex structure of quantitative (strength, speed, endurance, flexibility) and qualitative (coordination, agility, balance and precision) motor abilities (Badric, Sporis, Trklja, and Petrovic, 2012).

Most experts (Kurelic et al., 1975; Kukolj, Jovanovic, and Rupert, 1992; Nicin and Kalajdzic 1996) agree that in the latent space of basic motor abilities, the following features stand out:

- strength,
- coordination,
- endurance,
- speed,
- flexibility,
- balance, and
- precision.

Many authors have tried to define strength in the most adequate way by using different starting points. Thus, Opavski (1971, p. 169) identifies strength with force and says that "force is the ability to transform muscular tension in the composition of motor units into a kinetic or potential form of mechanical energy". In anthropomotorics, the term strength is defined as a human trait, i.e., its ability to overcome some external resistance or to oppose it with the help of muscular strains (Nicin, 2000). Strength represents the work of muscles in a unit of time against the force of gravity in overcoming the resistance offered by muscle contraction (Ugarkovic, 2004). Stone (1993) and Sif (2001) defined muscular strength as the ability to exert force on an external object or resistance. The most common criterion for classifying motor ability strength is the ratio of the magnitude of the force exerted to the mass of the body. It can be isolated on this basis of:

- absolute strength (maximum muscle strength that a person can develop with his/her overall muscle mass), and
- relative strength (amount of strength that a person can develop per kilogram of his/her weight) (Stojiljkovic, 2003).

The aim of the study was to determine the influence of absolute and relative strength of the muscles of the legs, upper arms and shoulder girdle on the success of performing vault in gymnasts aged 13 to 16 years.

In previous research studies related to vault, the authors have examined a variety of variables. Scharer, Lehmann, Naundorf, Taube & Hubner (2019) examined the relationships between run-up speed; the degree of difficulty (D-score); height and length of flight on the vault in artistic gymnastics for handspring; Tsukahara and Yurchenko-style vaults, and compared the performances of male and female elite and junior athletes during the 2016 European Championships. The results showed that for females, the run-up velocity correlated significantly with the difficulty (D) score and the height of flight for all vaulting styles ($r \leq 0.80$). In males, the run-up velocity correlated significantly with the D-score, height and length of flight of Tsukahara ($r \leq 0.69$) and Yurchenko vaults only ($r \leq 0.65$). Males reached 8–9% higher run-up velocity performing handspring and Tsukahara vaults than females, but similar run-up velocity performing Yurchenko vaults. Both male and female elite gymnasts achieved higher run-up speeds than junior gymnasts. The authors concluded that the knowledge of the required run-up velocity for each vault helps coaches to estimate each athlete's potential and/or to focus the training on developing the required physical qualities. A similar group of authors (Scharer, Haller, Taube & Hubner 2019) examined "Physical determinants of vault performance and their age-related differences across male junior and elite top-level gymnasts" with the aim to: 1) investigate interrelations between difficulty value (D-score) and run-up kinematics of handspring/Tsukahara and Yurchenko vaults as well as lower body power (25m-sprint, explosive and reactive strength) and 2) to explore age-related differences of these parameters across junior and elite gymnasts performing handspring/Tsukahara vaults. On a sample of 47 top-level male elite and junior gymnasts aged 14.3 to 28.3, results showed that D-scores for handspring/Tsukahara ($n = 33$) were strongly correlated with the run-up speed. There were no significant relationships with the D-score for Yurchenko ($n = 14$). Looking at the age-related differences for handspring/Tsukahara, D-scores increased significantly from the junior to the elite level (+11.6%; $p < 0.01$). The comparison between consecutive age groups revealed that the U19 group had higher run-up speeds, step lengths, body weights and heights than the U17 group, while the U21 group achieved significantly higher speeds (run-up, 25m-sprint) and explosive strength than the U19 group. They concluded that 1) the optimization of important physical determinants may increase the potential to perform more difficult handspring/Tsukahara vaults, and 2) first growth and maturation and later improvements of lower body power led to higher run-up speeds for handspring/Tsukahara in the subsequent age-group. Atiković, Kazazović, Kamanješavić and Nožinović-Mujanović (2019) examined the correlation of biomechanical parameters and the vault start value in men's artistic gymnastics. Tha aim of their research was to determine the correlation between the vault start value and the run-up velocity, the first flight phase, the table support, and the second flight phase. In the correlation matrix, the criteria variables from the Code of Points FIG MAG (2017-2020) effected a statistically significant postive correlation with two variables: run-up velocity on springboard and the second flight phase, but a negative correlation with two other variables, i.e., the first flight phase and vault support. The authors concluded that there were no differences in the values in relation to the two cycle Code of Points. Hwang, Kim, Choi and Choi (2020) dealt with "Dynamic modelling for the second flight phase of the Yurchenko layout vault based on msc. Adams". They used *a 3D* angle-driven computer simulation model of a gymnast who performs the Yurchenko layout vault using ADAMS software. Their results showed that increasing the initial horizontal velocity resulted in an increased horizontal flight distance, but had no connection with the duration of the flight and the angle of twists. The overall angle of twists is concerned with initial vertical velocity and angular velocities about the transversal and longitudinal axes. Also, increasing the initial vertical velocity and angular velocity about the transverse axis leads to an increase in the touchdown angle between the ground's horizontal axis and the gymnast's longitudinal axis.

In previous studies related to the strength in artistic gymnastics, authors have examined a variety of variables on a sample of respondents of different ages. The aim of the research of Kochanowicz et. all (2018) was to demonstrate the differences between non-athletes and gymnasts in the development of peak torque (PKTQ) in the pre- and post-pubertal age. They also examined the flexion/extension ratios at the elbow and the glenohumeral joints, as well as the relevance of the above activities for the co-activation of selected muscles. On a sample of 20 gymnasts and 20 non-athletes aged 8-9 years, in addition to 12 gymnasts and 16 non-athletes aged 18-25 years, the results showed that in the group of older gymnasts the PKTQ ratio of the glenohumeral flexors to extensors was the lowest (0.72) and was significantly different from the other groups. This result was consistent with the 30% higher PKTQ values ($P<0.01$) of the glenohumeral extensors and a 41% reduction in their EMG in flexion in comparison to non-athletes. Scharer et. all (2021) examined "Maximum strength benchmarks for difficult static elements on rings in male elite gymnastics". Subjects performed a concentric (1RM isoinertial) and eccentric (isokinetic: 0.1 m/s) conditioning strength test for the swallow/support scale (supine position) and inverted cross (seated position) on a computer-controlled device and a maximum strength test maintaining these elements for 5s on the rings with counterweight or additional weight. Results showed high correlation coefficients between the conditioning maximum strength for the swallow/support scale (r: 0.65 to 0.92; $p < 0.05$) and inverted cross (r: 0.62 to 0.69; $p > 0.05$) and maximum strength for the elements on the rings. Strength benchmarks varied between 56.66% (inverted cross concentric) and 94.10% (swallow eccentric) of body weight. They concluded that differences in biomechanical characteristics and technical requirements of strength elements on rings may (inter alia) explain the differences between correlations. Dallas, Kirialanis, Dallas and Mellos (2017) dealt with effects of training maximal isometric strength on young gymnasts. Subjects (57 gymnasts and 74 non-gymnasts) were tested for isometric strength during force flexion and extension of the upper and lower limbs during a 5-second maximal voluntary isometric strength test for the right and the left side respectively. The results showed significant differences between gymnasts and non-gymnasts ($p<.05$). Further, significant interaction revealed: a) for the right side with respect to the force flexion at the elbow and shoulder joints; b) for the left side with respect to the force flexion for the elbow, shoulder and hip joint, c) with respect to the force extension of the right side for the elbow, shoulder, hip and knee joints, d) for the extension of the left side for elbow, shoulder, and hip joints. In conclusion they indicated that such results should be considered by trainers seeking to improve the strength and overall training level of their athletes. Čeklić and Šarabon (2021) conducted a research study aiming to determine the differences in hip, knee, and ankle strength between female gymnasts and non-gymnasts, and secondly, to determine the effect of strength training interventions. Over the period of 8 weeks, the participants underwent 5 weeks of regular training and 3 weeks of targeted strength training intervention. After eight weeks, they were retested. It was found that there were significant differences between the two groups in the most observed hip strength parameters, but not in the knee and ankle strength. The intervention did not significantly affect any parameters of ILAs. Gymnasts and non-gymnasts differ in hip strength parameters. In conclusion, the authors stated that a longer intervention program might decrease the ILA parameters. Qomarrullah, Kristiyanto, Sugiharto and Hidayatullah (2018) examined the dominant factors of physical ability determining the achievement of artistic gymnastic techniques on the vault. The aim of the study was to analyze the relationship between the physical ability factor of running speed, the strength of leg muscle, arm muscle, abdominal muscle, and balance in the vault technique. The results showed that the speed and the running factor had no significant influence; while the leg muscle strength, the arm muscle strength, and the abdominal muscle strength had a significant effect. The most dominant factor of physical ability in the vault technique is the leg muscle strength, while the influence of the running speed is the lowest.

METHODS

The sample of respondents included 29 gymnasts (Table 1) from eight countries participating in the international tournament "Laza Krstic and Marica Dzelatovic" in Novi Sad, aged 13 to 16, who have practiced gymnastics from five to 12 years. The research was approved by the Ethics Committee of the Faculty of Sports and Physical Education, University of Nis, and was conducted in accordance with the Declaration of Helsinki (World Medical Association 2013).

The Japanese digital dynamometer IMADAZ2H-1100 with WinWedge 3.4 software was used to estimate the absolute strength of the leg, upper arm and shoulder girdle muscles. The values displayed on the digital meter represented the absolute value of the maximum force. When the absolute value of the force was divided by the weight of the participants, the value of the relative force was obtained. A scale (Gorenje) was used to estimate body weight and the results were recorded in kilograms (kg).

Table 1
Sample of respondents.

	Age	Training internship	Body weight
MIN	13	5	31
MAX	16	12	64
Mean	14.62	8.14	47.25

The measurement of the absolute force of the leg, upper arm and shoulder girdle muscles was performed immediately before the competition, so that it did not affect the outcome of the competition. To estimate the maximum force, the following features were measured: the maximum force of the leg extensors, the maximum force of the flexor muscles of the upper arm and the maximum force of the shoulder girdle muscles. The results (final score on vault) from the international tournament "Laza Krstic and Marica Dzelatovic" were used as an indicator of the success in performing vault.

To measure the maximum force of the leg extensors, the subject holds a dynamometer behind and below the back, with the knees in slight flexion and the feet spaced hip-width apart (Figure 1). The chain connecting the stand to the digital force meter is fully tightened. The subject pulls the dynamometer from the starting position with evenly extended arms with the strength of the extensor muscles of the lower extremities, during which he performs the movement of the extension in the knee joint. The result is measured in Newtons (N).

*Figure 1.*Leg extensors measurement.

To measure the maximum force of the upper arm muscles, the subject holds a dynamometer in front of him with a flexion in the elbow joint of 90 degrees (Figure 2). The feet are hip-width apart and the chain connecting the stand to the digital force meter is fully tightened. The subject pulls the dynamometer from the initial position evenly with both hands with the strength of the flexor muscles of the upper arm, during which he performs the movement of flexion in the elbow joint. The result is measured in Newtons (N).

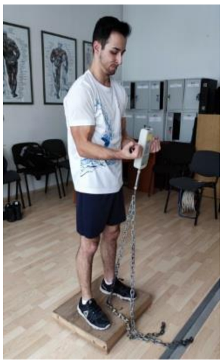

Figure 2. *Upper arm muscles measurement.*

To measure the maximum force of the shoulder muscles, the subject holds a dynamometer in front of him, arms outstretched with an angle of 90 degrees between the arms and the torso (Figure 3). The feet are hip-width apart and the chain connecting the stand to the digital force meter is fully tightened. The subject pulls the dynamometer from the initial position evenly with both hands with the strength of the shoulder girdle muscles, during which he performs the ante-flexion movement in the shoulder joint. The result is measured in Newtons (N). The description of the test was taken from Dopsaj, 2010.

*Figure 3.*Shoulder muscles measurement.

The sample of variables consisted of:

- final score on vault (DVAL),
- absolute leg muscle strength (ASLE),
- relative leg muscle strength (RSLE),
- absolute strength of the upper arm muscles (ASBI),
- relative strength of the upper arm muscles (RSBI),
- absolute strength of the shoulder girdle muscles (ASSH),
- relative strength of the shoulder girdle muscles (RSSH).

Statistical procedures corresponding to the problem under investigation were used for data processing. First, for each variable, descriptive parameters were calculated as follows:

- minimum value (MIN),
- maximum value (MAX),
- range (RAN),
- arithmetic mean (ARM),
- standard deviation (STD),
- skewness (SKE),
- kurtosis (KUR),
- Kolmogorov smirnov Z test (p).

Regression analysis was used to determine the influence of absolute and relative strength of the leg, upper arm and shoulder girdle muscles on success in performing vault. For this purpose, the following were calculated: standardized values of the regression coefficient – Beta, standardized tests of the significance of the regression coefficient – t, the level of significance of the standardized regression coefficient – p, coefficient of determination – R^2, adjusted coefficient of determination – R^2 adjust, standard error estimate – Std. Err. Est., significance test of multiple regression analysis – F, significance level of multiple correlation – p. The statistical program "SPSS v20" was used for statistical data processing.

RESULTS

Based on the obtained measurement results, adequate statistical procedures were applied.

Table 2 shows the basic statistical parameters of descriptive statistics and

Tables 3 and 4 show the regression analysis of absolute and relative strength, both sets of applied variables and for each variable separately.

Examining the results of descriptive statistics, it can be concluded that the results are normally distributed, as indicated by the values of skewness and kurtosis. The normality of the distribution of results is also confirmed by the values of Kolmogor's Smirnov Z test, which are higher than 0.05 for all applied variables.

The results of the regression analysis for absolute strength indicate that although there is an influence, it is not statistically significant, either for each variable separately (ASLE .290, ASBI .895, ASSH .074) or for a set of variables (*p*=.239). The values of the Beta coefficient indicate that there is a very small influence of leg muscles (ASLE -.296), slightly larger of shoulder girdle muscles (ASSH -.572), and almost no influence of the muscles of the upper arm (ASBI .031); none of them have any statistical significance. The values of the coefficient of determination agree with these results (R^2=.152) and an adjusted coefficient of determination (R^2_{adjust}=.051), which indicates a very small correlation with no statistical significance.

The influence of relative strength in relation to the absolute is greater, but without statistical significance, both for each variable separately (RSLE .166, RSBI .544, RSSH .060) and for a set of variables (*p*=.258). Beta coefficient values indicate a very small influence of the upper arm muscles (-.144), small influence of leg muscles (-.322) while the influence of the shoulder girdle muscles is larger (.525) and amounts to 52.5%. The values of the coefficient of determination (R=.146) and the adjusted coefficient of determination (R^2_{adjust} =.044) also support the previously mentioned results, which, as with absolute strength, indicate a very small correlation without statistical significance.

DISCUSSION

The aim of this study was to examine the influence of absolute and relative strength of the leg, upper arm and shoulder girdle muscles on the success of performing vault with gymnasts aged 13 to 16 years. The results showed that although there is some influence of the abovementioned muscles, it is not statistically significant.

Table 2
Descriptive statistics.

Variables	MIN	MAX	RAN	ARM	STD	SKE	KUR	KS - Z	
								KS - Z	p
DVAL	10.10	13.80	3.70	11.93	0.87	0.04	-0.12	0.38	1.00
ASLE	341.00	2232.00	1891.00	856.72	406.69	1.64	3.61	0.98	0.30
RSLE	5.78	36.59	30.81	17.99	6.14	0.65	1.80	0.52	0.95
ASBI	129.00	659.00	530.00	281.97	116.75	1.49	2.77	0.79	0.56
RSBI	3.79	18.31	14.52	6.00	2.61	1.03	1.02	0.66	0.78
ASSH	32.00	231.00	199.00	113.38	46.44	0.49	0.15	0.47	0.98
RSSH	0.98	3.79	2.81	2.35	0.64	-0.60	0.99	0.91	0.37

Legend: DVAL – final score on vault, ASLE – absolute leg muscle strength, RSLE – relative leg muscle strength, ASBI – absolute strength of the upper arm muscles, RSBI – relative strength of the upper arm muscles, ASSH – absolute strength of the shoulder girdle muscles, RSSH – relative strength of the shoulder girdle muscles, MIN – minimum value, MAX – maximum value, RAN – range, ARM – arithmetic mean, STD – standard deviation, SKE – skewness, KUR – kurtosis, KC-Z – Kolmogorov smirnov Z test, p – statistical significance of the KS-Z test

Table 3
Regression analysis of absolute strength.

Variables	Beta	t	p	R^2	R^2_{adjust}	Std. Err. Est.	F	p
ASLE	-.296	-1.081	.290					
ASBI	.031	-.133	.895	.152	.051	.843	1.498	.239
ASSH	-.572	1.862	.074					

Legend: *ASLE – absolute leg muscle strength, ASBI – absolute strength of the upper arm muscles, ASSH – absolute strength of the shoulder girdle muscles, Beta – standardized values of the regression coefficient, t – standardized tests of the significance of the regression coefficient, p – the level of significance of the standardized regression coefficient, R^2 – coefficient of determination, R^2 adjust – adjusted coefficient of determination, Std. Err. Est. – standard error estimate, F – significance test of multiple regression analysis, p – significance level of multiple correlation*

Table 4
Regression analysis of relative strength.

Variables	Beta	t	p	R^2	R^2_{adjust}	Std. Err. Est.	F	p
RSLE	-.322	-1.427	.166					
RSBI	-.144	-.615	.544	.146	.044	.846	1.430	.258
RSSH	.525	1.969	.060					

Legend: *RSLE – relative leg muscle strength, RSBI – relative strength of the upper arm muscles, RSSH – relative strength of the shoulder girdle muscles, Beta – standardized values of the regression coefficient, t – standardized tests of the significance of the regression coefficient, p – the level of significance of the standardized regression coefficient, R^2 – coefficient of determination, R^2 adjust – adjusted coefficient of determination, Std. Err. Est. – standard error estimate, F – significance test of multiple regression analysis, p – significance level of multiple correlation*

There are very few studies that deal specifically with this topic. In the first research by Paunovic et al. (2018), the authors examined the influence of the relative strength of different muscle groups on the results in all-around for gymnasts aged 14 to 16 years. It came up with results that are consistent with the results in this study. There is an influence of the relative strength of the leg muscles on the result in all-around, but it is not statistically significant and amounts to p=0.413, the upper arm muscle amounts to p=0.926 and, as in this study, the impact of the shoulder girdle muscles was the greatest (Beta=0.499) but still with no statistical significance (p=0.653). The results for the set of variables are also very similar to the results in this study (p=0.653).

In another study, Paunovic et al. (2019) examined the influence of absolute and relative strength on the success of performing the floor exercise. On a sample of respondents aged 14 to 16 years, results were obtained that are similar to the results in this and the abovementioned study. Although there is an influence of absolute and relative strength, it is not statistically significant. For absolute strength, it is at the level of p=0.295, and for relative, at the level of p=0.284.

In research by Qomarrullah, Kristiyanto, Sugiharto and Hidayatullah (2018), there were two variables as in this study, the leg and the arm muscle. In a slightly younger sample of subjects (10 to 12 years), the obtained results indicate a statistically significant influence of the above variables on the technique of performing the jump (leg muscle p <0.01, arm muscle p <0.01), in contrast to this study where, although there is an influence, it is not statistically significant.

Strength in boys aged 13 and 16 can vary greatly due to this sensitive period of development. Respondents of this age were selected because they competed in the same category. The internship is related to the age of the respondents. But it is not uncommon for children with good predispositions, which starts with training later, to progress equally well or better than those who have a longer internship.

CONCLUSION

Based on the obtained results, it can be concluded that strength, both absolute and relative, is not a decisive factor for success in performing vaults. Although gymnasts work out exclusively with their own weight, their relative strength is not crucial for success. This does not mean that strength is not important for success in gymnastics. Instead, the reason for the results obtained in this way should be sought in the age of the respondents. Namely, at this age, gymnasts perform elements that are more coordination-wise and technically demanding and require less strength. Given their age, this way of training and competition is justified since for many reasons, the development of strength can "wait" for a few more years.

The significance of this research is reflected in its determination of the influence of absolute and relative muscle strength of the muscles of the legs, upper arms and shoulder girdle on success in performing vault for gymnasts aged 13 to 16 years. Since a performance on the vault starts with a run-up towards the springboard, followed by the take-off with both feet from the springboard, then a support phase of take-off from the vault and finally landing on both feet, it can be said that the choice of muscle groups is justified.

Bearing in mind that gymnasts exercise only with their weight, without additional external load, it can be concluded that relative strength is crucial for success in artistic gymnastics. But other motor skills should not be disregarded, since artistic gymnastics is a very complex sport and does not tolerate well deficiencies in the development of any motor ability. Specifically, for a successful performance on the vault, the shoulder girdle muscles have the greatest influence (without statistical significance). The reason for the results obtained in this way lies in the fact that the flight phase and the landing phase depend on the support phase and the repulsion from the vault.

As there is a small number of studies that research the subject of this paper, regardless of the results obtained, this research represents a good foundation and basis for future studies of the absolute and relative strength in artistic gymnastics. It can also be used by trainers as a guide in the training process, as it indicates which muscle groups are most active on the specific apparatus.

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PHYSICAL FITNESS OF PUPILS OF SPORTS CLASSES WITH A SPORTS ACROBATICS PROFILE -A TWO-YEAR STUDY

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Abstract

The pre-school period is very important in early specialization disciplines (such as various forms of gymnastics). A wisely directed training process during this period ensures the prolongation of development and stabilization in shaping the child's motor skills. In order for gymnasts to perform a variety of gymnastic elements and routines effectively and accurately, the optimal level of their physical fitness is essential. The research material consists of the results of a two-year study of girls and boys aged 7-9. A total of 253 pupils took part in the study. It involved 167 pupils of general classes (75 girls and 92 boys) and 86 pupils from sports classes - sports acrobatics classes (50 girls and 36 boys). As part of the study, 3 series of measurements were carried out, covering the 2-year period of early childhood education (grades 1-3 of primary school). The girls and boys from sports classes (aged 7, 8, 9) obtained, on average, better results than their peers from general classes in the tests of physical fitness (except for the dynamometric force of the right and left hands). In the teams of both genders (aged 7, 8 and 9), the greatest differences in the level of development of features were noted in flexibility, arm strength and agility. In the subsequent series of studies, the differences in the level of physical fitness between the teams of sports and general classes deepened. In each section of the study, the increase in a given motor feature was greater in the teams of sports classes than in general (except for the dynamometric force of the right and left hands).

Keywords: *acrobatic gymnastics, sports classes, physical fitness, development.*

INTRODUCTION

The development of motor features is closely related to the stage of biological development, gender and individual somatotype. It takes place under the influence of physical effort of systematically increased intensity. A classic example of this type of load is sports training. In the first stage, it is general development, and then usually specialized, i.e., aimed at achieving the highest possible efficiency in shaping one or more motor features most desirable for a specific sports discipline or phase of the training cycle (Krawczyński, 2019).

The younger school period (ages from 7 to 11-12) is particularly important in early specialization disciplines such as swimming or various forms of gymnastics, including sports acrobatics (Osiński, 2019). A wisely directed training process during this period ensures the prolongation of development and stabilization in shaping the child’s motor skills.

Schools with sports classes play an important role in the Polish system of sports training of children and adolescents. Children with potential predispositions and motor skills are qualified for sports training in sports acrobatics within sports classes. The basic criterion here is good health (determined on the basis of internal medicine tests and medical interview) (Polish Gymnastics Federation, 2017). A candidate for the first sports class (of a sports acrobatics profile) does not need to have previous experience in sports. The predisposition to practise sports acrobatics is determined on the basis of the visual assessment of the child's body structure and basic physical fitness tests (which may defer depending on the location and school)(Hes, 2017). Having been enrolled in such classes, pupils follow an extended physical education program where classes are conducted with a given sports discipline in mind.

According to the Regulation of the Minister of National Education of 27th March 2017 on sports branches and schools as well as sports championship branches and schools (Polish Journal of Laws of 2017, Item 59), the compulsory weekly number of hours of sports activities in sports departments and schools is at least 10 hours, while in sports championship schools it is 16 hours. The number of these hours is determined by the school head in agreement with the governing body on the basis of the school's sports training program.

It is worth noting that in non-sport (the so-called 'general') classes, pupils only have 3 hours of physical education per week.

Gymnastic sports are sports disciplines requiring complex techniques, as well as comprehensive general and special preparation from their practitioners. A top-class practitioner must master the control of their own body, which cannot be achieved without a high degree of training in motor skills such as: strength, flexibility, agility, speed (Polish Gymnastics Federation, 2017).

A characteristic feature of school sports acrobatics training classes at the stage of early school education (grades 1-3 of primary school) is their complexity, taking into account the harmonious development of the whole organism and the simultaneous shaping of various motor skills, so indispensable when beginning to teach basic acrobatic elements. During these classes, a lot of strength exercises (overhangs, supports, with external resistance), as well as flexibility, jumping and balance exercises are used. During the entire training process, careful attention is paid to the consistency in enforcing the technical correctness of the elements trained and performed. The training program includes the acquisition of the basic elements such as: forward and backward flip, handstand, headstand, side flip, forward flip, single flip forward and backward. Basic trampoline and path jumping as well as team exercises are also introduced. The classes are aimed at developing interest in sports and this is often achieved through play-like forms of movement. To determine the child's predisposition to engage in sports competition, however, various forms of competition are introduced (Walczak, 2012; Polish Gymnastics Federation, 2017).

It should be remembered that an optimal level of physical fitness is essential for all gymnasts in order to be able to effectively and accurately perform a variety of elements and routines (Kiuchukov et al., 2019). Shaping the technique and economy of movement should be based on solid foundations. Hence, taking care of the participant's good motor preparation at all stages of the training, combined with impeccable technical preparation, increases the chance of achieving success (Polish Gymnastics Federation, 2017).

In order to determine the level of physical fitness and to monitor training processes various types of physical fitness tests are used. One of the most popular and widely used in school practice is the general physical fitness test (ICSPFT) (Dobosz, 2012).

The aim of the research was to compare the motor development of students attending sports classes (the sports acrobatics profile) against their peers who followed the basic physical education program. A different level of physical activity shall undoubtedly differentiate the examined students in terms of the level of development of motor skills. Still, this paper presents the scale of this phenomenon. It shows in which motor features the differences between students of acrobatic and general classes are the greatest and in which they are the smallest. Attempts are also made to answer the questions whether the differences on the level of development of individual motor skills were deepening year by year, and thus, what motor features are influenced by the acrobatic training the most in the initial stage of training.

It should also be borne in mind that physical fitness tests are also very useful as "measures of health" in assessing pupils biological development as well as their quality of life. Their use allows for a significant deepening of the developmental diagnosis and determining the adaptation abilities of not only a healthy child, but also one with various deviations in health to the living conditions and functioning of the child at school. (Jopkiewicz & Suliga, 2011).

METHODS

The research material consists of the results of a two-year study of girls and boys aged 7-9. A total of 253 pupils took part in the research. The research involved 167 pupils from general, non-sports classes (75 girls and 92 boys) and 86 pupils from sports classes with a sports acrobatics profile (called sports classes at work)(50 girls and 36 boys). In general classes, there is a basic physical education curriculum, while in sports classes pupils follow an extended physical education program and have more training classes per week.

The study involved the purposeful selection of the research group. Schools from Western Poland towns and cities where sports acrobatics classes are conducted were selected. The research was conducted in schools in Zielona Góra, Sulechów, Jawor and Poznań. In the sports classes examined, the weekly number of hours in sports acrobatics was 10 hours. Moreover, students from these classes had 2 hours of physical education with a teacher of early childhood education in order to implement the requirements of the core curriculum. In general (non-sports) classes, students completed 3 hours of physical education with a teacher of early childhood education.

Additionally, in sports classes, 68% of girls and 72% of boys participated in additional (extracurricular) sports activities, while in general classes, 35% of girls and 40% of boys did so.

The calendar age was calculated for each of the respondents using the decimal system (Drozdowski, 1998). As part of the research, 3 series of measurements were carried out, covering the 2-year period of early childhood education (grades 1-3 of primary school). The research was conducted in September 2017, when pupils attended the first year of primary school, then in September 2018 (in the second year of primary school) and again in September 2019 (at the beginning of the third year of primary school).

Selected physical fitness tests from the International Physical Fitness Test (ICSPFT) were used to assess the motor development of the studied teams (Dobosz, 2012). Measurements of the physical fitness of the examined pupils were made in the sports hall in the morning, strictly according to specific test instructions, following the same sequence. They concerned the following trials:

a) agility (determined by the time shuttle run 4x10m),

b) explosive strength of the lower limbs (determined by the distance standing broad jump),

c) abdominal muscles strength. (measured by the number of torso bends while lying down in 30 seconds), *d) arms strength (time determined by the time a pupil hangs on the bar on bent arms- bent arm hang),*

e) right and left hand force- hand grip (measured with a hand dynamometer)

f) flexibility (determined by the forward lean of the torso).

The research concept was approved by the Bioethics Committee at the Regional Medical Council in Zielona Góra (Bioethics Committee Resolution No. 17/82/2017 of 17th July 2017).

The collected material was then statistically processed. The arithmetic means (M), standard deviations (SD) and ranges of variation (min-max) for motor features were calculated. The level of the examined features of the girls and boys from sports classes was compared against the background of their peers from general classes aged 7, 8 and 9. To determine the significance between the mean values of the studied features, pupil's t-test was used (Arska- Kotlińska et al., 2002). Due to the fact that the results of the performed tests of motor fitness are expressed in different units, it was necessary to standardise them with the Mollison index for the set of general classes. It is assumed that the value of the Mollison index above 0.5 is treated as a large difference, and above 1 as a very large difference (Drozdowski, 1998).

RESULTS

The Girls

The girls from sports classes in all series of measurements were, on average, shorter than their peers from general classes, with statistically insignificant differences (Table 1). In the examined girls from sports classes, the annual increase in body height amounted to 5.71 cm (between 7-8 years of age) and 5.96 cm (between 8-9 years of age), while in their peers from general classes it was 5.12 cm (aged 7-8) and 5.81 cm (aged 8-9). During the 2-year observation period, the height gain in the acrobats was 11.67 cm, compared to 10.93 cm in the non-training girls.

With regard to body weight, it was noted that the girls from sports classes, in each series of measurements (ages 7, 8, 9) were on average lighter than their peers from the general classes (Table 1). From year to year, these differences deepened. In the examined girls, in the first series of measurements (age 7), there were no statistically significant differences between the average body weight, while in the second (age 8) and the third series (age 9), statistical significance was noted at the level of $p< 0.05$. In the girls from sports classes, the annual weight gain in the first period of the study was 2.81 kg, and 3.11 kg in the girls from general classes. In the second series of tests, the acrobats gained 3.26 kg on average, while their non-training peers 4.04 kg. During the 2-year follow-up period, in the girls from sports classes the increase in their body weight was 6.07 kg, and 7.15 kg in their peers.

The girls from sports classes in all series of measurements (ages 7, 8 and 9) obtained on average better results in tests of agility, arm strength, explosive strength of the lower limbs, flexibility and strength of abdominal muscles compared to their non-training peers (general classes); they fared worse in the test of dynamometric force of the right and left hands (Tables 2-4). Statistically significant differences between the compared features were noted in agility (at age 7, 8 and 9), arm strength (at age 7, 8 and 9), flexibility (at age 7, 8 and 9), strength of the abdominal muscles (at ages 8 and 9) and the explosive power of the lower limbs (at age 9).

Table 1
Numerical characteristics of the height and weight of the examined girls.

Feature	Age	Sports classes (n=50)		General classes (n=75)		d
		M	SD	M	SD	
Body height	7	122.39	4.92	123.69	6.39	-1.30
	8	128.10	5.11	128.81	6.62	-0.71
	9	134.06	5.43	134.62	6.73	-0.56
Body mass	7	23.99	4.58	25.70	5.39	-1.71
	8	26.80	4.80	28.81	5.92	**-2.01***
	9	30.06	5.28	32.85	6.52	**-2.78***

*p<0.05

Table 2
Numerical characteristics of the motor features of the examined girls aged 7.

Variables	Sports classes (n=50)				General classes (n=75)				p
	M	SD	min	max	M	SD	Min	max	
4x10m shuttle run	14.01	0.96	12.09	16.93	14.46	1.02	12.52	17.23	**-0.46***
Bent arm hang	6.60	8.04	0.00	36.00	3.80	3.87	0.00	18.00	**2.79***
Standing long jump	117.00	13.59	88.00	149.00	114.98	16.00	87.00	158.00	2.02
Bend trunk	9.62	5.49	-5.00	19.00	2.40	5.86	-7.00	17.00	**7.22****
Hand grip (R)	8.65	1.72	5.50	12.60	8.68	1.97	5.40	13.50	-0.03
Hand grip (L)	8.31	1.58	5.50	13.10	8.51	1.78	5.30	12.70	-0.20
Sit ups	13.60	4.26	2.00	19.00	12.24	3.98	1.00	20.00	1.36

*p<0.05, **p<0.01

Table 3
Numerical characteristics of the motor features of the examined girls aged 8.

Variables	Sports classes (n=50)				General classes (n=75)				p
	M	SD	min	max	M	SD	min	max	
4x10m shuttle run	13.35	0.92	11.30	15.34	14.03	1.05	12.25	16.72	**-0.68****
Bent arm hang	9.26	9.02	0.00	36.00	5.35	4.18	0.00	20.70	**3.91****
Standing long jump	128.48	13.89	99.00	165.00	123.69	17.13	93.00	167.00	4.79
Bend trunk	12.30	5.08	2.00	24.00	3.79	6.21	-8.00	19.00	**8.51****
Hand grip (R)	9.53	1.75	6.50	13.70	9.73	2.11	5.80	14.90	-0.20
Hand grip (L)	9.17	1.64	6.80	13.10	9.44	1.90	5.70	13.80	-0.27
Sit ups	16.66	3.88	4.00	23.00	14.93	3.71	1.00	21.00	**1.73***

*p<0.05, **p<0.01

Table 4
Numerical characteristics of the motor features of the examined girls aged 9.

Variables	Sports classes (n=50)				General classes (n=75)				p
	M	SD	min	max	M	SD	min	max	
4x10m shuttle run	12.73	0.83	11.37	15.00	13.60	0.87	11.97	15.80	**-0.87****
Bent arm hang	11.43	11.64	0.00	49.00	6.10	4.44	0.00	18.00	**5.33****
Standing long jump	140.68	15.95	118.00	176.00	133.49	17.02	102.00	177.00	**7.19***
Bend trunk	14.42	5.33	3.00	25.00	4.80	6.99	-11.00	22.00	**9.62****
Hand grip (R)	11.08	2.24	7.50	17.80	11.31	2.57	6.80	17.70	-0.24
Hand grip (L)	10.64	2.06	7.50	15.30	10.98	2.34	7.20	17.70	-0.33
Sit ups	18.92	3.30	9.00	25.00	16.73	3.63	2.00	23.00	**2.19****

*p<0.05, **p<0.01

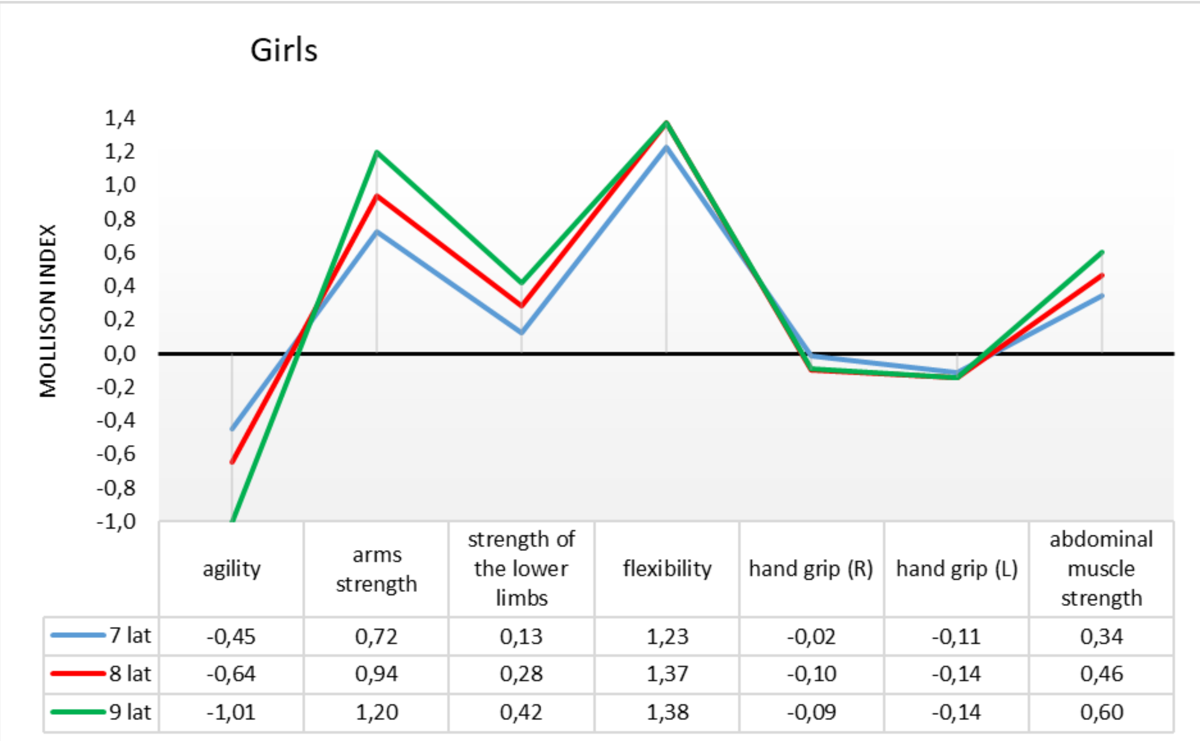


Figure 1. Normalized values of motor characteristics of the examined girls aged 7-9.

The normogram shows that the greatest differences in the level of development of motor skills of the examined girls aged 7, 8 and 9 were found in the area of flexibility (Mollison index value >1), arm strength and agility. In each successive series of measurements, the differences grew larger. The differences in the level of development of explosive strength of the lower extremities and strength of the abdominal muscles also deepened. The smallest differences in the level of development of motor skills were observed in the dynamometric strength of the right and left hand (Figure 1).

The boys

In contrast to the female teams under study, the boys from sports classes were, on average, taller than their peers from general classes, with statistically insignificant differences (Table 5). In the examined boys from sports classes, the annual increase in body height was 5.87 cm (between 7-8 years) and 5.96 cm (ages 8-9), while in peers from general classes it was 5.38 (the ages of 7-8) and 5.78 cm (the ages of 8-9). During the 2-year observation period, the height gain in the acrobats was 11.83 cm, while in the boys from general classes it was 11.16 cm.

With regard to body weight, it was noted that the boys from sports classes, in each series of measurements (between 7-9 years), are on average lighter than their peers from general classes (Table 5). From year to year, these differences deepened, and statistically significant differences between average body weights were recorded in the third series of measurements (age 9). In the boys from sports classes, the annual weight gain in the first period of the study was 2.85 kg, while it was 3.94 kg in the boys from general classes. In the second series of tests, the acrobats gained 4.05 kg on average, while their non-training peers put on 4.54 kg. During the 2-year observation period, the weight gain of the boys from sports classes was 6.9 kg, and of their peers - 8.48 kg.

The team of the boys from sports classes in all series of measurements (the ages of 7, 8 and 9) obtained on average better results in tests of agility, arm strength, explosive strength of the lower limbs, flexibility and strength of abdominal muscles, while worse in the dynamometric force of the right and left hands as compared to their non-training peers (general classes) (Tables 6-8). Statistically significant differences between the compared features were noted in arm strength (ages 7, 8 and 9), flexibility (ages 7, 8 and 9), agility (ages 8 and 9), explosive strength of the lower limbs (ages 8 and 9) and the strength of the abdominal muscles (age 9).

A graphic image of the values of the normalized motor features of the examined boys is presented in Figure 2.

Table 5
Numerical characteristics of the height and weight of the examined boys.

Feature	Age	Sports classes (n=36)		General classes (n=92)		d
		M	SD	M	SD	
Body height	7	125.77	6.43	125.65	5.18	0.12
	8	131.64	6.79	131.03	5.22	0.60
	9	137.60	6.92	136.81	5.31	0.80
Body mass	7	25.21	4.31	25.68	3.64	-0.47
	8	28.06	4.66	29.62	4.60	-1.56
	9	32.11	5.13	34.16	5.24	**-2.05***

*p<0.05

Table 6
Numerical characteristics of the motor features of the examined boys aged 7.

Variables	Sports classes (n=36)				General classes (n=92)				p
	M	SD	min	max	M	SD	min	max	
4x10m shuttle run	13.81	1.00	12.10	16.00	14.17	0.93	12.22	16.63	-0.36
Bent arm hang	7.00	6.46	0.00	22.00	3.95	3.90	0.00	20.00	**3.05****
Standing long jump	126.50	16.72	87.00	148.00	121.33	13.88	95.00	167.00	5.17
Bend trunk	4.19	6.21	-8.00	19.00	-1.88	4.84	-10.00	10.00	**6.07****
Hand grip (R)	8.86	1.83	6.20	12.50	8.96	1.77	5.40	13.50	-0.09
Hand grip (L)	8.57	1.68	5.40	12.70	8.64	1.61	5.30	12.70	-0.07
Sit ups	13.92	4.36	2.00	21.00	12.65	3.25	0.00	17.00	1.26

*p<0.05, **p<0.01

Table 7
Numerical characteristics of the motor features of the examined boys aged 8.

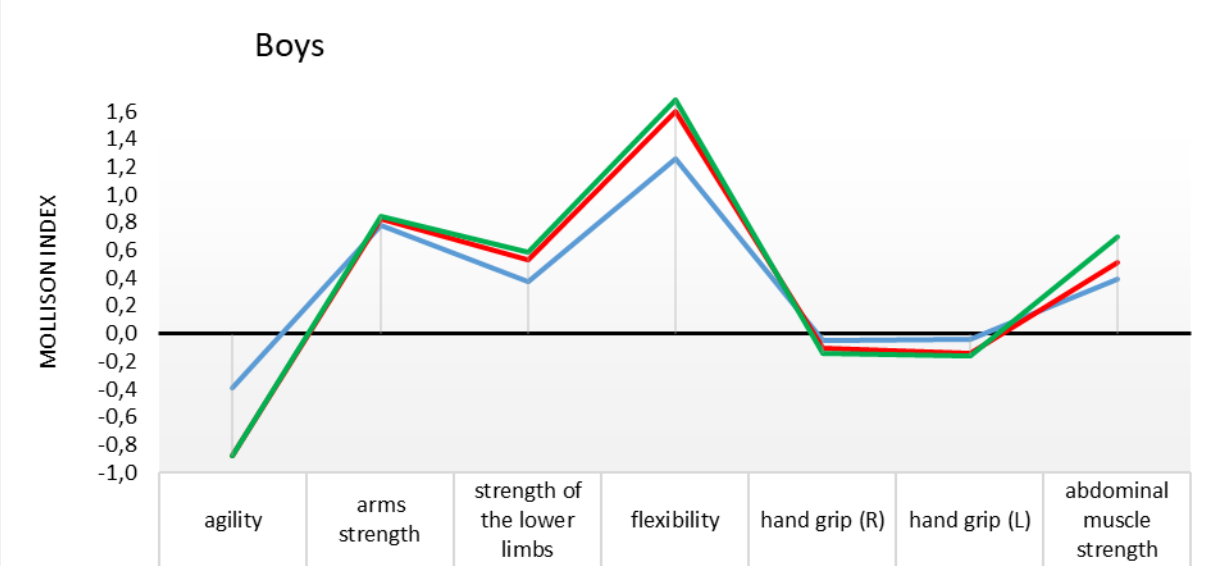
Variables	Sports classes (n=36)				General classes (n=92)				p
	M	SD	min	max	M	SD	min	max	
4x10m shuttle run	13.08	0.86	11.40	15.10	13.69	0.69	11.74	15.40	**-0.61****
Bent arm hang	10.83	8.25	0.00	31.00	6.03	5.82	0.00	30.00	**4.80****
Standing long jump	138.08	17.98	97.00	172.00	130.51	14.15	103.00	165.00	**7.57***
Bend trunk	6.42	5.99	-4.00	19.00	-0.77	4.48	-10.00	10.00	**7.19****
Hand grip (R)	9.80	1.84	6.80	13.00	10.00	1.86	5.80	14.90	-0.20
Hand grip (L)	9.38	1.69	7.00	14.00	9.63	1.75	5.60	13.80	-0.26
Sit ups	17.08	3.71	9.00	24.00	15.41	3.24	5.00	21.00	1.67

*p<0.05, **p<0.01

Table 8
Numerical characteristics of the motor features of the examined boys aged 9.

Variables	Sports classes (n=36)				General classes (n=92)				p
	M	SD	min	max	M	SD	min	max	
4x10m shuttle run	12.51	0.83	11.00	14.50	13.36	0.96	11.30	16.47	**-0.85****
Bent arm hang	13.13	11.16	0.00	50.00	6.82	7.45	0.00	49.00	**6.31****
Standing long jump	150.17	17.79	118.00	183.00	140.43	16.70	105.00	178.00	**9.73****
Bend trunk	8.28	5.38	-1.00	19.00	0.21	4.80	-10.00	12.00	**8.07****
Hand grip (R)	11.23	2.27	7.60	16.00	11.55	2.18	7.00	17.80	-0.32
Hand grip (L)	10.83	2.02	7.90	16.50	11.15	1.98	7.00	17.60	-0.32
Sit ups	19.39	3.10	14.00	25.00	17.24	3.09	9.00	23.00	**2.15****

*p<0.05, **p<0.01



	agility	arms strength	strength of the lower limbs	flexibility	hand grip (R)	hand grip (L)	abdominal muscle strength
7 lat	-0,39	0,78	0,37	1,26	-0,05	-0,04	0,39
8 lat	-0,88	0,82	0,54	1,60	-0,11	-0,15	0,52
9 lat	-0,88	0,85	0,58	1,68	-0,15	-0,16	0,69

Figure 2. Normalized values of motor characteristics of the examined boys aged 7-9 years.

The normogram shows that the greatest differences in the level of development of motor skills of the examined boys aged 7, 8 and 9 are in flexibility, arm strength and agility. With the consecutive year of research, the differences in the level of development of flexibility and strength of arms deepened. In the case of agility, the differences deepened after the first year of research and remained at the same level in the following year. The differences in the level of development of explosive strength of the lower extremities and strength of the abdominal muscles also deepened. The smallest differences in the level of development of motor skills were observed in the dynamometric strength of the right and left hand (Figure 2).

DISCUSSION

In the first series of studies (in the baseline studies, age 7), the girls and boys from sports classes obtained on average better results in the tests of physical fitness as compared to their peers from general classes (except for the dynamometric force of the right and left hand). It is related to enrolment in sports classes. In most sports schools, fitness tests are carried out to assess who qualifies for a class with a sports profile. Statistically significant differences between the compared features were noted in agility (the girls), arm strength (the girls and boys) and flexibility (the girls and boys). In the subsequent series of studies (age 8), the differences in the level of physical fitness between the teams of sports and general classes deepened. After two years of observation (age 9), both the girls and the boys showed statistically significant differences between the groups of sports classes and the general groups in all tests of physical fitness (except for the dynamometric force of the right and left hand). Obviously, this is related to the increased number of hours of sports activities of students from sports classes as compared to general classes. Researchers indicate a strong correlation between the number of training hours per week and the results of physical fitness tests (Fransen et al., 2012; Russo et al., 2021). An increased number of training sessions per week is associated not only with better overall physical fitness, but also influences the shaping of sport-specific features (Opstoel et al., 2015).

Changes in the level of motor performance can be explained by functional (increased recruitment of motor units, increased neuromuscular control) as well as structural aspects (increased muscle hypertrophy) (Behringer et al., 2011; Legerlotz et al., 2016) However, there is little evidence of muscle hypertrophy in children as a result of resistance training, so it is assumed that the increase in strength and the level of development of other motor features is caused by the adaptation of the nervous system rather than by hypertrophic factors (Faigenbaum at al., 2009). Such adaptation involves changes in motor unit coordination, firing and recruitment, and these are the crucial factors in movement optimization.

In the examined teams of both the sexes aged 7, 8 and 9, the greatest differences in the level of development of features were noted in flexibility, arm strength and agility (Figures 1-2). Although acrobatic training affects the harmonious and smooth development of motor skills (Lyulina, Zakharova & Vetrova, 2013), the authors note that acrobatic exercises require, in particular, strength, flexibility, balance, agility and control. Research among young gymnasts shows that they are characterized by great flexibility, strength, agility and jumping abilities (Vandorpe et al., 2011; Bencke et al., 2002; Carrick et al., 2007) and, as researchers point out, the development of strength and flexibility may allow contestants to perform complex gymnastic jumps (Leone, Lariviere & Comtois, 2002).

In each section of the study, the increase in a given motor feature was greater in the teams of sports classes than in the general ones. The exception is the dynamometric force of the right and left hands (hand grip). It should be stressed that the arm strength, in which the sports teams achieved much better results, was determined by the time of hanging on the bar on bent arms. The body weight of the respondents is not without significance here (relative strength). As indicated by Major (1996), gymnasts are among the strongest athletes when measuring strength in relation to body weight. It is attested by their ability to lift, move and hold their own body in various positions (Werner, 1994). In turn, the dynamometric force of the right and left hands (hand grip) is referred to as the absolute strength. From the results of research by other authors (Osiński, 2003; Raczek, 2010), it is evident that absolute strength is strongly correlated with body weight. Thus, the team members from general classes, who are on average heavier than their peers from sports classes, obtained better results in the dynamometric tests, and worse in the test of hanging on the bar. But this phenomenon can also be attributed to the leading role of the nervous system in the development of strength in children. It can be assumed that the results of the motor skills tests of the studied acrobats are caused to a greater extent by the adaptation of the nervous system than by the increase in muscle mass.

Participation in organized, regular sports activities influences the development of motor (physical) abilities of children (Torrance et al., 2007; Chalcarz et al., 2008; Wilk & Eider, 2014). According to Kiuchukov (2019) and co-authors, artistic gymnastics improves all health aspects of physical fitness and has a positive effect on the physical development of children. According to the authors, male and female gymnasts obtained better results in most of the international physical fitness tests carried out against standards for their age categories (Kiuchukov et al., 2019). According to the authors, the use of complex acrobatic exercises for the physical development of children aged 5-7 has a positive effect on sports performance, increases physical preparation and functional condition. In addition, the level of physical preparation is characterized by a smooth increase in physical characteristics (Lyulina, Zakharova & Vetrova 2013). It is important from the point of view of proper development to focus on the comprehensive development of all motor skills and the acquisition of new motor skills during the period of progressive development, and to avoid unilateral motor activity (typical for specialist training in most sports). From the perspective of child's development, gymnastics is a key physical activity as it is characterized by a great variety of movements (Novak et al., 2008; Nilges-Charles, 2008; Ávalos Ramos et al., 2014).

Sports acrobatics is one of the disciplines that harmoniously develops the whole organism, but martial arts can also be included here (Jasiński et al., 2002; Paszkiewicz vel Pipilewicz, 2019). As reported in Paszkiewicz vel Pipilewicz's work (2019), boys and girls, after a year of regular karate training, show more physical fitness than their non-training peers. The difference increases significantly after the second year of training. Among karate practitioners there was a significant progress compared to the previous year in each of the fitness tests carried out, while among the untrained pupils there was a minimal regression in general fitness (Paszkiewicz vel Pipilewicz, 2019).

Comparing own results to the percentile grids of physical fitness tests (ICSPFT) developed by Dobosz for the Polish population (2012), it was noted that girls and boys from acrobatic classes achieved good results in most of the trials. Particularly good results were achieved in the test of flexibility (9-year-old girls> 97th percentile, 9-year-old boys> 90th percentile), agility (9-year-old girls around the 10th percentile, 9-year-old boys within the 10-25th percentile) and explosive strength of the lower limbs (9-year-old boys and girls within the 75-90th percentile). Compared to the Polish population, the acrobats obtained worse results in the dynamometric force of the right and left hand. Against the general background of the population, girls and boys from general classes obtained good results in tests of explosive strength of the lower limbs (9-year-old boys and girls around the 75th percentile) and agility (9-year-old girls around the 25th percentile, 9-year-old boys within 25-50 percentile), while the worse (below the 50th percentile) results were obtained in the trials of hand grip, strength of the abdominal muscles, and arm strength. Flexibility scores were near or above the 50th percentile (Dobosz, 2012).

Numerous authors point to the negative phenomenon of decreasing the level of physical fitness (Przewęda & Dobosz 2003; Szklarska et al., 2004; Tomkinson et al., 2013). The secular trend of the development of somatic features is accompanied by the negative trend in the development of motor skills. A lot of studies, however, do not confirm the unequivocal direction of changes in individual motor features (Radziewicz-Gruhn et al., 2014; Asienkiewicz, 2015; Lopes et al., 2018).

Numerous observations indicate a decline in the level of aerobic motor skills. According to Tomkinson and Olds (2007), the efficiency of children is reduced by approx. 0.36% annually. Similar results were obtained by Tambalis and co-authors (2011) among the Greeks, Craig and co-authors (2012) in Canadian children, Ekblom with his team (2011) in the Swedish population, Freitas and co-authors (2017) among Portuguese children. In contrast to aerobic motor skills, Tomkinson (2007) observed an improvement in the results of anaerobic tests. It turned out that despite the increasing numbers of overweight and obese children, they obtained better results in terms of strength (approx. 0.03% per year) and speed (0.04% per year) in the years 1958-2003.

In the light of the research results and opinions of many teachers, trainers and parents, the number of hours of physical education in the initial years of primary school is insufficient. In the Polish education system, children in grades 1-3 of primary schools have 3 lessons of physical education per week. How do 135 minutes of physical activity a week correspond to the WHO recommendation of 60 minutes a day? (WHO, 2010). It is different in sports classes. Their pupils are offered a minimum of 10 lesson hours of sports activities thus satisfying the WHO recommendations regarding the hourly amount of physical activity.

Nowadays, pupils are less and less likely to undertake spontaneous physical activity. Children are rarely observed playing tag in the yard or turning over beats, and the school does not provide a minimum of physical activity. Therefore, teachers, trainers and instructors are faced with an extremely important task to encourage school children and youth to participate in organized sports and recreational activities.

CONCLUSIONS

Acrobatic training significantly influenced motor skills development. The girls and boys from sports classes (aged 7, 8, 9) obtained on average better results than their peers from general classes in the tests of physical fitness (except for the dynamometric force of the right and left hand, which is strongly correlated with body weight). In the groups of both sexes (aged 7, 8 and 9), the greatest differences in the level of development of motor skills were noted in flexibility, arm strength and agility. In each section of the study (7-8-, 8-9- and 7-9-year-olds), the percentage increase in the tested motor characteristics was greater in the groups of sports classes than in the general ones (except for the dynamometric force of the right and left hands). Therefore, it is justified to conduct athletic training as part of sports classes already in the early stages of primary school (in gymnastics).

Health and development values of physical activity, and especially that of organized forms of systematically conducted sports activities, remain the flagship argument for undertaking it at an increasingly younger age. Therefore, it is important to increase the duration of physical education classes in grades 1-3 of primary school.

LIMITATIONS

The limitation of this study lies in the fact that in individual acrobatic classes from different Polish towns and cities, sports training is somewhat different, as is the enrolment in these classes. It is obvious that in large cities, where "acrobatic traditions" are more established, the selection is greater, while in smaller locations, where there are relatively fewer children, the selection is more gentle. The limitations of this study is also the small number of boys, so the research should be extended to more sports schools from other regions of the country as well. It also seems justified to carry out a larger number of series of studies that would show the development of physical fitness of the studied students over a longer period of time.

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THE LEVEL OF DORSIFLEXION IN YOUNG GYMNASTS COMPARED TO YOUNG ATHLETES - PILOT STUDY

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Abstract

Gymnastic training develops strength, flexibility, concentration, balance, precision, and speed. The purpose of the study is to determine if gymnastic preparation leads to an increase in weight-bearing ankle dorsiflexion range of motion in a closed kinematic chain in young artistic gymnasts compared to a different type of sport. The weight-bearing lunge was chosen to measure the dorsiflexion range of motion in the ankle joint in the closed kinematic chain. The first group consists of members of the Slovak national youth team in artistic gymnastics (n-26). The second group consists of members of the Slovak national team in rhythmic gymnastics (n-13). The control group consists of young athletes (n-22). The mean dorsiflexion range of motion in artistic gymnasts was 47.32 ° in the right ankle joint and 44.75 ° in the left ankle joint. The mean dorsiflexion range of motion in rhythmic gymnasts was 44.32 ° in the right ankle joint and 43.41 ° in the left ankle joint. The mean dorsiflexion range of motion in young athletes was 44.27 ° in the right ankle joint and 42.32 ° in the left ankle joint. Results indicate a statistically significant difference in favor of artistic gymnasts compared to rhythmic gymnasts at the right ankle joint (p-0.04). In the left ankle, the two groups did not differ significantly from each other (p-0.38). There was no significant difference between artistic gymnasts and athletes in the right ankle joint (p-0.09) and the left ankle joint (p-0.19). There was no significant difference between rhythmic gymnasts and athletes at the right ankle joint (p-0.38) and the left ankle joint (p-0.24). A greater dorsiflexion range of motion in a closed kinematic chain in the ankle joint was detected in young gymnasts compared to rhythmic gymnasts. There was no significant difference between artistic gymnasts and athletes.

Keywords: *weight-bearing lunge test, range of motion, artistic, rhythmic gymnasts, athletics.*

INTRODUCTION

Gymnastics requires a high level of ability of motor control and a combination of several attributes to achieve optimal performance (Marcolin et al., 2019; Nassib et al., 2020). Gymnastics is a complex sport. Gymnastics can be divided into sports, modern, acrobatic, rhythmic, and aerobic gymnastics. Other gymnastic disciplines include tumbling and trampoline jumping. In artistic gymnastics, men have six apparatuses - floor exercise, pommel horse, rings, vault, parallel bars, and horizontal bar - on which they showcase their skills. Women compete on four apparatuses - vault, uneven bars, balance beam, and floor exercise. Modern rhythmic gymnastics is one of the few purely women's sports. Its main characteristic is the inclusion of equipment in exercises: skipping rope, hoop, ball, cones, and ribbon.

Gymnastics is a type of sport that requires a high level of anaerobic activity to achieve optimal results. Additionally, gymnastics enhances the development of abilities such as explosive strength, balance, coordination, and agility. The gymnast controls numerous basic elements to adapt to a higher load. Gymnastics also requires a high level of neuromuscular control (Kochanowicz et al., 2018). Repetition of difficult elements in training leads to skeletal adaptations (Knorr, 2014). The human body is adaptable due to its ability to react to repetitive loading. The human locomotor system is especially sensitive to adaptive changes during the adolescence period. Adaptation of range of motions in various joints is one of the adaptive factors for young gymnasts. Both decreasing or increasing the range of motion increases the risk of injury to gymnasts. Prevention of injuries in gymnastics is a great challenge (Kerr, 1990). In gymnastics, acute and chronic injuries can occur (Desai et al., 2019; Kolar et al., 2013). The most common cause of chronic injuries in gymnastics is overloading or inadequate treatment of acute injuries (Bradshaw & Hume, 2012; De Carli et al., 2012). The biomechanics of gymnastic exercises leads to the unique involvement of the body in different positions. These positions often require an excessive range of motion in various joints. It can lead to a higher incidence of hypermobility in gymnasts and predisposition to injury. Higher incidence of generalized joint hypermobility may result in musculoskeletal injuries in many sports activities (Schmidt et al., 2017). In addition to generalized hypermobility, localized hypermobility increases the risk of injury (Antonio & Magalhaes, 2018). In general, there is a higher incidence of hypermobility in gymnastics compared to other sports. One of the most common injuries in this sport is ankle joint injury (Edouard et al., 2018; Hart et al., 2018).

There are several testing possibilities to measure the range of motion of the ankle joint. Measurement using a weight-bearing lunge test in a closed kinematic chain is potentially one of them. This pilot study aims to determine the weight bearing ankle dorsiflexion range of motion in a closed kinematic chain in young artistic gymnasts compared to athletes engaging in different sports, and to determine whether gymnastic training causes hypermobility in the ankle joint.

METHODS

Three groups of athletes participated in the study – young artistic gymnasts, rhythmic gymnasts, and young athletes. Young athletes included in the study train for a minimum of two years in a certain sport and only in one discipline. Athletes who train in more than one sport discipline and athletes with acute lower limb injury or infectious disease were not included in the study. Gymnasts were tested in January 2021, during a gymnastic team camp in X-Bionic Sphere in Šamorín. The athlete testing took place in Banská Bystrica. Testing was conducted before training so that training did not affect the range of motion in the ankle joint. The informed consent was signed by the parents.

The first group consisted of 26 members of the Slovak national youth team in artistic gymnastics. Of these, 13 gymnasts were female and 13 gymnasts were male. The mean age was 14.28 years (±2.90). The mean weight was 47kg (±2.90). The mean height was 156.65 cm (±10.12). The mean training time was 9.34 years (±3.16). The median training time was 9 years.

The second group consisted of 13 female members of the Slovak national team in rhythmic gymnastics. The mean age was 14.84 years (±1.20). The mean weight was 48kg (±7.4). The mean height 162 cm (±4.4). The mean training time was 11 years (±1.8). The median training time was 11 years.

The third group consisted of 22 members of an athletic training group for children. Of these, 10 athletes were female and 12 athletes were male. The mean age was 13.54 years (±1.4). The mean weight was 47,14kg (±7.79). The mean height was 160, 7 cm (±9.55). The mean training time was 4.36 years (±1.68). The median training time was 4.5 years.

Artistic gymnastics training

Sports preparation in artistic gymnastics consists of physical activity focused on the development of physical abilities and aesthetic awareness. In competition, athletes perform their routines with standardized apparatuses. Evaluation of every routine reflects its difficulty and execution value according to the current Code of Points. Talent identification and selection in gymnastics occurs in children aged 4 to 5 years. At the age of 11 to 14 years, athletes already train 5 times a week; the mean time per training unit is 180 min. Training focuses mainly on mastering flawless techniques for difficult elements. It must consist of a comprehensive development of physical abilities and increasing the difficulty of routines in every discipline. The best gymnasts participate in international competitions. Typically, they participate in 6 to 10 competitions a year.

Rhythmic gymnastics training

Rhythmic gymnastics is coordination – aesthetic sport. It combines ballet, dance, and acrobatics with expressive movement and manipulation of hand apparatuses. Performance in rhythmic gymnastics consists of mostly noncyclic movements demanding a high level of neuromuscular coordination. Gymnasts perform a variety of body movements, often using a maximum range of motion with music and according to the current Code of Points. Training consists of developing a technique of floor (freehand) exercises such as leaps, balances, pivots, and flexibility movements along with techniques of manipulating the hand apparatuses such as tossing, catching, and rolling. Rhythmic gymnasts begin with systematic training at a very young age, achieving maximum performance before 20. At preschool age, training focuses mainly on the comprehensive development of all physical abilities. For young gymnasts, it is necessary to gain control over coordination in connecting various body movements and basic skills. Young gymnasts train five times a week, 3–5 hours a day, focusing mainly on joint flexibility, especially the hip joint and spine.

Young athletes training

Many children at the age of 13 already have 4–8 years of systematic training behind them. The mean time of a training unit is 60 min, twice a week. Training consists of athletic exercises, gymnastic exercises, conditioning, and sports games (Čillík & Willweber, 2018). Children participate in athletic competitions several times a year. Preparation focuses on building a foundation for simple athletic disciplines – sprints, middle-distance running, relay running, long jump, high jump, and ball throw. Training is universal, varied, and conducted in a playful way. At the age of 12 to 13 s, athletes train 3 times a week, 60 to 90 minutes per training unit. Training focuses mainly on achieving the correct technique in basic athletic disciplines. Regional competitions take place 7 to 8 times a year. Training is still very comprehensive at both levels an focuses on the development of physical abilities and athletic disciplines.

Weight-bearing lunge test.

The weight-bearing lunge test focuses on measuring the dorsiflexion range of motion in the ankle joint in the closed kinematic chain. The test is conducted in a lunge position using a goniometer. The tested athlete performs lunge position with heel and hallux aligned. An attempt is not valid if knee valgus-varus occurs or if the heel lifts off the floor. The heel is in contact with the floor during the whole movement. The physician ensures that the ankle joint reaches maximum dorsiflexion in the lunge position. The other lower limb stays on the floor. The physician measures the angle of dorsiflexion in the ankle joint. The mobile application was used for the testing (Banwell et al., 2019; Williams et al., 2013).

All three groups were tested before training without warming up.

Results were collected in an Excel spreadsheet and subsequently subjected to statistical analysis using software SAS® Enterprise Guide® (SAS Institute Inc., USA). Non-parametric tests were used. The difference in the mean values for the right ankle joint and the left ankle joint between three groups has been evaluated with Kruskal-Wallis one-way analysis of variance. To assess the difference in the mean values for the right ankle joint and the left ankle joint between two groups, Wilcoxon scores have been calculated using Wilcoxon Rank Sum Test. Pearson's correlation coefficient was used to test the correlation.

RESULTS

Table 1
Mean range of motion dorsiflexion (ROM) in artistic gymnasts, rhythmic gymnasts and athletes.

Average ROM (°) Group		Right	Left
Artistic gymnasts	Min	33.00	30.50
	Mean	47.32	44.75
	Max	63.00	65.00
	Range	30.00	34.50
	QRange	8.00	10.00
Rhythmic gymnasts	Min	36.00	35.20
	Mean	44.32	43.41
	Max	51.00	49.50
	Range	15.00	14.30
	QRange	6.00	3.30
Athletes	Min	29.00	29.00
	Mean	44.27	42.32
	Max	56.00	54.00
	Range	27.00	25.00
	QRange	11.00	9.00

Table 2
Mean range of motion dorsiflexion (ROM) in male and female.

Average ROM (°) Group	Sex		Right	Left
Artistic gymnasts	Female	Min	33.00	32.00
		Mean	47.88	44.45
		Max	57.00	62.50
		Range	24.00	30.50
		QRange	6.50	6.90
	Male	Min	36.00	30.50
		Mean	46.76	45.05
		Max	63.00	65.00
		Range	27.00	34.50
		QRange	9.20	11.00
Rhythmic gymnasts	Female	Min	36.00	35.20
		Mean	44.32	43.41
		Max	51.00	49.50
		Range	15.00	14.30
		QRange	6.00	3.30
Athletes	Female	Min	29.00	29.00
		Mean	43.30	40.80
		Max	56.00	54.00
		Range	27.00	25.00
		QRange	14.00	7.00
	Male	Min	36.00	36.00
		Mean	45.08	43.58
		Max	50.00	52.00
		Range	14.00	16.00
		QRange	10.00	8.50

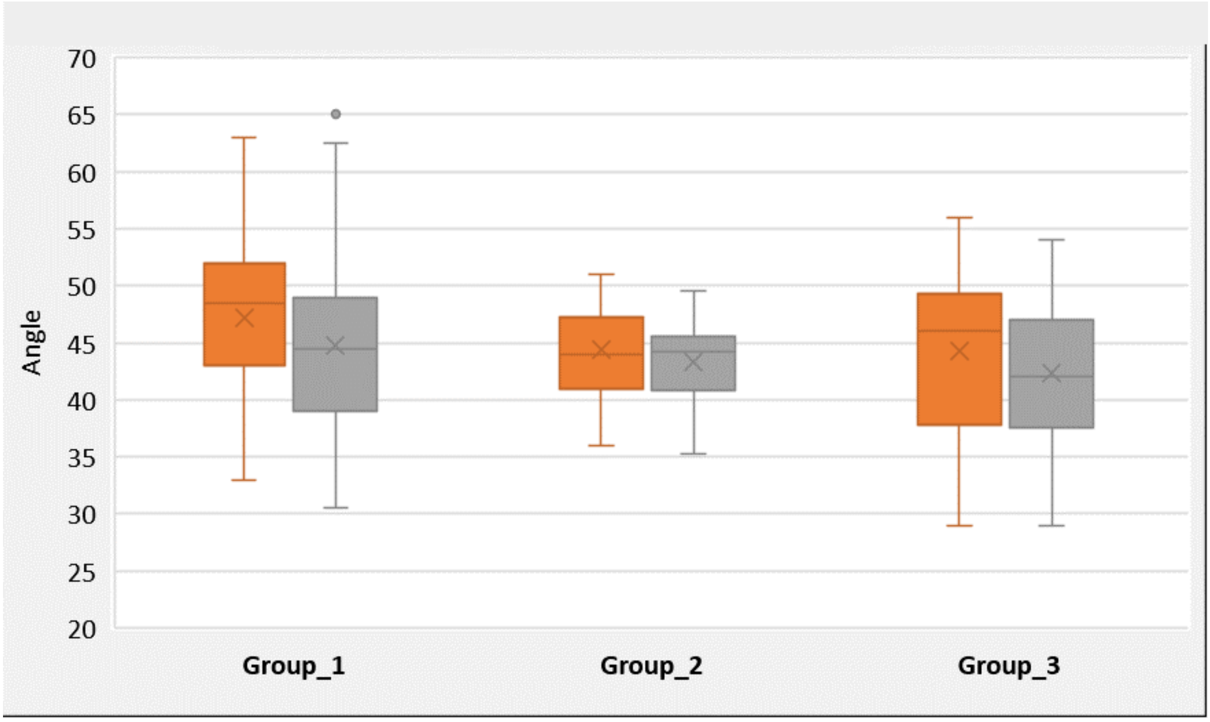

Figure 1. Comparison between artistic gymnasts, rhythmic gymnasts and athletes.

Table 3
Statistical difference between groups of artistic gymnasts (AG), rhythmic gymnasts (RG), and athletes (AT).

	All		Female		Male	
GROUPS	Right	Left	Right	Left	Right	Left
AG - RG	0.0417	0.3883	0.0231	0.4421	x	x
AG - AT	0.0904	0.1865	0.0907	0.1755	0.3708	0.3515
RG - AT	0.3848	0.2371	0.4532	0.0886	x	x

The mean dorsiflexion range of motion in artistic gymnasts was 47.32 ° in the right ankle joint and 44.75 ° in the left ankle joint. The mean dorsiflexion range of motion in rhythmic gymnasts was 44.32° in the right ankle joint and 43.41° in the left ankle joint. The mean dorsiflexion range of motion in young athletes was 44.27° in the right ankle joint and 42.32° in the left ankle joint. The results can be seen in Table. 1

The mean dorsiflexion range of motion in artistic gymnasts was 47.88 ° in the right ankle joint and 44.45 ° in the left ankle joint. The mean dorsiflexion range of motion in male artistic gymnasts was 46.76 ° in the right ankle joint and 45.05 ° in the left ankle joint. The mean dorsiflexion range of motion in rhythmic gymnasts was 44.32° in the right ankle joint and 43.41° in the left ankle joint. The mean range of motion of dorsiflexion in young female athletes was 43.30 ° in the right ankle joint and 40.8 ° in the left ankle joint. The mean dorsiflexion range of motion in young male athletes was 45.08 ° in the right ankle joint and 43.58 ° in the left ankle joint. The results can be seen in Table. 2.

Furthermore, we compared the statistical significance at α-0.05 significance level -0.05.

There was a significant difference in favor of artistic gymnasts compared to rhythmic gymnasts in the right ankle joint (p <0.04). In the left ankle joint, no significant differences were found (p-0.38). There were no statistically significant differences between artistic gymnasts and athletes in the right ankle joint (p-0.09) and the left ankle joint (p-0.19). No significant differences were found between rhythmic gymnasts and athletes in the right ankle joint (p-0.38) or the left ankle joint (p-0.24). A significant difference was detected in favor of female artistic gymnasts compared to rhythmic gymnasts (p-0.02) in the right ankle joint and no significant difference (p-0.44) in the left ankle joint. There were no significant differences between artistic gymnasts and athletes in the right ankle joint (p-0.09) and the left ankle joint (p-0.18). A significant difference was not detected between male artistic gymnasts and male athletes in the right ankle joint (p-0.37) or the left ankle joint (p-0.35). There was no significant difference between rhythmic gymnasts and female athletes in the right ankle joint (p-0.45) and the left ankle joint (p-0.08). The results can be seen in Table 2

Dorsiflexion in artistic gymnasts did not correlate with age (r-0.13-0.19), weight (r- 0.28-0,29), and sport age (r- 0.21-0.31). The range of motion of dorsiflexion in rhythmic gymnasts did not correlate with age (r-0.36), weight (r- 0.04-0.12), and sport age (r-0.22-0.30). In the young athlete’s dorsiflexion range of motion did not correlate with age RL (r-0.20), weight RL (r-0.13-0,15), and sport age (r-0.12-0.20)

DISCUSSION

Gymnastic training develops strength, flexibility, concentration, balance, precision of movement, and speed in young gymnasts. Young gymnasts dedicate a considerable amount of time to training (Zetaruk, 2000). Physical loading during training time stimulates changes in the musculoskeletal system. These changes have positive or negative effects. Maintaining a balance between flexibility and strength, training modification, and correct training periodization reduces the risk of injuries in the case of excessive training.

The highest mean range of motion for dorsiflexion was confirmed in the group of young gymnasts. These findings support the assumption that gymnastic training leads to adaptation of the musculoskeletal system including the dorsiflexion range of motion in the ankle joint. Despite a higher mean of dorsiflexion range of motion in the ankle joint, it still did not lead to hypermobility in young gymnasts. The appearance of dorsiflexion hypermobility in all groups was influenced by individual flexibility in the various joints rather than by the type of sport itself. A significant difference was found between female artistic gymnasts and rhythmic gymnasts. We assumed a greater dorsiflexion range of motion in the ankle joint in rhythmic gymnasts. This assumption was not confirmed; rhythmic gymnasts had a significantly lower dorsiflexion range of motion in the ankle joint. A possible explanation for this finding is that rhythmic gymnasts perform most of the movement in plantar flexion rather than in dorsiflexion in the ankle joint. The musculoskeletal system of rhythmic gymnasts lacks an adaptive stimulus to increase the range of motion of dorsiflexion. The mean range of motion of dorsiflexion in the ankle joint in artistic gymnasts was greater than in athletes. However, the difference was not statistically significant. Gymnastic training requires more flexibility training than athletic training. On the other hand, athletic training focuses on numerous activities that involve the ankle joint in various directions. It can lead to natural adaptation of a range of motion in the ankle joint. In the training of young athletes, adequate range of motion in the ankle joint is essential for sports performance, especially in sprints and jumps.

In a previous study (Líška et al., 2021), we focused on comparing the range of motion of judo and football players. The mean dorsiflexion range for judoists was 43.15-43.90° and for football players 41.02-42.09°. Compared to gymnasts in our study, the dorsiflexion was lower, which may indicate that gymnastic training involves more complex training for ankle joint than judo and soccer.

Systematic sports training in different disciplines leads to functional and structural adaptation of the human organism. In a systematic review, Jürimäe (Jürimäe et al., 2018) monitored the influence of gymnastic training on one group compared to another group without gymnastic training. The group of gymnasts had better bone density, lower body weight, delayed pubertal development, and lower levels of some hormones. Bukva et al. (2019) examined the association between generalized hypermobility in gymnasts. To examine the gymnasts, Beighton score was used. The sample consisted of 24 rhythmic gymnasts. The most common injury was lower back pain, followed by knee, shoulder, hip, and ankle injuries. The number of training years was correlated with the prevalence and incidence of injuries ($P<0.001$). The number of training hours per week was not correlated with the incidence of injuries ($P>0.05$). Young gymnasts are at an increased risk of injury due to overload. An overload injury occurs when there is an inadequate ratio between the training load and regeneration. In young gymnasts, inadequate body adaptation to the training load and inadequate range of motion at the ankle joint increase the risk of injury. Sweeney et al. (Sweeney et al., 2019) examined the relationship between flexibility and lower back pain in rhythmic gymnasts: 30 of 67 gymnasts experienced lower back pain in 5 years. Gymnasts who experienced lower back pain were those with higher age (11.7 vs 13.7, $P = 0.005$), weight (37.5 vs 43.4 kg, $P = 0.049$) and training time (19.1 vs 22.4 h / week, $P = 0.017$).

Gymnasts use various training methods to increase their range of motion. Dallas et al. (Dallas et al., 2014) examined the acute effect on flexibility in gymnasts using static stretching, proprioceptive, neuromuscular facilitation, and stretching on a vibrating platform. The most significant changes in the range of motion were found in the group using proprioceptive neuromuscular facilitation.

In our study, the weight-bearing lunge test was used to measure dorsiflexion in the ankle joint in the closed kinematic chain as a pilot test in gymnastics. This test was used in other sports, for example, in football. The range of motion of dorsiflexion in the ankle joint changes during the season depending on the level of physical activity. Moreno-Peréz (2020) examined this issue. The sample consisted of 45 football players tested before and after the match to determine the acute effect of physical activity. The long-term effect was tested before, during and after the competitive season. The dorsiflexion range of motion in the ankle joint in the closed kinematic chain was at the highest level. The preseason values were higher than the midseason values (8.1% dominant lower limb and 9.6% non-dominant lower limb). Post-season tests showed a significant decrease in dorsiflexion range of motion in the ankle joint (13.8% dominant lower limb, 12.5% non-dominant lower limb). A decrease in the dorsiflexion range of motion occurred in 30% of football players. An increase in dorsiflexion range of motion after the match indicates the immediate effect of physical activity (5.8% dominant lower limb). This increase in the dorsiflexion range of motion decreased during the next 48 hours. According to Moreno-Peréz, the decrease in the dorsiflexion range of motion in the ankle joint is related to a higher risk of injury during the mid-season and post-season period. Backman et al. (2011) also examined the relationship between injuries and the limited range of motion of dorsiflexion in the ankle joint. The sample consisted of 75 junior basketball players monitored during one season. Twelve of them experienced patellar tendinopathy during the season. They also had lower dorsiflexion range of motion in the ankle joint (P=0.038) in the dominant lower limb and in the nondominant lower limb (P = 0.024). Another data shows that players with dorsiflexion range of motion in the ankle joint less than 36.5° were at 18.5% to 29.4% higher risk of suffering patellar tendinopathy in one year compared to players with dorsiflexion range of motion in the ankle joint greater than 36.5° (1.8% - 2.1%). Macrum et al. (2012) examined the effect of limited dorsiflexion range of motion in ankle joints in a squat. The sample consisted of 30 participants who performed no-restriction squat-simulating motion restriction in the ankle joint. Limiting the range of motion in the ankle joint led to an increase in the knee valgus. Simultaneously, simulating motion restriction in the ankle joint is related to a lower activation of the m.quadriceps femoris and a higher activation of the m.soleus.

The optimal range of motion in the ankle joint in the closed kinematic chain in gymnasts is an important issue to be determined in future studies by examining the relationship between gymnastic training and the range of motion in the ankle joint. Determining the optimal range of motion of dorsiflexion enables setting the optimal reference values and advances the gymnastics training process. Training time was the limiting factor in influencing the validity of the tests in both groups of gymnasts in comparison to athletes. The mean training time of young athletes has been lower compared to gymnasts of the same age. However, the number of years of training did not correlate with the overall effect on the range of motion of dorsiflexion in the ankle joints in any group. To confirm the validity of this statement, it is important to test the potential relationship between different groups of professional gymnasts and athletes. Another limitation of our study was the relatively small sample.

CONCLUSIONS

A greater dorsiflexion range of motion in a closed kinematic chain in the ankle joint was detected in young gymnasts compared to rhythmic gymnasts. There was no significant difference between artistic gymnasts and athletes.

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KINEMATIC ANALYSIS OF TWO WAYS OF PERFORMING THE BACK HANDSPRING – A CASE STUDY

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Abstract

The aim of the study was to compare selected kinematic variables of the back handspring from a standing position (Bh) with a back handspring performed in the movement sequence: round off – back handspring – backward stretched somersault (R BhS). The study included 4 gymnasts (mean age: 19.5 years). The athletes performed 6 repetitions of Bh and RBhS. All gymnastic elements were recorded on film. The artistic gymnastics judges selected the best Bh and the back handspring in the sequence (RBhS) for each competitor, which were then subjected to kinematic analysis. Based on the phase division of the recorded gymnastic elements, the analysis of the temporal structure of movement, changes in displacements and velocity of the athletes' centre of gravity (CG), as well as changes in the position of their trunk in relation to the ground were analysed. In Bh and RBhS, the competitors' horizontal CG velocity component (v_x) *decreased from the beginning of the first flight phase until the end of the support phase on the lower limbs. In Bh, the median values (Me) of* v_x *decreased from 1.94m/s to 0.8m/s, and in RBhS, from 4.85m/s to 2.24m/s. In the case of the vertical component of velocity* (v_y)*, the highest values of Me for both back handsprings were recorded at the end of the support phase on the lower limbs (for Bh and RBhS: 3.27m/s and 4.79m/s, respectively). Both in Bh and RBhS, the value of CG velocity in the horizontal axis decreased from the beginning of the analysed movement until its completion.*

Keywords: *kinematics, artistic gymnastics, back handspring, technique.*

INTRODUCTION

In artistic gymnastics, there are different types of sports preparation for athletes. One of them is technical preparation, during which gymnasts learn and improve many gymnastic elements characterised by a diverse motor structure and degree of difficulty. The initial stage of this training comes down to the development of a wide technical and motor base that has a significant impact on the athletes' further sports development (Arkaev & Suchilin, 2004; Kochanowicz et al. 2015; Živčić Marković et al. 2015). A properly implemented sports training process should enable athletes to gradually learn increasingly more difficult elements and also planned movement sequences. In any situation, the priority of training gymnastic skills is to maintain a correct movement technique, which is also important with regard to injury prevention in sports (Bradshaw & Hume, 2012).

Therefore, the ability to introduce necessary modifications to the learned way of performing a task is as important as developing a repetitive movement technique. One of the basic gymnastic skills, performed initially as an independent element and later in different movement sequences, is the back handspring. Its learning begins when gymnasts already have several years of training experience. Most of them will perform it in various forms throughout their sports career. In its basic form, the back handspring begins and ends in a standing position. Another important skill in artistic gymnastics is mastering the handspring performed immediately after a round off. Ultimately, it is used by gymnasts as a transition skill preceding various acrobatic elements (Sands & McNeal, 2006; Potop, 2014), including those most difficult ones, such as the "Ljukin", or the "Ri Jong Song" (FIG, 2017). In addition, by mastering the back handspring, a gymnast can also learn the "Yurchenko" vault (Diener & Aedo-Muñoz, 2019). For female gymnasts, the back handspring is an element performed on a balance beam. It is also used in supplementary training carried out by athletes in other sports disciplines, such as rhythmic gymnastics or acrobatics (Huang & Hsu, 2009; Donovan & Spencer, 2019).

The aforementioned multiple use of the back handspring probably contributed to scientific research devoted to this element. Koh et al. (1992) analysed the forces of ground reaction on the upper limbs during the support phase of this element. Davidson et al. (2005) undertook research aimed at estimating the stiffness and damping properties of the wrist and shoulder in children by examining wrist impact on the outstretched hand in the back handspring and dive-roll. These authors demonstrated that the back handspring involved greater impact velocity and force compared to the dive-roll, indicative of an activity in which the body's full weight is decelerated by the hands. Grassi et al. (2005) analysed the short-term consistency of body trajectories during the performance of the back handspring.

When comparing the results achieved by male and female gymnasts, they found larger consistency between landmark trajectories in women than in men. Heinen et al. (2010) evaluated the effects of two manual guidance procedures on movement kinematics of a back handspring and a back tuck somersault following a round off on the floor. According to these authors, the sandwich-grip should be applied in the first instance if the coach's interest is to optimise the angular momentum of the somersault axis and the second flight phase in the back handspring. Mkaouer et al. (2013) compared kinetic and kinematic variables of the take-off between two acrobatic series leading to perform the backward stretched somersault (salto): round off, back handspring versus round off, tempo-salto. In these studies, it was shown that the combination of round off, tempo-salto to stretched salto allowed for greater horizontal displacement and momentum, while the combination of round off, back handspring to stretched salto allowed for better vertical displacement and velocity. Omorczyk et al. (2015) used reverse transfer to verify the usefulness of selected simple methods of recording and fast biomechanical analysis performed by judges of artistic gymnastics in assessing a gymnast's movement technique. Burton et al. (2017) presented the results of a study aimed at investigating the influence of hang position on the elbow and wrist joint coordination and variability during the performance of the back handspring in female gymnastics. Competitors performed this element with "inward", "parallel" and "outward" hand position. The authors concluded that lower variability within the parallel technique may be more suited to gymnastics performance, with the “inward” contributing more toward overuse injury reduction.

Other authors (Huang & Hsu, 2009; Penitente et al. 2011; Lovecchio et al. 2013) conducted biomechanical analyses of the back handspring, the results of which may also be helpful in the process of learning and improving this element by artistic gymnastics athletes, as well as in other sports.

So far, however, no comparison has been made between the technique of performing a back handspring from standing position with a back handspring serving as a transition element. Therefore, research was undertaken to compare selected kinematic variables of the back handspring from standing position (Bh) with the back handspring performed in the motor sequence: round off – back handspring – backward stretched somersault (RBhS).

METHODS

The study comprised 4 (n = 4), elite male gymnasts at the mean age of 19.5 ± 3.0 years, body height: 172.5 ± 2.5 cm, body mass: 65.8 ± 3.6 kg, and training experience: 14.3 ± 2.5 years. The inclusion criteria were: master class in artistic gymnastics; participation in the Polish Championships in Artistic Gymnastics; training for at least 10 years; no injuries to the musculoskeletal system, and the ability to safely perform a back handspring and the round off – back handspring – backward stretched somersault (confirmed by a coach).

The subjects participated in the research voluntarily. The study was approved by the Bioethics Committee at the Regional Medical Chamber in Krakow, Poland (Approval Ref. No. 42/KBL/OIL/2017).

Before initiating the tests, the competitors performed a general and acrobatic warm-up (series of forward rolls, backward rolls; handstand; cartwheel; round off; front handspring; forward and backward tucked somersaults). All exercises, both performed during the warm-up and the subject of research proper, were executed on the spring floor of the AWF Krakow gymnasium.

After the warm-up, the proper part of the research began. All tested men were asked to perform 6 back handspring repetitions as well as possible, followed by the same number of movement sequences including round off – back handspring – backward stretched somersault. The athletes performed their exercises in a fixed order, one after another. As a result, the duration of the interval between consecutive exercises performed by the same person was similar. A 5-minute resting interval was introduced between the Bh and RBhS. Bh was performed by all gymnasts from the same starting position: stance with the arms elevated, while the take-off was preceded by an arm swing. After Bh, the athletes performed a rebound and landed in standing position. RBhS began with the gymnasts performing a run-up, with no interference in its length, number of steps or speed. All 6 Bh and RBhS attempts were filmed with a digital camera (Sony DSC RX100 M4) at 120 Hz. The recording device was placed next to the spring floor, on a levelled, stable tripod, so that the optical axis of the lens was perpendicular to the direction of the subject's movement. In the described manner, 12 videos were recorded for each competitor.

Before beginning the recording, on the left side of the body (from the camera side), markers made of white, flexible adhesive tape were fixed to the subjects' skin, in the places corresponding to the rotation axis of the joints: shoulder, elbow, radiocarpal, hip, knee and shin-ankle. This was carried out on all athletes by the same person with appropriate anatomical knowledge.

Exercises recorded on the film were evaluated by a judge to select the best performance of Bh and RBhS for each competitor. This evaluation was made independently by 3 judges licensed by the Polish Gymnastics Association. The films selected by the judges (2 for each athlete) formed the basis for the subsequent kinematic analysis carried out with the use of the Skill Spector v.1.3.2 computer program, implementing a 10-point mathematical model of the body, created by the developers of this software. Thanks to this, on the basis of changes in the position of the centre of the previously marked main joints of the limbs (upper and lower), as well as the chin, forehead (glabella point) and the ends of the distal phalanges of the big toe and middle finger, the values of a number of kinematic indicators of movement were determined. Based on the phase division of the registered gymnastic elements (Bh and RBhS), an analysis was performed looking at the temporal structure of movement, changes in displacements and velocities of the gymnasts' centre of gravity (CG) and changes in the position of their trunk in relation to the ground.

Both analysed gymnastic elements were divided into phases. This was carried out by identifying the beginning and the end of the flight and support phases. As a consequence, nodal division points were determined:

A - beginning of analysis, initiation of the first flight phase,

B - completion of the first flight phase,

C - beginning of the second flight phase,

D - completion of the second flight phase,

E - end of analysis, end of the support phase on the lower limbs.

The proposed points were the basis for distinguishing the following successive phases of movement:

A-B - first flight phase ($\mathbf{F_I}$),

B-C - support on upper limbs ($\mathbf{S_{UI}}$),

C-D - second flight phase ($\mathbf{F_{II}}$),

D-E - support on lower limbs ($\mathbf{S_{LI}}$).

Based on the applied mathematical model, the following kinematic variables were determined:

$\mathbf{t_t}$ - total time [s],

$\mathbf{t_{FI}}$ - time of first flight phase [s],

$\mathbf{t_{SUI}}$ - support time on upper limbs [s],

$\mathbf{t_{FII}}$ - time of second flight phase [s],

$\mathbf{t_{SLI}}$ - support time on lower limbs [s],

$\mathbf{v_A}$ - resultant, initial CG velocity of gymnast at time of A [m/s],

$\mathbf{v_{Ax}}$ - gymnast's horizontal CG velocity at the beginning of movement (A) [m/s],

$\mathbf{v_{Ay}}$ - gymnast's CG vertical velocity at the beginning of movement (A) [m/s],

$\mathbf{v_B, v_{Bx}, v_{By}}$ - resultant, horizontal and vertical velocity CG at time of B [m/s],

$\mathbf{v_C, v_{Cx}, v_{Cy}}$ - resultant, horizontal and vertical velocity of CG at time of C [m/s],

$\mathbf{v_D, v_{Dx}, v_{Dy}}$ - resultant, horizontal and vertical velocity CG at time of D [m/s],

$\mathbf{v_E, v_{Ex}, v_{Ey}}$ - gymnast's final CG velocity (resultant, horizontal and vertical) (E) [m/s],

$\mathbf{h_{ACG}}$ - height of the CG position at initial period (A) [m],

$\mathbf{h_{BCG}, h_{CCG}, h_{DCG}}$ - altitude of CG at times B, C and D [m],

$\mathbf{h_{ECG}}$ - final height of CG position (E) [m],

$\mathbf{L_{FI}}$ - displacement in the first flight phase (horizontal distance between the location where the feet are removed from the ground and where the hands are placed; A-B) [m],

$\mathbf{L_{FII}}$ - displacement in the second flight phase (horizontal distance between the location where the hands are lifted off the ground and where the feet are placed; C-D) [m].

It should be noted that the vertical component of the CG velocity vector in the athletes (v_y) during their performance of the Bh and RBhS could change its turn. Therefore, the values of this variable marked with the sign "-" (minus) mean a turn towards the spring floor.

It is also worth noting that the linear displacements in the flight phase (L_{FI}, L_{FII}) comprise the value of the shortest horizontal distance between the take-off and the landing site.

The analysis of the collected footage also helped to distinguish the characteristics of changes in the angular position of the athletes' trunk in relation to the ground during the performance of both gymnastic elements: Bh and RBhS. The arms of that angle were two intersecting rays. The first was marked by the section connecting the athlete's shoulder and hip joints (trunk), and the second - the ground (spring floor). In this paper, it was decided to present only the instantaneous values of such an angle in relation to the boundaries of the distinguished phases.

Therefore, at the nodal points: A, B, C, D and E, the following variables were defined: $\boldsymbol{\alpha_A}$, $\boldsymbol{\alpha_B}$, $\boldsymbol{\alpha_C}$, $\boldsymbol{\alpha_D}$, $\boldsymbol{\alpha_E}$. The method of determining the angles and their vertices is presented in Fig. 1. This also enables the identification of the adopted phase division.

It was decided to reduce the statistical analysis of the results to determine the median (Me) as well as the minimum (min) and the maximum (max) values for all variables.

RESULTS

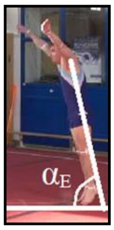
In Fig. 2, the total time to perform both analysed back handsprings is presented. As it can be seen, in the case of RBhS, the duration was shorter. The median values noted for Bh and RBhS differed by more than 0.2s.

A - beginning of first flight phase

B - completion of first flight phase

C - beginning of second flight phase

D - completion of second flight phase



E - completion of support phase on lower limbs

Figure 1. Method of determining instantaneous value of the trunk angle at nodal points separating individual phases of movement.

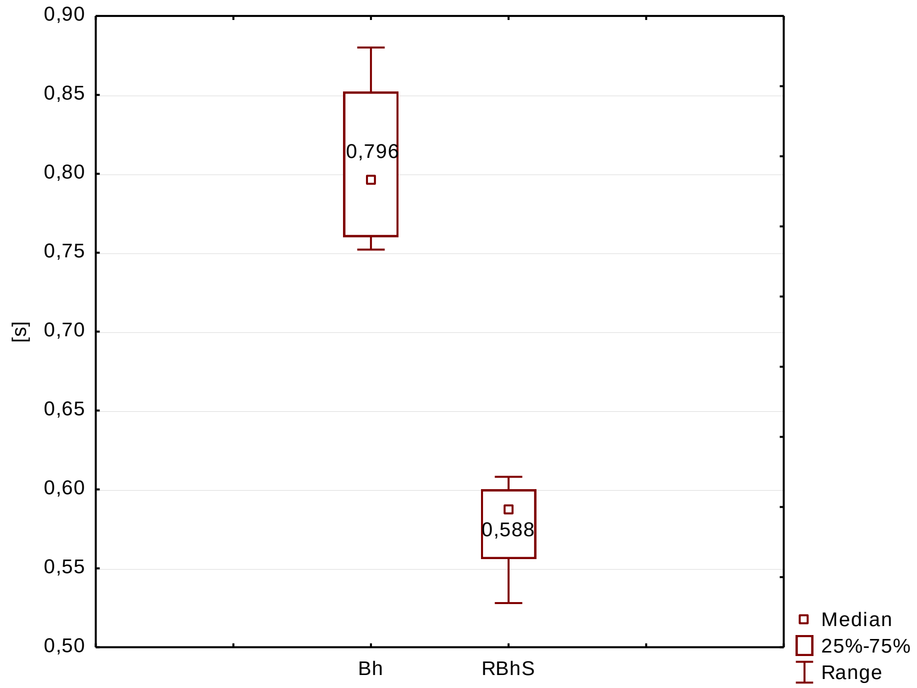


Figure 2. Total time (t_t) to perform a back handspring from standing position (Bh) and back handspring in the movement sequence (RBhS); [s].

Table 1

Duration of successive phases of back handspring from standing position (Bh) and back handspring in the movement sequence (RBhS) (t_{FI} - first phase of flight; t_{SUI} - support on the upper limbs; t_{FII} - second phase of flight; t_{SLI} - support on lower limbs).

Gymnastic element	t_{FI}		t_{SUI}		t_{FII}		t_{SLI}	
	Me	(min-max)	Me	(min-max)	Me	(min-max)	Me	(min-max)
	[s]		[s]		[s]		[s]	
Bh	0.21	(0.15 – 0.23)	0.27	(0.22 – 0.30)	0.18	(0.17 – 0.24)	0.15	(0.13 – 0.17)
RBhS	0.16	(0.14 – 0.17)	0.17	(0.15 – 0.18)	0.11	(0.10 – 0.13)	0.14	(0.13 – 0.14)

Table 2
Competitors' instantaneous CG velocity (x - horizontal, y - vertical and resultant) at the nodal points of the back handspring from standing position (Bh) and back handspring in the movement sequence (RBhS) (A, B - beginning and end of the first flight phase; C, D - beginning and end of the second flight phase, E - completion of the lower limb support phase).

Gymnastic element	A		B		C		D		E	
	v_{Ax}		v_{Bx}		v_{Cx}		v_{Dx}		v_{Ex}	
	Me	(min-max)	Me	(min-max)	Me	(min-max)	Me	(min-max)	Me	(min-max)
	[m/s]		[m/s]		[m/s]		[m/s]		[m/s]	
Bh	1.94	(1.57 – 2.04)	1.67	(1.20 – 1.85)	1.62	(1.31 – 2.28)	1.53	(1.16 – 1.75)	0.80	(0.36 – 2.01)
RBhS	4.85	(4.48 – 5.82)	4.43	(4.07 – 4.61)	4.32	(3.81 – 4.98)	4.29	(3.70 – 5.40)	2.24	(1.94 – 2.82)
	v_{Ay}		v_{By}		v_{Cy}		v_{Dy}		v_{Ey}	
	Me	(min-max)	Me	(min-max)	Me	(min-max)	Me	(min-max)	Me	(min-max)
	[m/s]		[m/s]		[m/s]		[m/s]		[m/s]	
Bh	0.68	(0.49 – 1.53)	-0.62	(-0.74 – 0.38)	0.11	(-0.08 – 0.38)	-1.73	(-1.55 – -1.88)	3.27	(2.65 – 3.66)
RBhS	0.78	(0.23 – 1.47)	-0.36	(-0.46 – -0.19)	-0.48	(-0.63 – -0.28)	-1.41	(-1.12 – -1.98)	4.79	(3.10 – 5.09)
	v_A		v_B		v_C		v_D		v_E	
	Me	(min-max)	Me	(min-max)	Me	(min-max)	Me	(min-max)	Me	(min-max)
	[m/s]		[m/s]		[m/s]		[m/s]		[m/s]	
Bh	2.06	(1.64 – 2.55)	1.73	(1.41 – 1.98)	1.62	(1.36 – 2.29)	2.27	(2.21 – 2.40)	3.57	(2.69 – 3.82)
RBhS	4.90	(4.51 – 6.00)	4.44	(4.09 – 4.62)	4.34	(3.86 – 4.99)	4.61	(3.87 – 5.60)	5.36	(3.90 – 5.51)

Table 3
Height of gymnasts' centre of gravity (h_{CG}) at the boundaries of movement phases during the back handspring from standing position (Bh) and back handspring in the movement sequence (RBhS); adopted symbols - as in Tab. 2.

Gymnastic element	A		B		C		D		E	
	h_{ACG}		h_{BCG}		h_{CCG}		h_{DCG}		h_{ECG}	
	Me	(min-max)	Me	(min-max)	Me	(min-max)	Me	(min-max)	Me	(min-max)
	[m]		[m]		[m]		[m]		[m]	
Bh	0.86	(0.79 – 0.91)	0.91	(0.85 – 0.98)	0.98	(0.97 – 1.01)	0.82	(0.81 – 0.82)	1.03	(1.00 – 1.07)
RBhS	0.91	(0.87 – 0.94)	0.95	(0.92 – 0.99)	0.92	(0.88 – 0.92)	0.80	(0.75 – 0.82)	1.09	(1.06 – 1.13)

Table 4
Displacement in the first (L_{FI}) and second (L_{FII}) flight phase during back handspring from standing position (Bh) and back handspring in the movement sequence (RBhS).

Gymnastic element	L_{FI}		L_{FII}	
	Me	(min-max)	Me	(min-max)
	[m]		[m]	
Bh	1.06	(0.83 – 1.19)	0.90	(0.64 – 1.11)
RBhS	1.40	(1.10 – 1.61)	1.49	(1.35 – 1.74)

Table 5
Values of angle between trunk and ground (α_A, α_B, α_C, α_D, α_E) during back handspring from standing position (Bh) and back handspring in the movement sequence (RBhS) recorded at the boundaries of the movement phases; adopted symbols - as in Tab. 2.

Gymnastic element	A		B		C		D		E	
	α_A		α_B		α_C		α_D		α_E	
	Me	(min-max)	Me	(min-max)	Me	(min-max)	Me	(min-max)	Me	(min-max)
	[deg]		[deg]		[deg]		[deg]		[deg]	
Bh	28	(21 – 30)	63	(58 – 89)	64	(48 – 86)	21	(15 – 23)	53	(47 – 56)
RBhS	34	(28 – 36)	65	(63 – 75)	50	(44 – 51)	18	(16 – 28)	81	(78 – 98)

Data from Tab. 1 indicate that not only was the overall time to perform the back handspring in the RBhS movement sequence shorter than that of Bh but also that all corresponding phases of the compared gymnastic elements were shorter for the back handspring after the round off. Our analysis of Me value shows that the greatest differentiation was related to the support on the upper limbs (t_{SUl}), and the smallest to the support on the lower limbs (t_{SLl}). In the first case, the difference was 0.1s, and in the second, 0.01s. The described differences for the first and the second flight phases ranged from 0.05s to 0.07s.

In Tab. 2, the characteristics of changes in the instantaneous CG velocity of the competitors at the nodal points Bh and RBhS are presented. These changes were described both in relation to all components of the velocity vector (horizontal and vertical) and the resultant vector.

In Bh and RBhS, the horizontal component (v_x) decreased in value from the beginning of the first flight phase (A) up to the end of the support phase on the lower limbs (E). For Bh, median v_x values decreased from 1.94m/s to 0.8m/s, while for RBhS, this value fell from 4.85m/s to 2.24m/s. As expected, the values of this variable were always higher in RBhS. A slightly different characteristic was found for the vertical component of velocity (v_y). The obtained results indicate that it changed not only the value but also its return. Basically, with one exception (beginning of the second flight phase, C), the sense of the vertical component at the boundaries of the movement phases was identical for both Bh and RBhS. In the case of the absolute values of the discussed variable (v_y), it turned out that both for Bh and RBhS, they were the highest at the end of the support phase on the lower limbs (E): 3.27m/s and 4.79m/s, respectively. Data from Tab. 2 additionally show that v_y values exceeding 1m/s were also recorded at the end of the second flight phase (D). This indicates that the highest values of the vertical component of CG velocity were recorded in the final part of the analysed gymnastic elements (from the end of the second flight phase). In turn, the lowest values of this velocity component (v_y) were recorded from the end of the first flight phase to the beginning of the second one (B and C), i.e., the middle part of the analysed elements (Bh and RBhS). The presented results demonstrate that the vertical CG velocity recorded at the beginning of the first flight phase (A) was 0.1m/s higher during the round off – back handspring – backward stretched somersault.

The resultant CG velocity of the athletes (v), recorded in the corresponding so-called nodal points of the back handspring, was always higher in RBhS than in Bh. The differences in the median values of this variable ranged from 1.8m/s (end of movement, E) to about 2.8m/s (beginning of movement, A). Data presented in Tab. 2 indicate that in the case of Bh and RBhS, the nature of changes in the resultant velocity was similar. At the beginning of the first flight phase (A), it was slightly higher than the values recorded chronologically later (the end of the first flight phase and the beginning of the second one, B and C). Finally, from the end of the second flight phase (D), the resultant velocity of the athletes increased, reaching its maximum value at the end of the support phase on the lower limbs (E).

In Tab. 3, information is provided on the athletes' height of centre of gravity (h_{CG}) at the boundary between the various phases of movement when performing back handsprings. Medians of this variable noted for Bh and RBhS varied from 2cm to 6cm. It can be noticed that the gymnasts performing RBhS in the initial and final phases (their limits - respectively: A, B and E) assumed a position in which the centre of gravity was higher than in the case of Bh. An opposite observation can be made in relation to the nodal points marking the beginning and end of the second flight phase (C and D) - in this case, higher h_{CG} values were noted for Bh.

In Tab. 4, the displacement of gymnasts was characterised in each of the two flight phases during the back handspring. As mentioned, this distance was marked by a horizontal line between the take-off and the landing site. The reported values indicate that the RBhS technique is different from Bh. For both indicators (L_{FI} and L_{FII}), the median values were higher for RBhS. Their absolute differences were 0.34m (L_{FI}) and 0.59m (L_{FII}). It is also worth adding that in the case of Bh, displacement in the second flight phase was smaller than in the first phase by 0.16m. On the other hand, in RBhS, the displacement in the second flight phase was greater by 0.09m than in the first one.

In accordance with the developed methodology, the values of the angle between the trunk and the ground were determined during the performance of Bh and RBhS. The effects of this part of the video recorded material analysis are presented in Tab. 5. The main differences concern the positioning of the gymnast's body at the beginning of the second flight phase (α_C) and at the end of the support phase on the lower limbs (α_E). The accumulated values show that when the second flight phase (α_C) began, higher values of the angle in question (by 14°) were recorded for Bh. At the end of the support phase on the lower limbs, the median values of α_E were higher for RBhS by 28°. The value of 81° recorded in this case indicates assuming a more straightened body in this position while performing RBhS. The angular values characterising the position of the trunk in relation to the ground at the beginning and end of the first flight phase (α_A, α_B) and at the end of the second flight phase (α_D) were similar in both types of back handsprings (Bh and RBhS).

DISCUSSION

The obtained results showed differences between two techniques of performing the back handspring: one began from a standing position (Bh) while the other was performed in the motor sequence: round off – back handspring – backward stretched somersault (RBhS). Data was also obtained on the method of performing the back handspring following the round off, which allowed the gymnasts to safely perform the backward stretched somersault, along with a flawless landing on the lower limbs referred to as the "stick landing" (Marinsek & Cuk, 2010).

As predicted, the RBhS demonstrated shorter durations of all movement phases (t_{FI}, t_{SUl}, t_{FII}, t_{SLl}) which also resulted in a shorter total time (t_t). The greatest differences in duration of the individual Bh and RBhS phases were noted for support on the upper limbs (t_{SUl}), while the smallest for support on the lower limbs (t_{SLl}). The horizontal component of the velocity for all athletes had direct impact on shorter execution times of all phases and the total time of movement in RBhS, which assumed higher values in the back handspring preceded by a run up and round off. The greatest differences between Bh and RBhS were noted at the beginning of the first flight phase (v_{Ax}). It was observed that in both variants of the back handspring, the value of CG velocity in the horizontal axis decreases from the beginning of the analysed movement until its completion (v_{Ax} – v_{Ex}). Penitente et al. (2011), analysing the back handspring performed after a round off by female artistic gymnasts at various levels of advancement, also noted the highest value for the horizontal CG velocity component during the take-off performed with the lower limbs (point A of this study). At the same time, however, they indicated a slightly higher value of this velocity in the examined competitors during the push-off performed with the arms preceding the second flight phase (point C in this work) compared to the beginning of the support phase on the upper limbs (point B in this paper).

The smallest differences between the values of the horizontal velocity component for Bh and RBhS were obtained at the end of the support phase on the lower limbs (v_{Ex}). At the same time, at the end of this phase, the greatest differences were observed between values of the vertical component of athletes' CG velocity (v_{Ey}) recorded for both back handsprings. Clearly smaller differences of this variable can be noted: at the beginning (v_{Ay}) and the end of the first flight phase (v_{By}), as well as and at the end of the second flight phase (v_{Dy}). In turn, at the beginning of the second flight phase, different returns regarding the vector of the vertical velocity component (v_{Cy}) were observed. This return was positive for Bh and negative for RBhS. This indicates that in Bh, at the beginning of this phase of flight, the competitors' CG moves up, and in RBhS, it goes down. Penitente et al. (2011) also observed different turns of the CG velocity vector in the vertical axis. However, the explanation for the various velocity turns in the vertical axis at this nodal point requires additional experiments. Nonetheless, it may be assumed that the negative return of this vector in RBhS results from higher rotational velocity in the flexion movement of the lower limbs in the hip joints. It is possible that this could also result in a smaller value of the angle between the trunk and the ground (α_C) in this version of the back handspring.

It is worth noting that the values of the velocity components obtained by the authors of this study at the end of the support phase on the lower limbs in RBhS (v_{Ex} and v_{Ey}, respectively: 2.24m/s and 4.79m/s) guaranteed the athletes performance of the planned backward stretched somersault. However, the volatility of the values regarding these indicators may be significant, as evidenced by the data presented in Tab. 2 and the collected literature. Compared to the present study, in their analyses, Mkaouer et al. (2013) noted a much higher value of horizontal velocity (3.743m/s) and a slightly lower value of vertical velocity (4.500m/s). These differences may result from technical differences in the execution of the described movement. They may also be related to the fact that the athletes tested by Mkaouer et al. (2013) performed gymnastic elements on an acrobatic track which could have different (better) elastic properties.

In both analysed gymnastic elements (Bh and RBhS), the general nature of changes in the resultant velocity and its vertical component were quite similar. Taking into account their absolute values (excluding the sense of v_y), it can be seen that they increase from the beginning of the movement to its completion. Additionally, they adopt their local minimal values between the first and the second flight phase. The described similarity may result from the necessity to perform the back handspring in such a way that moving the body upwards above the spring floor does not excessively restrict movement along the floor. Therefore, until the completion of the second Bh and RBhS flight phases, the value of the horizontal velocity of the athletes was greater than the vertical velocity. And it is this component (v_x) that more clearly influenced the resultant velocity. The situation changed at the end of the support phase on the lower limbs. At this point, the vertical velocity of competitors (v_y) reached its maximum and was significantly higher than the horizontal velocity.

Although the horizontal velocity of the athletes performing Bh and RBhS decreased from the beginning of the movement until its end, its value was sufficient for the effective movement of the gymnast. Until the completion of the support phase on the lower limbs, it had a major impact on the quality of technical performance of the back handspring, further enabling the performance of the round off – back handspring – backward stretched somersault.

Characteristics of changes in the height of athletes' CG position (h_{ACG} – h_{ECG}) during the back handspring from standing position and the back handspring in the movement sequence, were similar.

The total range of vertical CG oscillations, however, was greater in RBhS. Comparing the two methods of performing the back handspring, it can be seen that the gymnasts obtained a higher CG position at the beginning (h_{CCG}) and also at the end of the second flight phase (h_{DCG}) in Bh. At the remaining nodal points (h_{ACG}, h_{BCG} and h_{ECG}), CG was higher in RBhS.

As it is known, in each of the two phases of flight during the back handspring, the horizontal displacement of the athletes is related to the height of the CG position and its horizontal velocity (v_x). The results of the authors' research indicate that the back handspring that fulfilled the transition skill (RBhS) was characterised by a longer second (L_{FII}) and shorter first flight phase (L_{FI}). In this handspring, greater displacements were also noticed in flight phases (L_{FI} and L_{FII}) than in Bh. In turn, Bh was performed by athletes with a longer first (L_{FI}) and shorter second (L_{FII}) flight phase. Opposite proportions to the results recorded for Bh were obtained by Lovecchio et al. (2013), who also performed a kinematic analysis of the back handspring from a standing position (the study including male and female gymnasts). In the opinion of these authors, the reasons for the shorter first flight phase can be seen in the use of greater spine hyperextension during this phase of movement.

As already mentioned, the height of the CG position for both back handsprings was similar. At the same time, the values for the horizontal component of the velocity of movement in RBhS were higher than those recorded in Bh (even by 2.9 m/s). The results also show that at the beginning of the second flight phase, the velocity was lower (by 10 and 16%, respectively: RBhS and Bh) than that recorded at the beginning of the first flight phase. The combination of these facts can be the basis for the claim that the velocity value for the flight distance is the key, provided that the optimal CG altitude is maintained.

In both types of back handsprings, at the beginning and the end of the first flight phase and at the end of the second flight phase (α_A, α_B, α_D, respectively), the values of the angles between the trunk and the ground were similar. The angle α_C determined for the beginning of the second flight phase indicates that in RBhS, the trunk of the gymnasts was more inclined toward the floor than in Bh. The greatest differences were observed at the end of the support phase on the lower limbs (α_E), which was certainly related to various motor tasks performed immediately after Bh and RBhS. Smaller values of this angle were observed in Bh. It is worth noting that the take-off angle (α_E), which allowed the gymnasts to do the backward stretched somersault (81°), was similar to the results obtained by other authors (Mkaouer et al. 2013).

In gymnastics training, it is possible to interfere with the technique of back handspring initiated from a stance. This interference is implemented for the performance of this element in an acrobatic sequence (after a round-off). It is effective to make use of the assistance of an experienced coach who can support and guide the gymnast during the movement. Performing the back handspring on equipment with greater elasticity (e.g., standard trampoline or tumble track) may also be helpful. The obtained results show that the exercises carried out independently or with coach's assistance should enable athletes to gradually become used to the increased speed of movement (the shorter time of all phases of the back handspring) as well as longer first and second flight phases. Our analysis of the angular position of the trunk in relation to the ground led us to note that it is necessary to reduce the value of this angle at the beginning of the second flight phase. On the other hand, for the performance of the backward stretched somersault, the trunk must be positioned closer to the vertical axis during the final part of the support phase ending on the lower limbs. The obtained results also indicate other differences between the two methods of performing the back handspring. However, due to the small number of participants, the possibility of formulating unambiguous conclusions requires further research with a larger sample size.

CONCLUSIONS

The conducted research indicated the differences between the selected kinematic variables of the back handspring from standing position and this movement throughout the transition. In the process of technical training, it should be noted that the back handspring performed in the movement sequence ending in a backward stretched somersault requires a higher resultant velocity of the gymnast than in the case of a back handspring started from a standing position and ending in a rebound and then landing. Obviously, decreasing the horizontal velocity component in both ways of performing the back handspring in the subsequent stages of movement should be considered. However, in RBhS, its value should be greater than in Bh.

In advanced artistic gymnasts, the beginning of the second flight phase in Bh is characterised by a positive return of the vertical velocity vector CG (v_{Cy}). However, in RBhS, the sense of this vector may change. Therefore, in the handspring performed in the movement sequence (round off – back handspring – backward stretched somersault), there is no scientific justification for the competitors to try to achieve a positive return in vertical velocity during this phase.

In RBhS, the greater horizontal velocity component contributed to the reduction in the duration of all specified phases of the back handspring, and thus, to obtain a shorter time of the total movement.

The differences between the height of the gymnasts' CG positioning (h_{CG}) in Bh and RBhS seem to be insignificant. The authors' own observations showed that in RBhS, the competitors' CG was slightly higher at the beginning (h_{ACG}) and at the end of the first flight phase (h_{BCG}), as well as at the end of the support phase on the lower limbs (h_{ECG}). However, it was lower at the beginning (h_{CCG}) and at the end of the second flight phase (h_{DCG}).

When comparing the two methods of performing the back handspring, it should be stated that RBhS requires longer both flight phases (L_{FI} and L_{FII}). Nevertheless, on the basis of the obtained results, it seems important to reverse the proportion of flight phases - in RBhS, the second flight phase (L_{FII}) should be longer than the first one (L_{FI}).

In both types of the handspring, the position of the trunk in relation to the ground is similar at the beginning and the end of the first flight phase, and also at the end of the second flight phase (successively α_A, α_B, α_D). In RBhS, at the beginning of the second flight phase, the trunk should be at a lower angle in relation to the ground (α_C), and lower at the end of the support phase on the lower limbs (α_E).

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CONCERNS ABOUT STRENGTH TESTS IN GYMNASTICS: A SYSTEMATIC REVIEW

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Abstract
This study aims to analyze the specialized literature on the protocols, instruments, and techniques used to train and assess strength in gymnastics practitioners or athletes who are represented by the International Gymnastics Federation (Fédération Internationale de Gymnastique – FIG). The systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Systematic searches on the PubMed, Web of Science, Scopus, LILACS, SciELO, and SPORTDiscus databases were conducted using the following keywords: "assessment," OR "measurement," OR "evaluation," AND "child," OR "young," OR "adolesc*," AND "athlete*," OR "practitioner," OR "gymnast*," AND "gymnastic*," OR "trampoline," AND "muscle strength," OR "muscle power," OR "strength," OR "power," OR "concentric," OR "performance," OR "explosive strength," OR "motor tests". Studies included in this review address the assessment and training of strength in gymnastics or athletes. Fourteen studies assessing the physical capacity strength in practitioners or gymnastic athletes were the basis of this systematic review. These articles describe low-cost, easy-to-apply protocols and instruments performed in the training gym. The included articles focused on assessing the strength level of adolescent male and female practitioners or athletes for talent selection and detection, as well as lesion reduction. Despite the benefits of strength training, such as better performance and fewer injuries, in general, strength is not regularly assessed. Only studies encompassing artistic and rhythmic gymnastics were found.*

Keywords: g*ymnastic, trampoline, muscle strength, motor tests.*

INTRODUCTION

According to the International Gymnastics Federation (*Fédération Internationale de Gymnastique* – FIG) gymnastics modalities include acrobatic gymnastics, aerobic gymnastics, artistic gymnastics for women, artistic gymnastics for men, rhythmic gymnastics, trampoline gymnastics, gymnastics for all, as well as parkour. Each sport style has its own previously defined technical regulation and punctuation code (rules) (FIG, 2021). Jumping movements, acrobatics, spins and precise landings are common motor demands in gymnastics sport modalities (Abuwarda, 2020; Hall, Bishop & Gee, 2016). Therefore, gymnastics performance requires substantial flexibility, strength, power, coordination, rhythm, agility, and endurance (Batista, Garganta & Ávila-Carvalho, 2017; Malina et al., 2013; Sleeper, Kenyon, Elliott & Cheng, 2016; Russo et al., 2021).

In the context of gymnastics sport characteristics, performing routines is related to important requests in terms of muscle strength, power, and endurance (Kerr, Heyden, Barr, Klossner & Dompier, 2015). Indeed, muscle strength and power are essential to support increasing physical performance, as well as motor skills improvement (Cooper et al., 2015). Considering competitive circumstances, these muscle characteristics are important conditions to reach high levels of athletic practice in artistic (AG) and rhythmic gymnastics (RG), in addition to being involved with jumping and pivot movements (Batista, Garganta & Ávila-Carvalho, 2017; Mkaouer, Hammoudi-Nassib, Amara & Chaabène, 2018; Hammoudi-Nassib, Mkaouer, Riahi, Wali & Nassib, 2020). Indeed, physical fitness related to health and/or sport performance is directly associated with muscle strength improvement (French et al., 2004), and measuring muscle strength has been considered an important performance parameter in sports (Mohamed, 2011).

Based on this, training programs should include prescribed specific training and control actions to improve sport performance as organizational strategy for both aerobic and anaerobic demands (Batista, Garganta & Ávila-Carvalho, 2017; French et al., 2004). Gymnastics training methods and analyses need to be better clarified since they have been used not only for talent detection but also for improving athletic performance (Batista, Garganta & Ávila-Carvalho, 2017; Sleeper, Kenyon & Casey, 2012; Sleeper, Kenyon, Elliott & Cheng, 2016). Previously, while some studies documented biomechanical aspects (Kochanowicz et al., 2016; Shärer, Haller, Taube & Hubner, 2019), other investigations reported performance skills associated with movement demands on gymnastics apparatus (Aleksic-Veljkovic, Djurovic, Dimic, Mujanovic & Zivicic-Markovic, 2016; Andreyeva, 2013). Regarding strength assessment in gymnastics modalities, the Gymnastics Functional Measurement Tool (GFMT) (USA Gymnastics, 2014; Sleeper, Kenyon, Casey, 2012; Sleeper, Kenyon, Elliott & Cheng, 2016), the Talent Opportunity Program (TOPS) (Bacciotti, Baxter-Jones, Gaya & Maia, 2019) and FIG analyses (Batista, Garganta & Ávila-Carvalho, 2019; Mkaouer, Hammoudi-Nassib, Amara & Chaabène, 2018) are the most used analytical methods, as well as dynamometry tests (Russel, Quinney, Hazlett & Hillis, 1995) and jump tests (French et al., 2004; Dobrijevik, Moskovljevic, Markovic & Dabovic, 2018).

However, the presented methods have been mainly used for identifying and selecting sport talents. Although monitoring training effects is important in gymnastics, the description of methods and respective uses are yet to be defined (Bacciotti, Baxter-Jones, Gaya & Maia, 2019). Indeed, assessing athletic performance in gymnastics is a fundamental step to indicate progress and potential for practice, hence the importance of knowing which tests are most applied and useful to trainers for strength training. Therefore, this study aims to analyze protocols, instruments, and techniques used to train and assess strength in gymnastics practitioners or athletes who are represented by the FIG.

METHODS

The systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and the protocol was registered with PROSPERO.

The following databases were used: PubMed, Web of Science, Scopus, LILACS, SciELO, and SPORTDiscus. The following search terms were used: “assessment,” OR “measurement,” OR “evaluation,” AND “child*,” OR “young,” OR “adolesc*,” AND “athlete*,” OR “practitioner,” OR “gymnast*,” AND “gymnastic*,” OR “trampoline,” AND “muscle strength,” OR “muscle power,” OR “strength,” OR “power,” OR “concentric,” OR “performance,” OR “explosive strength,” OR “motor tests”.

Original articles published in English or Portuguese until March 2021 were eligible for inclusion. Additionally, the authors also considered studies that: sampled both sexes; had at least one of the modalities represented by the International Gymnastics Federation (*Fédération Internationale de Gymnastique* – FIG); assessed muscle strength in gymnasts; included clear description of methods and instruments, and/or were performed at the training site. Studies were excluded if the results were not stratified by sex; published after March 2021, or had a sample composed by elderly subjects, subjects with physical or mental disabilities, as well as those that did not aim to assess strength as part of conditioning. The bibliography of each study included was also screened by title to identify any additional studies suitable for gathering background information.

Abstracts using the terms and bases described above were independently reviewed by two authors who selected the studies according to their relevance regarding the subject that met all the inclusion criteria. Both researchers compared the selections and addressed the identified differences with the senior author input. Each article was then reviewed in its entirety by one or two co-authors, relevant information was extracted, and discrepancies were solved by discussion between the researchers. EndNote was used as a search and selection manager.

RESULTS

The article selection process is detailed in the flowchart (Figure 1). In general, 8240 studies were identified, out of which 25 remained after removing duplicates and reading titles and abstracts. After full reading, 11 articles were removed for not meeting the inclusion criteria. Finally, 14 articles met all the criteria and were used as the basis for this systematic review.

In this study the results are presented in tables. Table 1 presents a summary of eligible studies, extracting information on authors, study design and year, gymnastic modality, sample characteristics and country, capacity surveyed, body segments, and strength tests. Table 2 shows information regarding training techniques, modality, and authors and year.

The titles of the evaluated works mentioned at least one of the types of gymnastics constituting the FIG programs, with studies addressing artistic gymnastics (male athletes: 3; female athletes: 6) and rhythmic gymnastics (n=5) being predominant. The search did not produce any studies on other types of competitive gymnastics.

Regarding the characteristics of the sample, most of the studies were composed of elite gymnasts (n=6), followed by comparative studies between elite and non-elite groups (n=4), in the age range of 6 to 22 years (French et al., 2004; Sleeper, Kenyon & Casey, 2012). Most studies used a cross-sectional design (n=8), and six had a longitudinal design.

For the assessments of muscle strength, only studies that were carried out at the training site were selected to minimize the cost and take advantage of the practical context. In the analysis of physical fitness and/or strength, the most cited physical skills were strength (isometric, dynamics, resistance, and explosive; 100% of selected studies), flexibility (42.8%), speed (21.4%), balance (14.2%) and agility (7.1%), of upper and lower limbs, highlighting Russo et al. (2020) emphasizing AG and RG. Regarding the tests used to assess muscle strength, there is a predominance of vertical jumps (countermovement and squat jumps) (n=6), FIG battery (n=3), Gymnastics Functional

Measurement Tool (GFMT) (n=2), and the Talent Opportunity Program (TOPS) (n=1).

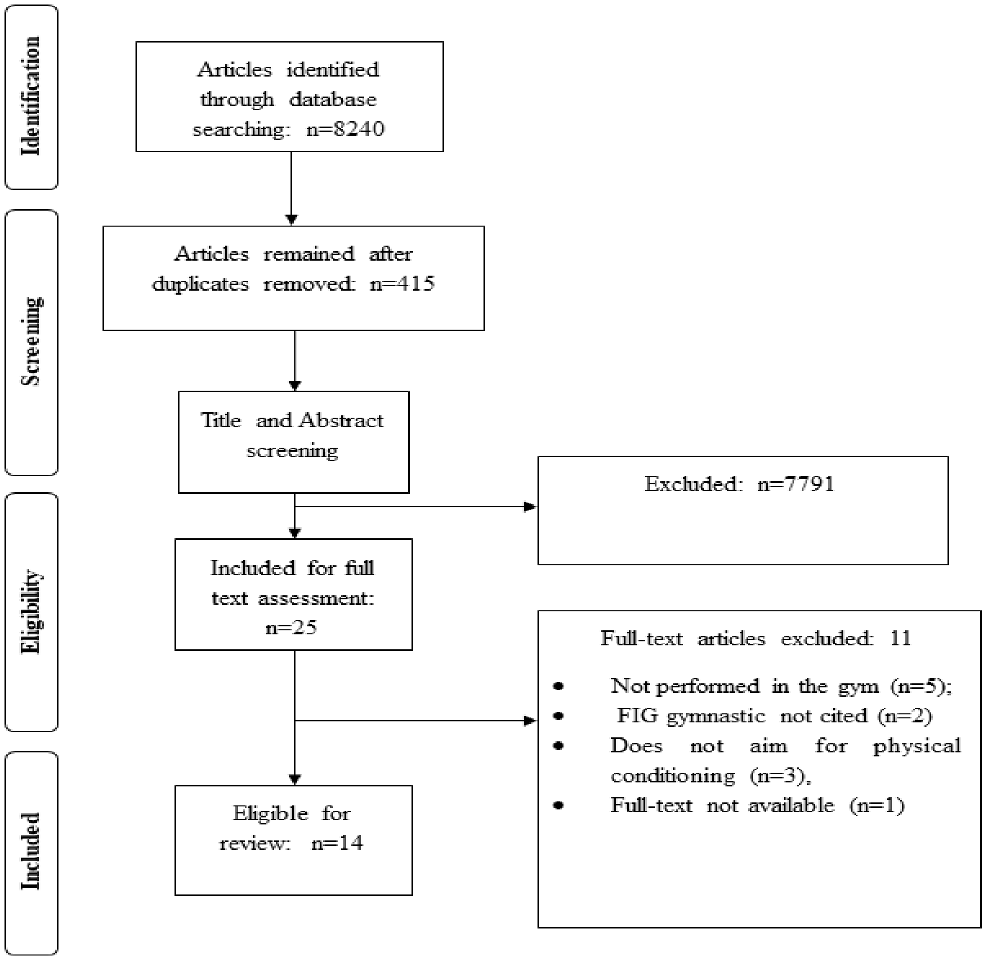

Figure 1. Flow chart describing the identification of articles related.

Table 1
Summary of the studies that assess strength in gymnasts.

AUTHORS, STUDY DESING AND YEAR	GYMNASTIC MODALITY	SAMPLE AND COUNTRY	CAPACITIES ASSESSED	BODY SEGMENTS	STRENGTH TESTS
French, et al. Longitudinal (2004)	Artistic Gymnastics (AG)	20 female gymnasts Age: 18-22 years Country: EUA	Peak power output and time to peak power	Lower limbs	2 tests: Two vertical jump protocols (countermovement and squat jumps)
Douda, et al. Longitudinal (2007)	Rhythmic Gymnastics (RG)	Sample:152 female 71 rhythmic gymnastics (RG) athletes 81 non-athletes (control) Age: 8-17 years	Speed, muscular strength, jumping ability, explosive power, and flexibility	Lower limbs	2 tests: Standing long jump Countermovement jump test

		Country: Greece			
Mohamed. Longitudinal (2011)	Artistic gymnastics (AG)	Sample: Two groups, an experimental group consisting of (7) elite female gymnasts, and a control group consisting of (4) elite gymnasts Age: 11 ± 1,36 years Country: Egypt	Strength, power and performance level	Legs	4 tests: Vertical jump test Seated medicine ball throw Leg strength back strength by dynamometer Dynamic strength test, Performance levels of landing in floor exercise
Sleeper, Kenyon, Casey. Cross-sectional (2012)	Artistic gymnastics (AG)	Sample:105 competitive female gymnasts Age: 6-18 years Country: EUA	Strength, power, upper and lower extremity power, abdominal strength, hip flexor strength, flexibility, and grip strength	Upper and lower limbs and trunk	Battery tests GFMT 7 tests: Rope climb test Jump test Hanging pikes test Over-grip pull-up test Push-up test 20-yard sprint test Handstand test
Gateva. Cross-sectional (2013)	Rhythmic gymnastics (RG)	Sample: 120 rhythmic gymnasts Age: 10-19 years Country: Bulgária	Strength abilities	Abdomen, back and legs	3 tests: Sit ups Back strength Vertical jump
Hall, Bishop, Gee. Longitudinal (2016)	Artistic gymnastics (AG)	Sample: 20 female gymnasts Age: 12,5 ± 1,67 years Country: United Kingdom	Explosive power	Lower limbs	1 test: Countermovement jump test
Sawczyn, et al. Longitudinal (2016)	Artistic gymnastics (AG)	Sample: 24 male gymnasts Age: 12-13 years Country: Poland	Maximum static strength (isometric) and dynamic strength	Upper limbs	2 tests: Maximum static strength (isometric Fmax peak) Dynamic (peak of force) established based on the ergometer and ergo power

					dynamometric system (Globus, Italy)
Sleeper, et al. Cross-sectional (2016)	Artistic gymnastics (AG)	Sample: 83 male gymnasts Age: 7-18 years Country: EUA	Flexibility, strength, power, agility and balance	Multiple body segments	Battery tests MGFMT 6 tests: Rings hold test Vertical jump test Hanging pikes test Over-grip pull-up test Handstand push-up test Handstand test
Batista, et al. Cross-sectional (2017)	Rhythmic gymnastics (RG)	Sample: 68 rhytmic gymnasts Age: 11,7 ± 0,6 years Country: Portugal	Resistance strength, muscular endurance and explosive strength	Abdomen and legs	FIG test battery 6 tests: Front power kick Back power kick Partial trunk elevations Partial curl-ups Rope skipping Vertical jump test
Dobrijevic´ et al. Longitudinal (2018)	Rhythmic gymnastics (RG)	Sample: 47 rhytmic gymnasts Age: 7-9 years Country: Serbia	Explosive strength	Legs	2 tests: Countermovement jump test Standing long jump test
Mkaouer, et al. Cross-sectional (2018)	Artistic gymnastics (AG)	Sample: 50 male gymnasts Age: 11,03 ± 0,95 years Country: Tunisia	Strength, flexibility, speed, endurance, and power	Upper and lower limbs and trunk	FIG test battery 4 tests: Double legs circle (on mushroom) V lever (legs to or over vertical) Tucked top planche (body horizontal through shoulder, arms stretched) Back hang scale (body horizontal, legs and arms stretched)
Bacciotti, et al. Cross-sectional (2019)	Artistic gymnastics (AG)	Sample: 249 famale gymnasts Age: 9-20 years Country: Brazil	Strength, flexibility and explosive strength	Upper and lower limbs and trunk	TOPS 3 tests: Rope climb Press handstand Leg lift

Batista, et al. Cross-sectional (2019)	Rhythmic gymnastics (RG)	Sample: 164 rhytmic gymnasts Three different levels: Base age 13.5±2.3; 1st division age 13.6±2.1; Elite age 14.8±1.8 years Country: Portugal	Resistance strength, muscular endurance and explosive strength	Abdomen and legs	FIG test battery 6 tests: Front power kick Back power kick Partial trunk elevations Partial curl-ups Rope skipping Vertical jump test
Russo, et al. Cross-sectional (2020)	Artistic gymnastics (AG) and rhythmic gymnastics (RG)	Sample: 45 volunteer female artistic and rhythmic gymnastics Age: 10-12 years Country: Italy	Joints mobility, balance, explosive strength, speed, and endurance	Lower limbs	1 test: Long jump test

Table 2
Training techniques used for strength capacity in gymnasts.

TRAINING TECHNIQUES	MODALITY	AUTHORS / YEAR
Combined conditioning	Artistic gymnastics (AG)	French, et al. (2004) Mohamed (2011)
Increasing training load for specific movements	Rhythmic gymnastics (RG)	Douda, et al. (2007)
Plyometrics	Artistic gymnastics (AG)	Hall, Bishop, Gee (2016)
Specific suspension trainig	Artistic gymnastics (AG)	Sawczyn, et al. (2016)
Proprioceptive training	Rhythmic gymnastics (RG)	Dobrijevic, et al. (2018)

For the training techniques applied to improve strength, we verified studies targeting upper limbs (n=1) and mostly lower limbs (n=5), using proprioceptive training program (Dobrijevik, Moskovljevic, Markovic & Dabovic, 2018), conditioning combining strength/power/endurance training (French et al., 2004; Mohamed, 2011), program with increased training load (volume and intensity) of modality specific movements (Douda, Avloniti, Kasabalis & Tokmakidis, 2007), plyometrics (Hall, Bishop & Gee, 2016), or specific suspension training (Sawkzyn et al., 2016). However, we observed that eight of the selected works (57.2%) performed only tests to assess and quantify the strength capacities of gymnasts.

DISCUSSION

This study aimed to analyze the specialized literature on the protocols, instruments, and techniques used for training and assessing strength in gymnastics practitioners or athletes based on the FIG reports. The studies included in this review provided information about different tests used to measure strength in gymnastic modalities. This information will be discussed below based on the analyses of the results.

In general, the studies were carried out with gymnasts from artistic (9 articles) and rhythmic gymnastics (5 articles). The absence of studies on other types of gymnastics may be associated with their relatively recent inclusion in the FIG (aerobic gymnastics included in 1995; acrobatic gymnastics in 1998; trampoline gymnastics in 1999; and parkour in 2017) (FIG, 2021), or less publicity by the media. After the final reading of the selected works, we found a study addressing strength training in the gymnastics-for-all modality which is not competitive; however, it does not mention the city where the study was carried out (Karagiani, Donti, Katsikas & Bogdanis, 2020).

In general, there is a greater interest in studying elite athletes as researchers seek to identify variables associated with the gymnasts' motor and competitive performance (i.e., speed, agility, flexibility, and balance). Other studies have demonstrated the importance of these variables in gymnastics modalities (Mlsnová, 2016; Dallas, Pappas, Ntallas & Paradisis, 2018; Ceklic & Sarabon, 2021). Specifically for the assessment of muscle strength, only studies that were carried out at the training site were selected in order to minimize the costs and take advantage of the practical context. Thus, the results indicate that the vertical jump and long jump tests were used in most studies. The benefit of using these tests is associated with cost-effectiveness, especially the easy application and use in the context of practical execution. The specificity of the vertical jump test in connection with gymnasts' performance is highlighted, since coaches, physical education and health professionals use height in the vertical jump to assess their motor performance and the ability to generate muscle strength and power (Teramoto, Cross & Willick, 2016). However, vertical jump analysis is limited in terms of similarity or description of specific movement linked to the modality.

Instead, the test batteries of FIG, GFMT and Talent Opportunity Program (TOPS) were used in 6 studies, as shown in Table 1. The FIG battery is specific to artistic and rhythmic gymnastics and is generally used to identify talent and quantify physical evolution; in addition, it can be applied in local training sites. In general, it consists of assessing strength, flexibility, speed, endurance, and power in the context of AG. Tests for analyzing strength in male artistic gymnastics are double legs circle (on mushroom), V lever (legs to or over vertical), tucked top planchet (body horizontal through shoulder, arms stretched), and back hang scale (body horizontal, legs, and arms stretched) (Mkaouer, Hammoudi-Nassib, Amara & Chaabène, 2018).

In RG, the FIG battery assesses modality-specific motor patterns using elements and body movements that guarantee results in the sporting context (Batista, Garganta & Ávila-Carvalho, 2017; Batista, Garganta & Ávila-Carvalho, 2019). Therefore, it assesses flexibility, balance, strength, power, endurance, and speed (Dias, Aleksandrova, Lebre, Bobo & Fink, 2019) using the front power kick, back power kick, partial trunk elevations, partial curl-ups, rope skipping, and vertical jump test as protocols for measuring strength.

Conversely, the GFMT battery is specific to female and male artistic gymnastics (The Men's Gymnastics

Functional Measurement Tool – MGFMT) and comprises individual tests that are easy to apply, reflect the physical abilities inherent to the modalities with quantitative results and do not require an expert appraiser (Sleeper, Kenyon & Casey, 2012; Sleeper, Kenyon, Elliott & Cheng, 2016). In addition, they help to identify deficits in physical fitness, which can be useful to prevent injuries. The GFMT assesses strength, power, upper and lower extremity power, abdominal strength, hip flexor strength, flexibility, and grip strength (Sleeper, Kenyon & Casey, 2012) using the rope climb test, jump test, hanging pikes test, over-grip pull-up test, push-up test, 20-yard sprint test, and handstand test. The MGFMT evaluates flexibility, strength, power, agility, and balance (Sleeper, Kenyon, Elliott & Cheng, 2016), using the rings hold test, vertical jump test, hanging pikes test, over-grip pull-up test, handstand push-up test, and handstand test.

In women's artistic gymnastics, the TOPS battery of the American Gymnastics Federation has been used as a talent identification tool (Bacciotti, Baxter-Jones, Gaya & Maia, 2019) using the rope climb, press handstand, and leg lift tests. Regarding strength, it is important for gymnast's performance as has been described in previous studies (French et al., 2004; Mkaouer, Hammoudi-Nassib, Amara & Chaabène, 2018; Sawkzyn et al., 2016). However, gymnasts perform exercises repeatedly, in routines that require a great level of not only strength, but also power, and endurance from the body extremities (Kerr, Hayden, Barr, Klossner & Dompier, 2015). Therefore, a complete proceeding of performance evaluation is more applicable to determine sports performance in gymnastics.

On the other hand, most of the sample was composed of elite athletes aged between 6 and 22 years, which may be associated with the moment of peak performance at the age of between 15 and 21 years (Law, Côté & Ericsson, 2008; Longo, Siffredi, Cardey, Aquilino & Lentini, 2016; Feeley, Agel & LaPrade, 2016). The countermovement jump (CMJ) is most used to predict lower limb muscle power for school-age children (Gomez-Bruton et al., 2019). It demonstrates greater reliability in this specific population (Acero et al, 2011). Furthermore, the vertical jump is also proposed as an important marker of health and quality of life, in addition to its importance in sports, as it is fundamental for the child development (Malina, 2001). Since this age group is still at the beginning of sport specialization, the jump test may be appropriate to evaluate physical skill levels.

This review implies some limitations as only articles published in English or Portuguese (Brazil) do not represent the totality of studies addressing gymnastics modalities. No studies were found that would focus on other modalities of competitive gymnastics included in the FIG programs. However, the study has a great potential, namely: a) considering there is a lack of consensus among researchers, it improves the understanding of the procedures used to assess strength and performance in gymnasts; b) the search could not find reports on the control system of neither training nor assessment, therefore, technicians should perform and share such control for further specific analyses. Thus, the current findings are of interest to sport science practitioners and medical teams who have considered using analytical methods to evaluate and monitor the develeopment of gymnastics performance.

CONCLUSIONS

Artistic and rhythmic gymnastics are the most studied modalities represented by the FIG and there are more works researching female than male gymnasts. Modality-specific strength assessment protocols proved to be more efficient in measuring general physical abilities in gymnastics. Specific applied training techniques, on the other hand, can contribute toward better performance and help minimize the risk of injury.

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WHY THE VAULT BECAME SUPERIOR TO OTHER EVENTS IN WOMEN'S ARTISTIC GYMNASTICS AT THE OLYMPICS?

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Abstract
Critics argue that disciplines in women's artistic gymnastics are not equal and the vault is generally scored much higher than the uneven bars, balance beam and floor exercise. The aim of this study is to understand why the vault became superior to other women's events. The data are the official results for the 586 women gymnasts in Qualification at Olympics from 2000 to 2020. The One-Way ANOVA was used to analyze the variance of D-scores, E-scores and F-scores for women gymnasts obtained on each apparatus. Our research shows that disciplines in women's artistic gymnastics have not been equal for gymnasts when trying to obtain high F-scores in the past 6 Olympics. Among the four women's events, the vault came to be the one on which gymnasts are more likely to obtain high F-scores after the 2000 Olympics. We indicate that the strength of vault resulted from the introduction of the new vaulting table in 2001 and the new open-ended rules in 2006. Although the two big changes implemented by the International Federation of Gymnastics in the beginning of the new millennium were aimed at improving safety of the vault and fairness of judging, the interplay of the two big changes unintentionally promoted the vault to become the most powerful event in women's artistic gymnastics. Such unanticipated consequence of purposeful action may constitute the most important element (i.e., imbalance of disciplines) in the sport. Accordingly, this research has the potential to shed new light on not only this important topic of equality between disciplines, but also broader trends in modern artistic gymnastics.

Keywords: *artistic gymnastics, vault, discipline, equality, Olympics.*

INTRODUCTION

Women's artistic gymnastics (WAG) made its first appearance at the 1928 Olympic Games in Amsterdam. In 1933, the women's technical committee (WTC) was founded and governs the development of WAG (Pajek, 2018). The Code of Points (CoP) is utilized by the WTC to encourage particular movements or styles, including acrobatics and artistry. During the 1950s and 1960s, the CoP was centered around artistry and enlivened by ballet. Consequently, in that period, achievements in the sport favored those who brought elegance to exercises (Atiković, Kalinski, & Čuk, 2017; Kerr, 2006). Since then, however, women's artistic gymnastics evolved from this balletic tradition into a more acrobatic sport. As a result, in the 1970s, this sport saw an abundance of young athletes performing high level acrobatics at the expense of elegance and artistry (Barker-Ruchti, 2009; Cervin, 2015; Kerr, Barker-Ruchti, Nunomura, Cervin, & Schubring, 2018). Since 1996, gymnasts have no longer performed compulsory routines on each apparatus and instead only competed in optional routines (Pajek, 2018). In 2006, the International Federation of Gymnastics (FIG) removed the “perfect 10” as a maximum score, and replaced it with the open-ended scoring system, in which difficulty scores no longer have a ceiling. In the open-ended format, the total score consists of two scores: the requirements and the difficulty of a routine (D-score) plus execution (E-score). Since 2006, updates to the scoring system in each Olympic cycle have pushed the sport in the acrobatic direction (Cervin, 2015). This trend, however, has been controlled to some degree as the FIG gave more weight to the performance quality of a routine after Beijing 2008. The key aspects are both greater deductions for errors and the scoring of artistry introduced into the women’s CoP (on both the balance beam and the floor exercise) which means that the performance quality significantly affects the results in the finals (He, Montez de Oca, & Zhang, 2020).

While the weight between ‘difficulty’ and ‘artistry’ has been adjusted so that the new judging system can work well, another issue emerged. This issue is with the equality between disciplines, as disciplines of artistic gymnastics are quite different from each other in terms of skills, compositional requirements, connection bonus, specific penalties, etc. Bučar, Čuk, Pajek, Karacsony, and Leskošek (2012) indicated that the vault and the floor exercise finals were sessions with the largest scope between high and low E-scores, but they also noted that more inspections should be made on this issue in future analyses of judging. Further research studies identified that the vault, compared to other WAG disciplines, is one on which deductions in execution tend to be minor (Kalinski, Atiković, Jelaska, & Milić, 2016; Kalinski, Jelaska, & Atiković, 2017; Kalinski, Padulo, Atiković, Milić, & Jelaska, 2016), and one on which F-scores are significantly different from those on other apparatuses in WAG all-around qualification results (Atiković et al., 2020; Massidda & Calò, 2012).

Despite the aforementioned research that focused on the most important apparatus for WAG all around success, there is a paucity of literature that explains why the vault is scored much higher than other WAG events. Consequently, the aim of this research is to understand how the vault has become superior to other disciplines in WAG. We analyze the question by focusing on two major changes that are unprecedented in the history of artistic gymnastics: one is the replacement of the vaulting horse by the vaulting table in 2001, and the other is the introduction of open-ended rules in 2006 (Naundorf, Brehmer, Knoll, Bronst, & Wagner, 2008). We believe that the interplay of these two major forces led to the superiority of the vault over other WAG disciplines. By focusing on the perspective of key changes within this sport, we believe that this research has the potential to shed a new light on not only this important topic, but also broader trends in modern artistic gymnastics.

METHODS

Since gymnasts strive to achieve the best performances and highest scores at the Olympic Games (OG) (as cited in Čuk & Atiković, 2009; Kalinski, Atiković, et al., 2016), we sampled all women gymnasts who have participated in the Olympic Games since 2000, as that was when competitors started to perform only optional routines (i.e., OG2000, OG2004, OG2008, OG2012, OG2016, OG2020). There were 98 women gymnasts at each Olympics, except at OG2000 and OG2012 (97 women gymnasts). Altogether, 586 women gymnasts were analyzed from the past 6 Olympics. Further, WAG competitions at the Olympic Games include four sessions: Qualification (C-I), All-around Final (C-II), Apparatus Finals (C-III) and Team Final (C-IV), which are held on different days. We analyzed performance scores in Qualification since this session can be considered the most important; it is the round where both teams and individual gymnasts compete to qualify for the finals (Kalinski, Atiković, et al., 2016). In our analysis, we used scores on the first vault since generally most competitors completed only one vault in world competitions (Kalinski, Atiković, et al., 2016).

We analyzed the D-score, E-score, and F-score for exercises performed by women gymnasts on all events (i.e., vault, uneven bars, balance beam and floor exercise) in Qualifications from OG2000 to OG2020. There were only F-scores at the OG2000 and OG2004 because exercises were judged under the traditional "perfect 10" system. Additionally, we dropped cases with "0" points from the statistical analysis. We retrieved these scores from the results book available at the Gymnastics Results website (https://gymnasticsresults.com/).

First, we calculated means and standard deviations of D-, E-, and F-scores. We presented our results in the "mean $\pm$ standard deviation" manner in Table 1. Then, we conducted the One-Way ANOVA to detect the mean difference of scores across four apparatuses, i.e., the vault (VT), uneven bars (UB), balance beam (BB), and floor exercise (FX). For the WAG Qualifications at the OG2000 and 2004, the means of F-scores on these apparatuses were analyzed. For data after 2004, we applied this analytical strategy to D-, E-, and F-scores. Each ANOVA with a statistically significant ($p<0.05$) F ratio indicated that at least one apparatus had a different mean score. We computed the eta square (η^2) as the overall effect size of the mean difference across four apparatuses. To further demonstrate which apparatus had a mean that was different from another three, we used the Levene's test result to guide our choice of the suitable multiple comparison test statistic. When the Levene's test was not statistically significant, we conducted multiple mean comparisons by using the Tukey's B statistic. When the Levene test returned a statistically significant result, we performed the analysis again with the Games-Howell test. For each significant mean difference identified by either Tukey's B or Games-Howell statistic, we further calculated the Cohen's d value to assess the effect size. To follow the convention, we used eta square values of 0.01, 0.06, and 0.14 and d values of 0.20, 0.50, and 0.80 as thresholds of small, medium, and large effects, respectively (Cohen, 1988). All statistics was obtained from the IBM SPSS Statistics 22.0.

RESULTS

Differences in F-score means of WAG disciplines from OG2000 to OG2020

Table 1 shows the One-Way ANOVA with post hoc comparisons in F-score means, D-score means and E-score means for the past six Olympics (i.e. from OG2000 to OG2020). As far as the F-score mean is concerned, at OG2000, which was the first time compulsory routines were no longer required, there were no statistical differences of F-score mean between WAG events, although the F-score mean on both balance beam and particularly uneven bars looked a little bit higher than the vault and the floor exercise. The following Olympics in 2004 were not only the last time that competitions at the Olympics were judged under the traditional "perfect 10" system, but also the first time that the traditional vaulting horse was replaced by the new vaulting table. It can be seen that at the OG2004, the vault stands out from all WAG events and shows significantly higher results in terms of F-score mean than both the balance beam and the floor exercise, and is equal to the uneven bars. With the Cohen's d value, we know that the effect size of 0.83 (the mean difference between the vault and the balance beam in standard deviation units) and 0.50 (the mean difference between the vault and the floor exercise in standard deviation units) are considered to be large and medium respectively.

Four years later at the OG2008, when the "perfect 10" scoring system gave way to the "open ended" system, however, significant differences only emerged between the vault and the floor exercise, with the medium effect size of 0.68. But it can be seen that at the OG2008, the F-score mean for the vault was quite a bit higher than for the other three WAG events vis-à-vis the previous Olympics (i.e., OG2000 and OG2004). At the OG2012, the vault pulled away in terms of the F-score mean, extending its lead to around 0.6 points, i.e., there were significant differences between the vault and the other three events (effect sizes of 0.56, 0.86 and 0.80 are considered to be medium and large respectively). Meanwhile, no significant differences existed between the uneven bars, the balance beam and the floor exercise at the 2012 Olympics. At OG2016 and OG2020, the F-score mean on the vault was significantly higher than on the other three WAG events, particularly at the OG2020 where the F-score mean for the vault was around 1.0 point higher than for other WAG events, and the effect sizes of 0.80, 1.36 and 1.47 were all large. Additionally, it should be noted that at the OG2016, the F-score mean for the uneven bars was significantly higher than both for the balance beam and the floor exercise, but not so at the OG2020. It can be concluded that basically the four WAG disciplines have not been equal for gymnasts in terms of obtaining high F-scores in the past six Olympics (eta square values for F-scores of all events were considered to be medium at OG2004 through to OG2012 and large at both OG2016 and OG2020). Among them, the vault came to be the one on which WAG gymnasts are more likely to obtain high F-scores after OG2000 (especially at the Olympics in 2012 and beyond). Although sometimes the uneven bars showed the momentum to rise in terms of the F-score mean, it lagged behind the vault most of the time. In the following section, we further examine the components of F-score (i.e., D-score and E-score) from OG2008 through to OG2020.

Differences in D-score means for WAG disciplines from OG2008 to OG2020

We investigated the D-score means (as well as E-score in the following section) for WAG disciplines since OG2008 where the F-score began to be calculated by using D-score and E-score under the new open-ended system. At OG2008, the D-score means on both the uneven bars and the balance beam are significantly higher than those on the vault and the floor exercise, and further scores in the floor exercise are significantly higher than on the vault. Consequently, the D-score mean for the vault is the lowest in comparison with the other three WAG events at the OG2008, which is similar to the maximum D-score differences between WAG disciplines in 2008 (Figure 1). At OG2012, the D-score means on all apparatuses but vault decreased mainly because the difficulties counted in routines on the uneven bars, the balance beam and the floor exercise decreased from 10 at OG2008 (FIG, 2006) to 8 at OG2012 (FIG, 2009), so that the D-score means for all WAG events approximated each other (only the uneven bars event was significantly different from the floor exercise). At OG2016, the D-score means on all WAG events increased only a little in comparison to those at the OG2012, with significant differences between the uneven bars, the vault and the floor exercise. At OG2020, despite a sharp fall of D-score means for all WAG events compared to OG2016 (especially the vault on which the maximum D-score was 6.0, which is much less than four years earlier), both the uneven bars and the balance beam scores were significantly higher than those on the vault and the floor exercise. In short, it is obvious that the maximum D-scores are different for each event from OG2008 to OG2020. Coupled with the differences for D-score means between WAG events, we can conclude that although the difficulty value for elements on each apparatus varied at different Olympics due to the updates to the CoP, WAG disciplines are literally not equal: eta square values for D-scores for all events were considered to be small at both the OG2008 and the OG2012 and medium at the OG2016 and the OG2020. Gymnasts are more likely to achieve high D-scores on both the uneven bars and the balance beam relative to the vault and the floor exercise, although such chances seemed to decrease on the whole as Cohen’s d value for each significant D-score mean difference showed a downward trend after OG2008.

Differences in E-score means for WAG disciplines from OG2008 to OG2020

When we refer to E-score means, the situation seems pretty much the reverse of how the D-score means work. At the OG2008, the E-score means for both the vault and the floor exercise are significantly higher than those for the uneven bars and the balance beam. Particularly the vault stands out where the E-score mean was 9.150 points with small standard deviation. Additionally, the maximum vault E-score reached 9.650 points (Figure 2). Such numbers appeared to large extent also at the following Olympic Games from 2012 to 2020 (eta square values for E-scores for all events were considered large from OG2008 to OG2020), although the E-score means and the maximum E-score for all WAG events dropped by different degrees after the OG2008, mainly due to stricter deductions for execution and artistry: e.g., apart from a deduction for a fall that was increased from 0.8 in 2006 to 1.0 in 2009, the FIG added the evaluation of artistry on both the balance beam and the floor exercise to the new scoring system in the 2009 CoP (FIG, 2009), and refined it afterwards in the Rio (FIG, 2015) and Tokyo cycle (FIG, 2017). Additionally, the vault rules of landing within the corridor down the center of the landing mat was introduced to the CoP in 2009, while on the uneven bars, more specific deductions for E-panel, like the angle of completion of elements, were implemented in the London Olympic cycle (FIG, 2009). Regardless of the updated rules regarding execution in different WAG events, the vault has consistently remained the apparatus where the deductions for execution are the lowest among WAG events (the E-score means were almost above 8.8 points at the OG2008 and beyond) and had a small standard deviation (around 0.4 points from OG2008 to OG2020), which is congruent with the results of previous research (Atiković, Kalinski, Bijelić, & Vukadinović, 2011; Kalinski, Atiković, et al., 2016; Kalinski et al., 2017; Kalinski, Padulo, et al., 2016). The other three events typically score lower on E-score than the vault. This can be demonstrated by Cohen’s d value for each significant E-score mean difference between the vault and the other three WAG events at the Olympics from 2008 to 2020 (Table 1), nearly all of which exceed one and a quarter standard deviation units, representing substantial effect sizes.

Moreover, we noted that among the four WAG events, the balance beam is the event on which women gymnasts are more challenged to perform with perfection, probably due to the anxiety caused by the risk of injury (Kolt & Kirkby, 1994; Sands, 2000), the instability of balance, and deductions for artistry (Kalinski, Padulo, et al., 2016). This is especially striking at the OG2020 where the E-score mean and the maximum E-score on the balance beam is less than 7.3 and 8.4 points respectively, which was the lowest since OG2008 when the new open-ended scoring system made its Olympic debut. Nevertheless, it should be noted that although the difficulty value (both the D-score mean and the maximum D-score) of the balance beam increased at OG2016 in comparison to OG2012, the E-score mean for the balance beam did not decrease correspondingly at the OG2016 (with fewer standard deviations relative to OG2012), although the maximum E-score decreased a little. This result presented a challenge to Kalinski (2017) who argued that the higher difficulty values on the balance beam would lead to a lower score for execution, based on the assumption that the performance of more complex and difficult elements was more challenging. This suggests that further research on whether or not routines that comprise more complex and difficult elements lead to lower E-scores and consequently F-scores should be conducted.

Table 1
ANOVA results with post hoc comparisons.

Games	Contents	VT	UB	BB	FX	F	Eta square	Levene statistic	Sig.mean difference (Cohen's d)
OG 2000	N	83	84	81	83				
	F-score	9.197 ±0.32	9.329 ±0.51	9.267 ±0.42	9.126 ±0.54	2.57			
OG 2004	N	84	85	85	83				
	F-score	9.182 ±0.22	9.105 ±0.53	8.853 ±0.57	9.004 ±0.50	9.82 ***	0.06	16.41 ***	1-3(0.83), 1-4(0.50), 2-3(0.46)
OG 2008	N	82	84	84	82				
	D-score	5.461 ±0.45	6.189 ±0.66	6.167 ±0.47	5.696 ±0.42	43.52 ***	0.27	4.61 **	2-1(1.31), 2-4(0.91), 3-1(1.54), 3-4(1.07), 4-1(0.54)
	E-score	9.150 ±0.33	8.124 ±0.64	8.260 ±0.66	8.492 ±0.42	91.82 ***	0.35	12.22 ***	1-2(2.11), 1-3(1.79), 1-4(1.76), 4-2(0.70), 4-3(0.43)
	F-score	14.606 ±0.65	14.283 ±1.07	14.426 ±0.94	14.123 ±0.77	6.53 ***	0.04	4.07 **	1-4(0.68)
OG 2012	N	80	78	83	82				
	D-score	5.463 ±0.57	5.685 ±0.71	5.553 ±0.59	5.391 ±0.45	3.59 *	0.03	3.54 *	2-4(0.51)
	E-score	8.647 ±0.47	7.808 ±0.82	7.618 ±0.96	8.070 ±0.51	41.53 ***	0.22	13.58 ***	1-2(1.30), 1-3(1.43), 1-4(1.18), 4-3(0.62)
	F-score	14.092 ±0.85	13.492 ±1.31	13.167 ±1.29	13.405 ±0.88	13.46 ***	0.08	7.17 ***	1-2(0.56), 1-3(0.86), 1-4(0.80)
OG 2016	N	81	79	82	82				
	D-score	5.512 ±0.52	5.816 ±0.61	5.670 ±0.52	5.444 ±0.67	6.52 ***	0.05	0.99	2-1(0.54), 2-4(0.58)
	E-score	8.862 ±0.42	8.146 ±0.63	7.801 ±0.72	7.970 ±0.51	74.49 ***	0.33	11.69 ***	1-2(1.37), 1-3(1.87), 1-4(1.94), 2-3(0.51)

	F-score	14.356 ±0.72	13.963 ±1.12	13.464 ±1.11	13.297 ±1.39	19.61 ***	0.12	2.66 *	1-2(0.43), 1-3(0.97), 1-4(1.00), 2-3(0.45), 2-4(0.53)
OG 2020	N	84	88	91	85				
	D-score	5.055 ±0.55	5.350 ±0.85	5.279 ±0.53	5.034 ±0.51	5.72 **	0.04	5.86 **	2-1(0.43), 2-4(0.46), 3-1(0.42), 3-4(0.47)
	E-score	8.829 ±0.33	7.593 ±0.85	7.283 ±0.86	7.706 ±0.51	171.08 ***	0.42	20.61 ***	1-2(2.07), 1-3(2.54), 1-4(2.67), 4-3(0.62)
	F-score	13.863 ±0.72	12.869 ±1.74	12.559 ±1.18	12.695 ±0.86	43.08 ***	0.15	9.92 ***	1-2(0.80), 1-3(1.36), 1-4(1.47)

*Note: VT=Vault, UB=Uneven bars, BB=Balance beam, FX=floor exercise; * P<0.05, ** P<0.01, *** P<0.001;*
In Multiple Comparisons, 1=Vault; 2=Uneven bars; 3=Balance beam; 4=floor exercise; "1-3" shows that the mean of scores on vault is significantly higher than that of balance beam at 0.05 level, etc;
We carried out Games-Howell test for all the D-, E-, and F-scores of the four WAG events from OG2004 to OG2020, except the D-scores at OG2016 for which Tukey's B is used;

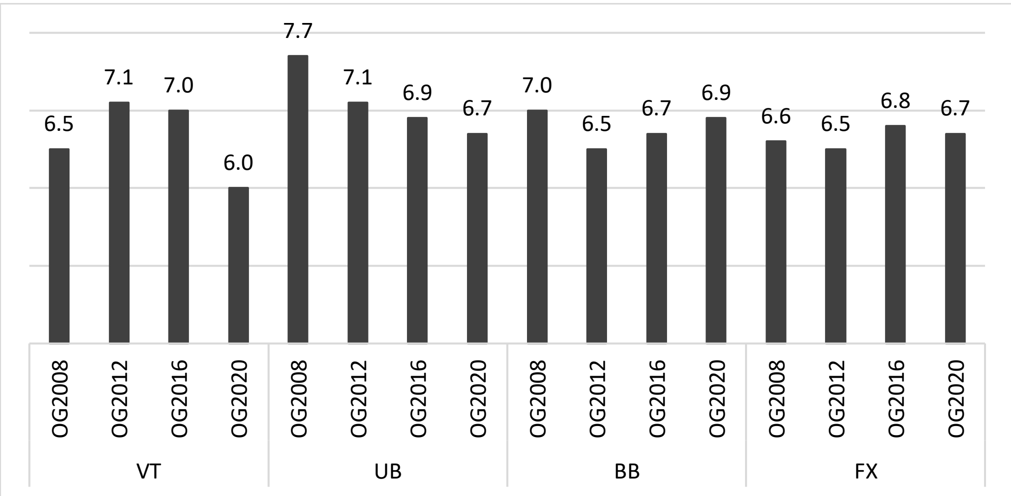

Figure 1. Maximum D-score on each apparatus in WAG Qualification at Olympics 2008-2020.

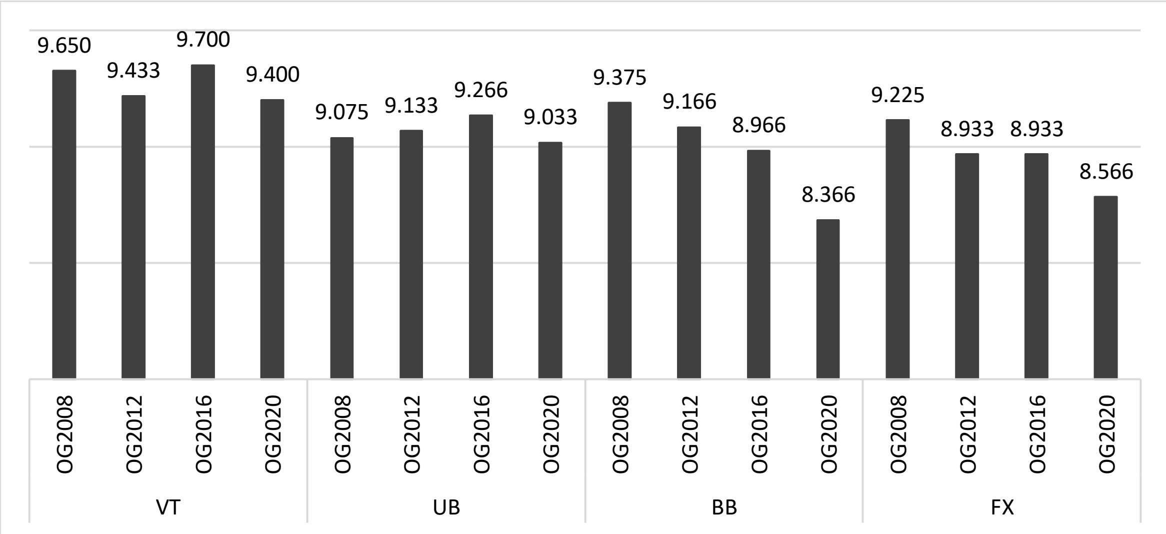

Figure 2. Maximum E-score on each apparatus in WAG Qualification at Olympics 2008-2020.

DISCUSSION

The aim of this study is to investigate why the vault has stood out since OG2004 relative to the uneven bars, balance beam and floor exercise in WAG. The vault includes only one element, which is distinct from the uneven bars, the balance beam and the floor exercise where the content (D-score) includes the highest 8 difficulties, compositional requirements, connection values and a bonus. Scholars argue that compared to the uneven bars, balance beam and floor exercise that require multiple skills and combinations, gymnasts can obtain higher scores on the vault since it is judged on a single skill alone (Atiković et al., 2011; Atiković et al., 2020). Such proposition is, however, contradicted by the results at the OG2000, where the superiority of the vault over other WAG events in terms of high scores barely existed. It can be seen that at the OG2000 the F-score mean for the vault is a little lower than for the uneven bars and balance beam, although no significant differences existed between these events. This result can confirm the point proposed by Kalinski, Padulo, et al. (2016) that the vault is a highly demanding apparatus and can never be considered easy simply because it includes only one element (Čuk & Atiković, 2009).

At the following Olympics in 2004, where the competition ran under the same "perfect 10" scoring system as in 2000, however, the vault distinguished itself with F-score means significantly higher than both on the balance beam and the floor exercise. The question, hence, is why there is a significantly higher F-score mean for the vault than for the other WAG events except on uneven bars four years later? As we know, among many factors, modifying an apparatus will promote new elements and development of routines on the apparatus. For example, modifications endorsed by the FIG to the apparatuses in the 1970s, such as wider-set bars, carpeted springboards, padded beam, and "double sprung" floor enabled gymnasts to perform new moves on the bars, somersault on the beam, and tumble to greater heights in the floor exercise in the following decades (Cervin, 2015). In this sense, we believe that the introduction of the new vaulting table in 2001 played a crucial role.

The replacement of the traditional vaulting horse with the vaulting table in 2001 by the FIG represents the largest single change in artistic gymnastics in recent times (Irwin & Kerwin, 2009). Although the new table was introduced by the FIG for safety (Kalinski et al., 2017) and is identical to the traditional horse in height, the design and construction of the new table enabled a higher run-up velocity (Milčić, Živčić, & Krističević, 2019; Schärer, Lehmann, Naundorf, Taube, & Hübner, 2019), facilitated more anatomically functional position of the arms during the support phase, which allows for a more effective transfer of horizontal kinetic energy to vertical and angular one for the second flight phase (Čuk & Ferkolj, 2012). Moreover, scholars indicate that the larger and flatter surface area of the new table have not only perceptually and materially changed the vaulting technique in handspring forward vault (Irwin & Kerwin, 2009), but also made Yurchenko (round-off) and Tsukahara (handspring with ¼ - ½ turn) much easier to complete (Sands & McNeal, 2002). Consequently, we can conclude that the new apparatus has influenced performance on the vault (Jackson, 2010), although it remains to be determined if the new table has facilitated more advanced vaults (Irwin & Kerwin, 2009). Therefore, we believe that the introduction of the new vaulting table by the FIG in 2001 with the aim of improving safety has also increased the probability of getting higher scores on the vault for women gymnasts since OG2004.

In 2006, the FIG reworked the scoring system in response to the issue of fairness under the traditional "perfect 10" judging system (Kerr & Obel, 2015). Critics have since argued that the open-ended scoring system has led to a loss of artistry as gymnasts achieved top scores with acrobatic movements (Kerr & Obel, 2015), since under the new rules the sport saw a great increase in difficulty levels from 2006 on (Leskošek, Čuk, & Pajek, 2013; Thornton, 2010). To prevent the trend of "sacrificing execution for difficulty" (Leskošek et al., 2013), the FIG has been weighting performance quality in the open-ended CoP since 2009. Particularly in WAG, as mentioned above, apart from the highest difficulties in a routine (except on the vault) that were reduced to 8 and a fall deducted by 1.0, the FIG added the evaluation of artistry on both the balance beam and the floor exercise to the new scoring system in the 2009 CoP, and refined it in the Rio and Tokyo cycles. As a result, the sport has seen a shift from difficulty to elegance and artistry since 2009, which is a drastic change at the institutional level (He et al., 2020).

The new open-ended scoring system used to modify the balance between artistry and difficulty in scoring coupled with the adoption of the vaulting table intended to promote safety but unintentionally it increased the superiority of the vault over other WAG events. Although significant differences only existed between the vault and the floor exercise chiefly owing to much lower D-scores for the vault versus other three WAG events (particularly in comparison with uneven bars and balance beam) at the OG2008, the vault came to be dominant in terms of F-score mean among the WAG events ever since the 2012 Olympics. We believe that there are two reasons for this: one is the D-score means for all events but the vault dropped sharply at the OG2012 because the number of difficulties counted in a routine decreased from 10 to 8, which rendered all WAG events more even in terms of difficulty value. Also, stricter deductions for execution and artistry carried out in the open-ended scoring system after OG2008, when coupled with the performance advantages of the new vault table, made the vault score higher than other events in WAG.

It can be said that the interplay of the two big changes brought about what the sociologist Robert Merton would call "unanticipated consequences" (Merton, 1936). The FIG worked to introduce a new vaulting table, ostensibly for safety reasons, but this equipment served to encourage greater height and force generated in the event, thus making the vault superior over the uneven bars, balance beam and floor exercise in the light of the "perfect performance" gymnasts can present. Furthermore, when the ceiling for the "perfect 10" was removed in 2006, the "perfect performance" the gymnast can assume on the vault was maximized by the new scoring philosophy, particularly when greater weight was attached to execution and artistry after OG2008. That is, where the FIG intended to address safety and fairness in gymnastics competitions, it unintentionally promoted the superiority of the vault over other events. Suffice to say, this unanticipated consequence may constitute the most important element (i.e., imbalance of disciplines) in modern women's artistic gymnastics.

CONCLUSIONS

This study marks a tentative step towards explaining why the vault seems to stand out among WAG events. Our conclusion shows that the strength of vault scores resulted from the introduction of the new vaulting table in 2001 and the new open-ended CoP in 2006, as well as further modifications in the balance between artistry and difficulty since 2009. Although these two significant changes carried out by the FIG in the early 21st century aimed to improve safety of the vault and fairness of judging, the interplay of the two significant changes promoted the vault to become the most powerful event in women's artistic gymnastics. Predictably, this unanticipated consequence may constitute the most important element (i.e., imbalance of disciplines) in the process of reification of key values (i.e., safety, artistry and difficulty) in modern women's artistic gymnastics. Moreover, as the imbalance of disciplines will definitely impact a variety of other aspects of international gymnastics (e.g., talents selection and training, judging in competitions, strategies of competitors and national teams, to name a few), we suggest research regarding such issues should continue due to the rapid progress of the sport.

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THE INVERTED RELATIVE AGE EFFECT IN KOREAN GYMNASTS

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Abstract

Students born in earlier months likely have higher academic achievement than those born later even though they are in the same grade (relative age effect, RAE). Some studies reported no RAE in gymnastics. This study aimed to determine the RAE in Korean gymnasts. Data were collected on the birth month of 806 Korean gymnasts: 482 elementary (181 men; 301 women) and 324 middle-high (189 men; 135 women) school gymnasts registered by the Korea Gymnastics Association. Four quarters were used: Q1 (January–March), Q2 (April–June), Q3 (July–September), and Q4 (October–December). The χ^2 test and its probability were applied for hypothesis testing. Overall, 164 (20.3%) gymnasts were born in Q1, 191 (23.7%) in Q2, 220 (27.3%) in Q3, and 231 (28.7%) in Q4. We could not confirm the birth frequency of Q1 as high. Descriptive data of RAE showed that the frequency of Q1 was the lowest among the quarters of participants. Contrary to RAE expectations, Q4 showed the highest frequency in both elementary and middle-high (χ^2 elementary=2.431, p-value=0.487; χ^2 middle high=17.827, p-value=0.001) school gymnasts, and this appeared like an 'inverted relative age effect'. The inverted RAE was more pronounced in middle and high school gymnasts.

Keywords: *inverted relative age effect, Korean gymnasts, RAE, birth month.*

INTRODUCTION

In school systems used in most countries, academic years are divided on the basis of chronological age of students. In some countries, a new school year begins in March (e.g., Korea), whereas in others it begins in September (e.g., United States). Since each academic year covers one year, students attending the same academic year may be born in different months. Students born in earlier months are likely to be more advanced in physical and cognitive development compared to those born in later months; therefore, it is well known that they have advantages in academic performance (Armstrong, 1966; Freyman, 1965). In the same academic year, students born in earlier months often have an advantage over those born in later months, and this effect is referred to as the relative age effect (RAE) (Baker, Schorer, & Cobley, 2010).

RAE is especially prominent in competitive environments that require physical development, such as sports. Barnsley, Thompson, and Barnsley (1985) and Grondin, Deshaies, and Nault (1984) made the first reports of RAE in sports, focusing on Canadian ice hockey players and volleyball players. Subsequently, many researchers have confirmed RAE in athletes (Delorme & Raspaud, 2009; Hollings, Hume, & Hopkins, 2014; Votteler & Honer, 2014). Previous studies (Helsen, Hodges, Van Winckel, & Starkes, 2000; Sherar, Baxter-Jones, Faulkner, & Russell, 2007) indicated that adolescent athletes may demonstrate different athletic performance depending on their physical maturation (i.e.

being relatively order) because of the RAE and argued that RAE should not be mistaken for superior talent of some athletes. In other words, there is a need to devise specific methods to decrease or eliminate RAE for each type of sports (Baker et al., 2010).

Baker, Janning, Wong, Cobley, and Schorer (2014) analysed RAE in athletes of individual sports and reported differences in RAE depending on the characteristics of each type of sports. Baker et al. (2014) reported that more skiers and figure skaters are born in earlier months (earlier than March) than those born in later months (later than October), thus confirming RAE in these sports. In other words, since skiers and figure skaters born in later months are at a disadvantage in comparison to those born in earlier months in terms of physical maturation they may drop out.

Although RAE has been confirmed in most group and individual sports, previous studies on gymnastics have not found that gymnasts born in earlier months are at an advantage compared to those born in later months (Baker et al., 2014). Baker et al. (2014) found that most gymnasts were born between April and September, denying the RAE hypothesis that relatively older and more mature gymnasts will have advantages.

Moreover, Hancock, Starkes, and Ste-Marie (2015) analysed RAE in female gymnasts and found the following interesting results: RAE could not be found in female gymnasts below the age of 15, but it was present in those older than 15. In particular, when female gymnasts above 15 were analysed, there was a high proportion of those born in later months, and this was referred to as the inverted RAE. Since women gymnastics is characterised by relatively earlier peak performance compared to other sports, Hancock et al. (2015) concluded that inverted RAE may be present. However, the inverted RAE in female gymnastics reported by Hancock et al. (2015) is limited to a Canadian group of gymnasts, so it is difficult to generalise the findings. Whether inverted RAE is a characteristic limited to Canadian female gymnasts or is a general characteristic that can also be seen in male and female gymnasts from other countries is an interesting theme. Therefore, this study aimed to confirm inverted RAE in male and female South Korean gymnasts.

METHODS

This study was planned to elucidate RAE in Korean gymnasts. For this purpose, the year and month of birth were investigated in all elementary (grades 1-6), middle (grades 7-9), and high school (grades 10-12) gymnasts registered with the Korea Gymnastics Association in 2018. The Korea Gymnastics Association as a national organization registers highly trained gymnasts to effectively manage gymnasts and teams, and all highly trained gymnasts seeking to participate in competitions are required to register with the Korea Gymnastics Association. In 2018, there were 806 elementary, middle, and high school gymnasts registered with the Korea Gymnastics Association. There were a total of 482 elementary school gymnasts (181 men and 301 women) and 324 middle-high school gymnasts (189 men and 135 women) (see Table 1). They were selected as gymnasts when they were around 7-8 years old and highly trained to achieve the highest level of performance.

To confirm RAE in gymnastics, those that entered elementary school earlier than other gymnasts and those that entered later should be separated. This is because age in months may differ in the same school grade depending on their age when entering elementary school. In the South Korean educational system, students born between March and February of subsequent year were previously grouped into the same school year. However, students born between January and December of one calendar year are now grouped together. Therefore, the birth months of those born before 2000 at which time the new system was implemented (cohort A) and those born after 2000 (cohort B) are linked, as shown in Figure 1.

Most previous studies analyzing RAE in education and sports have investigated the difference between each quarter to confirm patterns of RAE (Arrieta, Torres-Unda, Gil, & Irazusta, 2016; Lavoie, Laurencelle, Grondin, & Trudeau, 2015; Nakata & Sakamoto, 2012). Therefore, we also categorised those born between January and March as Q1 (first quarter), those born between April and June as Q2 (second quarter), those born between July and September as Q3 (third quarter), and those born between October and December as Q4 (fourth quarter).

The expected and observed frequencies were calculated based on the collected data on all gymnasts using MS Excel. Frequency and percentage for all gymnasts as well as those for elementary and middle-high school gymnasts were calculated separately. χ^2 analysis was carried out to confirm differences between expected and observed frequencies, and the level of statistical significance was set as α=.05. χ^2 was calculated according to the following formula:

$$\chi^2 = \frac{\sum(\text{Observed} - \text{expected})^2}{\text{expected}}$$

(Formula 1)

RESULTS

With RAE, individuals born in earlier months are known to be at an advantage as they are relatively older and more mature physically and cognitively. In this study, 20.3% of male and female gymnasts belonged to Q1 (n=163), 23.7% to Q2 (n=191), 27.3% to Q3 (n=270), and 28.7% to Q4 (n=231). There was a higher frequency of male and female gymnasts born in later months than those born in earlier months (Figure 1). χ^2 was 13.53, so there was a statistically significant difference at the level of p=.003. In other words, there was a higher proportion of gymnasts born in later months than those born in earlier months (see Table 2).

Figure 2 shows the frequency and proportion of birth months in each quarter calculated separately for elementary and middle-high school gymnasts. For elementary school gymnasts, Q1 (n=106, 22.0%) had a relatively lower frequency than Q2 (n=123, 25.5%), Q3 (n=128, 26.6%), and Q4 (n=125, 25.9%); however, no significant difference was found (χ^2 = 2.43, p=.487). In contrast to elementary school gymnasts, for middle-high school gymnasts, there were significant differences between Q1 (n=58, 17.9%), Q2 (n=68, 21.0%), Q3 (n=92, 28.4%), and Q4 (n=106, 32.7%) (χ^2 = 17.83, p=.001). In particular, the following differences in the frequency of birth month were observed between elementary and middle-high school gymnasts (Figure 2): 48 for Q1, 55 for Q2, 36 for Q3, and 19 for Q4. The differences were greater for Q3 and Q4 than for Q1 and Q2, indicating that more middle-high school gymnasts are born in later months than elementary school gymnasts.

DISCUSSION AND CONCLUSIONS

Previous studies (Musch & Grondin, 2001; Helsen, Van Winckel, & Williams, 2005; Rađa, Padulo, Jelaska, Ardigo, & Fumarco, 2018; Ramos-Filho & Ferreira, 2021; Wattie, Schorer, & Baker, 2015) related to RAE claiming that later birth persons were disadvantaged in sports competitions do not apply to gymnastics in Korea. Contrary to RAE in earlier research, this study found that Q4 showed the highest frequency in both elementary and middle-high school gymnasts; thisappeared like an ‘inverted relative age effect’. In addition, this study identified that the inverted RAE appeared to be more pronounced in middle and high school than in elementary gymnasts.

According to previous literature on athletes, RAE is more prominent in groups that require high performance (Baker et al. 2010; Votteler & Höner, 2014; Werneck et al., 2016). RAE refers to the phenomenon where those born in earlier months are more mature physically and cognitively and thus are at an advantage in comparison to those born in later months competing together in a group; this phenomenon is observed because more mature individuals are given more social opportunities.

Table 1
Number of male and female participants in each grade (N).

Grade	Quarter1	Quarter 2	Quarter 3	Quarter 4	total
Grade1	0	4	3	7	14
Grade2	9	11	13	11	44
Grade3	15	21	20	21	77
Grade4	36	25	46	34	141
Grade5	29	37	29	37	132
Grade6	17	25	17	15	74
Grade7	11	19	22	23	75
Grade8	13	14	14	17	58
Grade9	5	7	14	21	47
Grade10	13	12	15	19	59
Grade11	6	8	15	15	44
Grade12	10	8	12	11	41
total	164	191	220	231	806

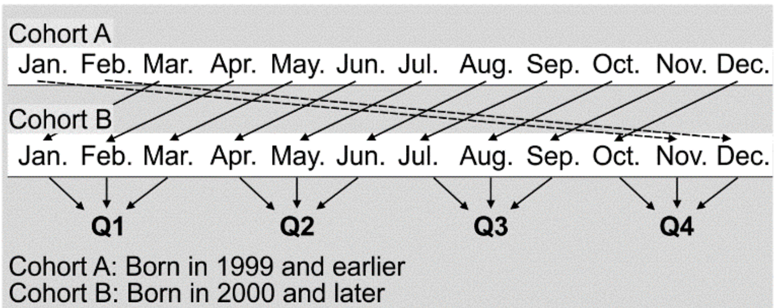

Figure 1. Linking the birth month of gymnasts born in 1999 and earlier and those born in 2000 and later, and the composition of quarters.

Table 2
Quarterly birth rate of highly trained Korean gymnasts.

Category	Q1	Q2	Q3	Q4	χ^2	p
Elementary male	36 (19.9%)	40 (22.1%)	53 (29.3%)	52 (28.7%)	4.834	0.184
Elementary female	70 (23.3%)	83 (27.6%)	75 (24.9%)	73 (24.3%)	1.232	0.745
Elementary total	106 (22.0%)	123 (25.5%)	128 (26.6%)	125 (25.9%)	2.430	0.488
Middle-high male	34 (18.0%)	41 (21.7%)	55 (29.1%)	59 (31.2%)	8.735	0.033
Middle-high female	24 (17.8%)	27 (20.0%)	37 (27.4%)	47 (34.8%)	9.681	0.021
Middle-high total	58 (17.9%)	68 (21.0%)	92 (28.4%)	106 (32.7%)	17.827	0.000

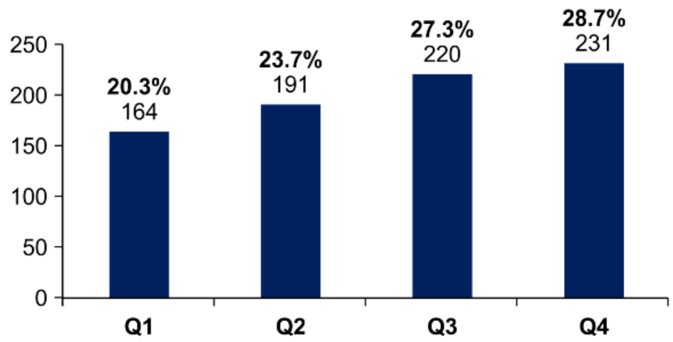

Figure 2. Distribution of birth month in each quarter for all gymnasts (elementary, middle, and high school gymnasts). Note: Difference in frequency between quarters for all gymnasts: χ^2=13.53, p=.003.

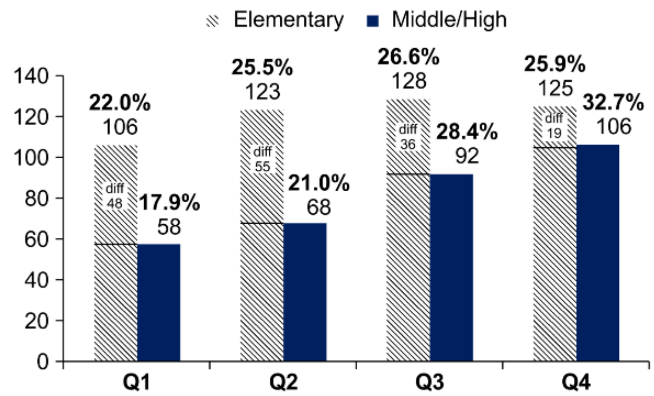

Figure 3. Distribution of birth month in each quarter for elementary and middle-high school gymnasts. Note: diff = frequency in elementary school gymnasts minus frequency in middle-high school gymnasts. Difference in frequency between quarters for elementary school gymnasts: χ^2 = 2.43, p=.487. Difference in frequency between quarters for middle-high school gymnasts: χ^2 = 17.83, p=.001.

Werneck et al. (2016) analysed RAE in Olympic basketball athletes according to sex, country, and continent and reported that the frequency was the highest for athletes born in months belonging to Q2. Baker et al. (2014) argued that RAE is more prominent in group sports than in individual sports and mentioned the Q2 effect for those born between April and June. Baker et al. (2014) reported an absence of significant RAE in athletes.

This study hypothesised that there would be factors contributing to or hindering social selection depending on the birth month and aimed to elucidate RAE in gymnasts, which was previously reported to be absent. Previous studies analysing RAE in athletes did not reflect the fact that academic years begin at different times in different countries. RAE assumes that students born in January will be at an advantage. However, depending on the definition of academic year, students at an advantage in different countries may be born in different months. For instance, in the United States, one academic year comprises those born between September and August of the subsequent year. In contrast, South Korea sets an academic year to comprise students born between January and December of one calendar year. In Japan, one academic year includes students born between April and March of the subsequent year. Herein, students born in September are at an advantage in the US, whereas those born in April and those born in January are at an advantage in Japan and South Korea, respectively.

Therefore, this study calculated relative ages considering gymnasts' birth month and the month of entrance into the educational system (Figure 1). In the past, the South Korean educational system grouped those born between March and February of the subsequent year into one academic year. In contrast, one academic year now includes those born between January and December of one calendar year. This system was first applied to those born in 2000, so months between March and June for those born in 1999 and earlier, and months between January and March for those born in 2000 and later comprise Q1. Q2 may have had high frequencies in the studies of Baker et al. (2014) and Wemeck et al. (2016) since the authors did consider the different educational systems in different countries.

Hancock et al. (2015) reported an absence of RAE in gymnasts aged under 15 and an inverted RAE in those above 15. In addition, the relative age effect performed on male and female gymnasts who participated in the Olympic Games reported by Delaš Kalinski, Mandić Jelaska, & Atiković, (2018) did not confirm that athletes with an earlier birth month were advantaged. This study supports the findings of Hancock et al. (2015) and Delaš Kalinski et al. (2018). The inverted RAE seen in gymnasts could be interpreted as a general phenomenon observed in Canadian female and Olympian gymnasts as well as male and female South Korean gymnasts. In general, the effects of relative age that favour athletes born in earlier months act in an inverse manner in gymnasts; in other words, there is an inverted RAE.

Interestingly, RAE is weaker and statistically non-significant in elementary school gymnasts and is very prominent in middle-high school gymnasts. This indicates that the inverted RAE is not reflected when gymnasts are initially selected. However, as gymnasts progress to middle-high school, those born in earlier months may be more likely to drop out than those born in later months. It could be because later physical maturation is more advantageous in gymnastics. This supports the findings of Jelaska, Delaš Kalinski, & Crnjak (2017) that simple chronological age does not affect the best performance of gymnasts.

As the present study did not longitudinally investigate the proportion of South Korean elementary, middle, and high school gymnasts who drop out, it is difficult to conclude that students born in earlier months drop out as they progress to middle-high school. This is because this study is a cross-sectional study conducted on athletes registered with the Korea Gymnastics Association in 2017. However, since this study analysed the birth month of all gymnasts registered with the Korea Gymnastics Association in 2017, there is no logical fault in deducing the inverted RAE in gymnastics. If future studies can analyse the inverted RAE in gymnasts based on longitudinal data, they are expected to yield interesting findings of physical and social advantages of birth month.

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SELF-REGULATION OF GYMNASTIC SKILLS LEARNING IN INITIAL TRAINING: STUDENT-CENTERED STRATEGIES

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Abstract

Within the framework of the perspectives of self-determination, self-control and self-regulation, this research analyses the management of difficulties encountered during the implementation of strategies to support autonomy and collaboration in gymnastic learning. The approach of the study is qualitative and is based on the experiences of university students of Physical Activity and Sport Sciences, using personal diaries during classroom practice as an information tool. The data analysis is carried out using AQUAD 7 software. The results show that during the learning process, students experience difficulties associated with anxiety, especially in the final moments of educational process, together with perceptions of gymnastic incompetence, which decreases as the training period ends. As a response to coping with learning difficulties, students mainly resort to personal reflection, adopt attitudes of victimisation and, to a lesser extent, turn to their peers to help solve their problems, among others. The high level of the sense of victimisation in high pressure situations reveals the need to design emotional management strategies to reduce students' resistance to assessment tasks that can damage and distort the action achieved in the learning process and reduce self-control.

Keywords: *higher education, decision-making, gymnastics, autonomy support, collaboration.*

INTRODUCTION

In teaching and learning of Physical Education (PE), it is necessary to consider self-determination, self-control, and self-regulation since there are many situations of anxiety, frustration, and mental blocks in performances and tests of motor execution. Several authors (Haarens et al., 2018; Reeve, 2009; Ryan & Deci, 2017) have specifically investigated human behaviour in relation to motivation as applied to teaching and learning. In this sense, the authors identify three basic needs in students: the need for autonomy, the need for achievement and training, and the need for inter-relationships. In the field of physical education, self-determination theory has been extensively researched. Currant et al. (2016), Woods et al. (2012) or Rhodes, McEwan, and Rebar (2019), among others, stipulate that the need to be autonomous, to meet challenges and to interrelate with others are aspects to be considered by PE teachers as they help to establish commitments with the proposed tasks. These initial needs and motivations must be considered when planning learning strategies in an appropriate way. Autonomy must be worked on and if it is not developed, it loses effectiveness. Its absence can generate difficulties in learning contexts, as some students may opt for dependence on the teacher. Similarly, it can also be considered that there are other related needs, such as self-esteem or pleasure and the relationship between ability, motivation, and opportunity (Rhodes et al., 2019) as other determining factors. Positive attitudes towards practice were strongly associated with gaining physical, personal, and social benefits from PE (Li, Chen, & Baker, 2014) and these attitudes clearly corresponded with students' needs. However, considering that the benefits require effort, motivation must be defined by conscious evaluation of physical activity, which requires cognitive and mental action if we want it to lead to a continuous practice of physical activity and sport in the future (Rhodes et al., 2019).

Also, attention control theories (ACT) are important because they help us understand students' responses to actions under pressure, as generated by competitions, quizzes, and tests. Taylor, Boat and Murphy (2018) propose models which integrate self-control and motivation as key elements. Baumeister, Vohs and Tice's (2007) model of self-control claims that the practitioner is unable to persevere in difficult taskswhen he or she wants to reduce discomfort and uneasiness. In these cases, self-control allows us to focus our attention on long-distance targets and on the task to distance ourselves from the present discomfort or tiredness. Therefore, we believe that working on internal motivation together with self-control are two important factors in achieving training and improvement. In this sense, Englert and Bertrams (2015) studied the responses of people facing pressure and situations of anxiety and ego depletion or exhaustion. Their research found that self-control reduces anxiety and increases positive behaviors under pressure. Participants with high anxiety have more trouble maintaining self-control during high-pressure situations. In their studies, Englert and Bertrams (2015) used the ACT and they concluded that pressure produces anxiety, and this causes distraction, disruption, and disturbance on the attention level. On the other hand, attention regulation is an act of self-control which moderates anxiety and improves performance. Acting under pressure occurs for example in tests and exams and it is therefore a factor of concern to teachers. Teachers observe how this may not occur in class assignments since in the absence of pressure the ability to control oneself can overcome any difficulty or impairment, just as self-control can counteract the effects of low anxiety. But in times of greater pressure, such as exams and tests, the authors describe the phenomenon of "ego depletion", a momentary block produced by anxiety. They use the right muscle metaphor. Just as it is necessary to train a muscle for its development and effective use, it is equally important to learn self-control if we want to use it in moments of tension (Lang et al., 2016). According to Englert (2016), self-control is what makes it possible to regulate emotions and activate persistence in the face of difficulties and pressures. Likewise, Hagger et al. (2010), point out that the power of self-control during stressful situations can diminish which leads to the ego becoming blocked. In this regard, Hill et al. (2018) highlight how resilience allows us to adapt to adverse contexts to a greater or lesser degree. In our opinion, the capacity of resilience would be a sustained self-control.

Strategies for autonomy and collaboration in the gymnastic field

The most innovative teaching strategies that can make it easier for teachers to anticipate students' responses and needs by giving them the prominence in their learning process can still be overshadowed by more conventional strategies (Moy et al., 2019). Conventional methodologies refer to those where students have little participation in the teaching and learning process. Where teaching is centered on a technical and analytical model, the student has a passive role at a cognitive level. The characteristics of the tasks are centered on repetition, detailed explanations by the teacher who acquires a technical or instructor role, generating a great dependence. Among them we can mention the style of direct command or the assignment of tasks (Núñez & Oliver, 2020).

Current methodologies such as active methodologies, for example Cooperative Learning, the Comprehensive Model of Sport Initiation, the Personal and Social Responsibility Model, and other more current methodologies such as Attitudinal Style, Adventure Education, Motor Literacy, Health Education, or hybrid models (Fernández-Ríos et al., 2016), allow learners to take responsibility and make independent decisions, leading them to report greater enjoyment and perceived competence compared to PE lessons delivered through traditional direct instruction (Gil-Arias et al., 2020). In this sense, PE teachers should master the mentioned methodologies based on different models since the combined use of strategies can allow for diversification of teachers' and students' functions, depending on the time of the teaching-learning period (Fletcher y Casey, 2014). Gradually, educational trends known as Model Based Practices or pedagogical models are being implemented, such as the Sport Education Model (Hastie & Casey, 2014); the Activist Pedagogical Model that aims to offer learning options and possibilities for all and to challenge stereotypes (Oliver & Kirk, 2015), or student-centered research models as a curriculum that combines the actions of students and teachers, taking into account the voice of students and the social construction of the contents to be integrated in the curriculum (Oliver & Oesterreich, 2013). Clearly, the teaching methodology alone will not be more effective in facilitating learning for students, and it cannot be the only variable. The new methodologies applied to the field of PE and to the context of educational gymnastics can contribute to the long-term benefits, but they also require that both students and teachers familiarize themselves with them and are able to build upon them.

Collaborative work, together with strategies of autonomy and decision-making to learn gymnastic skills, can help a group of students to reach a common goal jointly (O'Grady, 2012). Likewise, in the gymnastic context, collaborative work facilitates reinforcement of students' skills, increasing their satisfaction as well as their predisposition towards gymnastic activities (Bayraktar, 2011). The group itself offers almost immediate feedback to its members; their contributions are interconnected and added up as has been the case in other collaborative studies conducted in the context of Physical Activity and Sport (Collins, Overson, & Benassi, 2020; O'Grady, 2012). Sharing responsibilities and dealing with and solving difficulties together will allow them to learn in a more authentic environment.

From these premises, this research aims to identify the difficulties encountered in a teaching intervention to support autonomy and collaboration in the learning of gymnastics and to analyze how students manage these problems.

METHODS

Topics such as motivation, difficulties encountered, perceived competence or achievement expectations are relevant lines of study in Physical Education. Qualitative and interpretive or narrative approach as part of qualitative research is necessary and appropriate to understand what participants perceive, feel or experience (Jha, 2018), in this case, in the teaching-learning process of gymnastic content.

Our intentional sample included 38 students: 10 women and 28 men (average age 19.3 years ± 2.72 years) belonging to one of three internship groups that study the subject of Gymnastics Skills as part of their degree in Sciences of Physical Activity and Sport (PASS) at a Spanish public university. In addition, students were informed that the collected data were used for research purposes and that the study was carried out according to the Helsinki declaration and involved the approval of the Ethics Committee of the university (UA-2020-09-28).

The instrument for data collection was a journal of personal reflection. Students should reflect and write after each practice on the following issues:

✓ What difficulties did you encounter during the session and how did you solve them?

✓ Remarks you want to provide.

The diary was kept and collected after each practice. The students had a room with a relaxed and personal atmosphere where they spent on average 20-25 minutes to write down their reflections. They submitted them via the university's online platform and in word format. This procedure ensured that students' anonymity was maintained. The teaching staff was not present at the time of completing the reflections but was accessible in case a student needed help. 494 diaries were originally collected. Finally, it was decided to analyse 190 diaries for sessions 1, 5, 6 ,7 and 13 - as the most representative sessions of each phase according to three experts in the field, and to develop the method of using the class diaries. In this way, the influence of classroom activities specific to each learning phase, e.g., some assessment activities, collaborative work, etc., were represented and analysed. In addition, the selected personal diaries had to belong to students who attended all practical sessions of the subject.

Initially, the strategy to support autonomy and collaboration was developed by two teachers specialized in PE and gymnastics.

The strategy was implemented throughout the 13 practical sessions (3 hours per session) of the subject. Throughout the educational process, the classroom was organized into 6 teams made up of 6-7 students who were grouped according to their preference. Students took up three roles: performer, assistant, observer-informant. The design of the learning process was organized into 3 phases: initial, progress and final. The main strategies developed are listed in Table 1.

Session 1. This session corresponds to one of the 4 sessions of the initial phase. In it, the functioning of the subject was explained, an initial test of execution of four basic acrobatic skills was carried out and the main activity was developed where motor gymnastic actions were implemented. Students enter university with a very basic previous experience in gymnastic content. This fact can generate some insecurity in the initial assessment, especially for students who have not practised these contents before, even though the initial test is composed of very basic skills. For this reason, students could decide whether to perform the skill at this initial stage if they did not feel confident or had never performed the skill before. Also, decision-making was present for the self-selection of groups and the assignment of major work roles.

Sessions 5, 6 and 7. These sessions are three of the six that make up the progress phase. They were carried out in the group structures noted above. Students developed group and individual decision-making actions associated with designing progression exercises, implementing them, and detecting and correcting errors in the proposed gymnastic tasks. In addition, six-station circuit design and implementation tasks were performed. Practice of progression exercise activities for cartwheel learning, handstand, roundoff, handspring forward, …, in which all three roles (executor, observer, and assistant) were exercised, through a rotating system. Decision-making was also developed through the design and group implementation of an Acrosport practice.

Session13. It is the last session of the three belonging to the final phase of the learning strategy. In it, the final resolution of 4 practical assumptions of the competences developed in relation to the role of assistant and observer was carried out. The score obtained included an individual percentage (50%) and a group percentage (50%).

The role of the researchers was to place themselves in the context of the participants; to immerse themselves in the observation and in the reading and interpretation of the class journal, and to establish relationships between the keys emerging from the diaries and the conceptual framework that has guided the structure of the research.

From the selected journals, the first interpretative readings led to a categorization that connected the emerging codes from student narratives with the conceptual framework and research issues. After repeated approximations, the final theme and categories were determined as follows:

Theme I. Management and evolution of difficulties in gymnastic learning:

Category 1. Perceived difficulties in autonomous and collaborative gymnastic learning.

Category 2. Management strategies for difficulties during gymnastics learning.

The data has been analyzed using the AQUAD 7 software (Huber & Gürtler, 2015). The choice of this software is based on its potentialto interconnect the categories arising from students' reflections with the process of conceptualization and structuring as set by the two researchers on the basis of the state of content analysis. The emerging categories are interpreted and organized in a recursive process as advised by Miles and Huberman (1994). The units of meaning in the reflective diaries of meaning in the participants' reflective diaries are coded in line with the categories deduced both from the state of the field of knowledge and those that emerged from the meanings from the diaries. The AQUAD program allows for this flexible and revisable process of continuous dialogue between the categories of analysis that emerge from the students' own reflections and the effort of structuring and consistency that the researchers must make in the categorization based on the conceptual framework. The resulting code maps have been discussed and validated on the basis of triangulation of the assessments of three teachers, leaving the definitive configuration for the analysis of this research to a mixed deductive-inductive method. In this way, this program allowed us to organize the categories and encodings extracted from the student reflections and thus complement the qualitative analysis with quantification. For this reason, we present the code tables with the absolute frequency (AF) or the number of findings related to a concept and the percentage of it (%AF) in the results.

RESULTS

The presentation of the results is organized according to the categories extracted from the research. Complementarily, there are several excerpts from student journals that exemplify the codes of analysis. To guarantee anonymity, students were assigned numbers (e.g., Student12), and to identify the session to which the submitted diary excerpts belong, the initial "S" is used next to the corresponding session number (S1; S5; S6; S7 or S13).

Perceived difficulties in autonomous and collaborative gymnastic learning

The deficiencies and incompetence perceived by university students (Table 2) in executing a gymnastic or acrobatic skills are the main causes of dissatisfaction in the progress phase of the implemented strategy (S5: 59%; S6: 56.63%):

> *I have very little flexibility and strength, for example. I noticed when performing the work, we didthe "bridge" and handstands (Student12.S5).*

Table 1
Main strategies developed during the implementation of Gymnastic and Artistic Skills.

Initial Phase (Sessions 1-4)	Progress Phase (Sessions 5-10)	Final Phase (Sessions11-13)
Subject description. Distribution of spaces. Methodology to be used. Creation of work teams. Function of the journals.	Progressions of acrobatics of greater technical difficulty such as the roundoff or the backward roll to handstand. Development of Acrobatic Gymnastics discipline.	Final tests were prepared in groups according to the needs and in a mutually supportive way.
Initial test of individual performance.	Students group and individual decision-making actions associated with: Designing progression exercises. Implementing them. Detecting and correcting errors in the proposed gymnastic tasks. Decision-making also developed through the design and group implementation of an Acrobatic Gymnastic practice. Group practical test of this discipline.	Test of individual technical execution.
Main activity practice gymnastic motor actions in pairs, quartets, and sextets. Progression exercises. Main errors were identified. Protocol of support.	Meets for reviewed and clarified doubts.	Final resolution of 4 practical assumptions of the competences developed in relation to the role of assistant and observer.
Decision-making for the self-selection of groups and the assignment of major work roles (execution, observation, and support).	Students in their groups worked on the competence to identify errors, on the feedback and on the aids in a collaborative way. Design decision-making and implementation.	Final meeting for subject assessment.
Completion of reflection journals at the end of the session.		

Table 2
Causes of dissatisfaction with gymnastic learning, by session.

	IP (S1)		PP (S5)		PP (S6)		PP (S7)		FP(S13)	
Codes	AF	%AF	AF	%AF	AF	%AF	AF	%AF	AF	%AF
Gymnastic incompetence	79	45.6	105	59	64	56.6	79	49.7	68	30.1
Fear and anxiety	59	34.1	33	18.5	23	20.4	37	23.3	137	60.6
Lack of peer support	18	10.4	18	10.1	0	0	17	10.7	12	5.3
Physical discomfort	6	3.5	14	7.9	5	4.2	12	7.5	5	2.2
No dissatisfaction	11	6.4	8	4.5	21	18.6	14	8.8	4	1.8
TOTAL	173		178		113		159		226	

Legend: IP: initial phase; PP: progress phase; FP: final phase; AF: absolute frequency.

Table 3
Management strategies for difficulties during gymnastics learning, by session.

	IP (S1)		PP (S5)		PP (S6)		PP (S7)		FP(S13)	
Codes	AF	%AF	AF	%AF	AF	%AF	AF	%AF	AF	%AF
Self-assessment	41	29.5	39	47	32	26.7	47	35.6	48	31.2
Victimisation	39	28	9	10.8	15	12.5	34	25.7	71	46.1
Group support	34	24.5	25	30.1	37	30.8	29	22	17	11
Support from teachers	8	5.8	7	8.5	13	10.8	9	6.8	1	0.7
No reflection	17	12.2	3	3.6	23	19.2	13	9.8	17	11
TOTAL	139		83		120		132		154	

Legend: IP: initial phase; PP: progress phase; FP: final phase; AF: absolute frequency.

Another cause of perceived dissatisfaction was fear and anxiety, especially in the final phase (S13: 60.6%) and in the initial phase (S1: 34.1%) of the learning process:

> *In the initial test, my feeling was negative as I was not able to perform the acrobatic skills correctly (Student12.S1).*
>
> *At the beginning, I was nervous, as it is normal when there is an exam, because although you feel that you control the subject you do not know where the questions can go; additionally, it was oral and hence there were more nerves and silly mistakes. The problems I had were the doubts in regards to some questions, but in the end, I knew how to solve it by taking my time and getting the idea of each execution in my head (Student25.S13).*

Groupmates were also noted with some dissatisfaction. The lack of commitment on the part of their peers was mentioned, albeit less frequently. This perception was present mainly in the progress phase (S7: 10.7%) and in the initial phase (S1: 10.4%):

> *I have felt very uncomfortable, since in some of the exercises we did at the stations, we had partners who were not helping, they were unfocused. (Student31.S7).*
>
> *In this first session, I observed my companion's difficulties like mine, as well as lack of initiative in some colleagues when it comes to acting and helping (Student10.S1).*

Finally, there were few mentions of muscle discomfort, especially in the progress phase (S5: 7. 9%; S7: 7. 5%):

> *In this week's session, my feeling could not be good because in the middle of the session, while doing backwards rolls, I hurt my neck and could not continue. So, my big problem in this session was that*

I got hurt; I tried to continue with the help of my teammates but it was not possible (Student09.S7).

It should be noted that there were many statements in which students specified that they had no reason for dissatisfaction; this was noted particularly in the progress phase (S6:18. 6%; S7: 8.8%):

I have had no problems this week and no problems last week either, I am very comfortable in the class (Student24.S6).

Management strategies for difficulties during gymnastics learning.

We present how PASS students dealt with the difficulties and obstacles encountered throughout the development of Gymnastics Skills sessions (Table 3). The participants significantly reflected on their diagnosis and personal analysis of the situation to manage and solve their problems. This strategy was used mainly in the progress phase (S5: 47%; S7:35.6%):

When it comes to performing an acrobatic series, I lack coordination; with practice, more time and reinforcement exercises, I think I will improve (Student06.S5).

Other difficulties that I have observed were that I needed a little more flexibility to perform exercises; with this I became aware that I had to improve (Student04.S7).

Similarly, victimization reactions to problems also occurred and these attitudes were reflected on, particularly in the final phase of the process (S13: 46.1%) when the test was closer, and in the initial phase (S1: 28%):

It is true that the exam has been chaotic and there have been complicated moments, but what has bothered me is that one classmate blamed me for performing poorly when perhaps it was him who was not performing well (Student03.S13).

At the beginning of the exam when the teacher was throwing questions to the whole group, I felt comfortable and answered correctly, but when it was my turn to solve a question, I just went blank. I was angry and helpless because I remembered everything only a few minutes earlier, but during the exam, I failed, and I felt very bad (Student01.S13).

Students also pointed out that in the face of obstacles they relied on the group of colleagues to solve difficulties, especially in the progress phase (S6: 30.8%; S5: 30.1%):

In the handstand, I find it hard to hold myself up for long with my legs together. I solved all of this by asking two of my classmates for help, and with time, I know that I will be able to do it correctly without any help (Student07.S6).

I felt quite useful in the aids part. Besides, with the support of my group I discovered that changing partners and looking for people of my own weight was easier (Student 06.S5).

In addition, the participants went to teachers to a lesser extent to solve their difficulties; they turned to the teacher more frequently in the progress phase (S6: 10.8%; S5: 8.5%):

At the beginning, when the positions of the aids were new, I did them carefully in case I could not manage to catch my partner in time, but I called the teacher and she explained it to me again, helping me with the first intervention. This helped me feel more confident and secure and helped also my classmate be confident (Student10.S5).

Finally, we noted a group of statements that indicated that students did not react to the difficulties or reflect on the possible drawbacks. This lack of reaction was particularly strong in session six (19.2%):

> *I found the class a little boring, especially the topic of error correction, since I had passed the rolls and therefore spent a lot of time doing nothing (Student03.S6).*

DISCUSSION AND CONCLUSSIONS

The capacity for self-assessment and reflection on one's learning is an essential variable for student's autonomy. We may say that this has been a relevant achievement of our methodological strategy since it progressed increasingly from the beginning, and its decrease in the last session was not alarming despite the pressure of the final examination. One could say that students reflected enough on their own mistakes. Conversely, reports that do not show any reflection on students' achievements in the tasks after they were completed are fewer, but they certainly reveal that there are students who prefer not to reflect on their actions, thus not taking an opportunity to learn from their mistakes or successes. In this context, Giacobbi and Weinberg (2000) studied responses from athletes facing sporting events. An athlete can react in an emotional or a problem-focused way. If he or she focuses on the problem, he or she will try to solve it by increasing his or her effort by planning and/or imagining alternatives, or using breathing strategies to get out of the block. The acceptance of errors, structuring of a problem and reflection are valuable and valid strategies. We must ensure that the ability to deal with a problem in a reflective way becomes a stable attitude to reduce anxiety. Undoubtedly, all reflective strategies, such as the task journal in our case, are formulas which should be encouraged and analyzed in the learning of PE, and specifically in gymnastic skills. In our study, reflections in the class journal were maintained and did not diminish nor were abandoned even in the moments of evaluation. This shows that communication and reflection strategies, such as journals, self-talk or think-aloud, and narrative interviews (Jha, 2018), all work. Ekkekakis and Brand (2019) insist that knowing how people feel when learning and practicing is an important predictor of their perseverance.

Victimization statements occurred intermittently but continuously; the lowest level occurring in the middle of the process and peaking in the final session. This is a studied psychological strategy that shows the way in which people face a problem or failure by becoming victims of circumstances (Nicholls et al., 2016). It is worrying that in the last session the victimization exceeded the capacity to reflect positively. The high presence of variables on fears, worries and anxiety, such as perceived dissatisfaction during tasks, indicated the presence of this very negative defence strategy. Anxiety is cognitive and somatic; it should not be forgotten. Therefore, there are many adaptive and maladaptive responses. The more anxiety, the less adaptive responses and the more victimization, as we have observed in this study. Anxiety before competition is the most researched obstacle in athletes, but not so in PE students. Ahsan and Kumar (2016) in a study on anxiety in PE students found that students with better study habits and strategies had less test anxiety. The greater the mastery of learning, the lower the anxiety.

The fact that people seek support, according to their narratives, evolves up to the session six, but falls off in the pressure sessions, following the most frequent pattern established for the rest of the variables. When the student's goals and expectations are very high, it generates greater anxiety; the teacher must therefore help generate alternatives that are more realistic and appropriate to the student's abilities (Nicholls et al., 2016). Additionally, the feedback offered by both teachers and peers is of vital importance, since it may encourage learning. Alternatively, depending on its provision, it may also lead to a loss of confidence and abandonment of the task (Krijgsman et al., 2019; O'Grady, 2012).

This dimension may have been underdeveloped in this intervention as we focused more on enabling autonomy and collaboration. Although an initial test of competencies was carried out in our intervention, we did not perceive any case in which students could not achieve the expected results. Then we focused more on anxiety and emotional distress than on real competency difficulty.

Finally, within the limits of this research, we appreciate that students' narratives indicate that this strategy is valuable and worth implementing. The initial and middle phases of the process were associated with negative perception of gymnastic competition, while self-control of fears and insecurities was managed. This changed in the third phase of the intervention where anxiety increased. Therefore, the problem, not quite expected by teachers, was the drop in motivation and satisfaction as students became unable to control the pressure of the final tests (Sonlleva et al., 2018). Teachers should strive to create environments of focus on the task, motivation, and reflection on self-perception of one's ability to work under pressure. In this way students will become more involved in the process of learning and their performance will be more effective.

Among the limitations of the study, we found that we could increase the sample and make some association in terms of students' gender and previous experience in gymnastics. However, the strategy implemented has been valuable, as it has allowed us to identify students' problems and their strategies to solve them. These results will guide us to readapt the implemented strategy by revising the evaluation activities. In future research, assessment activities could be designed more in line with the collaborative and autonomous strategy as a whole; for example, role-play practices, activities that simulate the type of assessment test, and even creating discussion groups for students and teachers to share their reflections on the practice.

In short, we point out that further research by considering some variables associated with management of evaluation tasks along these methodological lines is necessary. This could reduce the pressure and underline the achievements that positive and optimal learning based on autonomy and the collaboration can provide.

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MALTREATMENT (PSYCHOLOGICAL, PHYSICAL), SOCIAL PHYSIQUE ANXIETY, BODY DISSATISFACTION AND DRIVE FOR THINNESS IN GREEK FEMALE ATHLETES (RHYTHMIC GYMNASTICS AND OTHER SPORTS) AFTER DROPOUT

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Abstract

Maltreatment by coaches is a significant issue for all athletes, and particularly female athletes. The purpose of the present study was to examine whether psychological and physical maltreatment by coaches could affect social physique anxiety, body dissatisfaction and drive for thinness in former Greek female athletes. Two hundred and fifty former athletes participated in the study, former athletes in rrhythmic gymnastics (RG) and other sports (OS). They completed self-reported questionnaires assessing maltreatment (psychological, physical) by coaches, social physique anxiety, body dissatisfaction and drive for thinness. Results revealed that RG reported both higher psychological and physical maltreatment than others, but there were no differences in body dissatisfaction, drive for thinness and social physique anxiety. Although there were significant relations between maltreatment and body dissatisfaction, and drive for thinness, it was predictive for other sports athletes and not RG athletes. These findings can potentially help all types of sports become a context that promotes female athletes' health rather than undermines it.

Keywords: *coaches, social physique anxiety, body dissatisfaction, drive for thinness*.

INTRODUCTION

The number of children and adolescents participating in organised athletic activities worldwide is increasing (Carter & Micheli, 2011). The issue of safety of young athletes in sport is as old as modern sports themselves (Kerr, Kidd, & Donnelly, 2020). Child maltreatment is the abuse and neglect that occur to children aged under 18 years and includes all types of physical and/or emotional ill-treatment, sexual abuse, neglect, negligence and commercial or other exploitation, which result in actual or potential harm to the child's health, survival, development, and dignity, in the context of a relationship weighed by responsibility, trust and power (WHO, 2020). Child maltreatment in sports is also an issue under research and is a major and growing concern around the world (Fortier, Parent, & Lessard, 2020). Sport psychology researchers and practitioners need to play more prominent roles in safeguarding athletes from harm (Kerr & Stirling, 2019). There is a confusion about terminology and a lack of consensus on the definition of maltreatment in sport studies (Fortier et al., 2020; Stirling, 2009). As

Brackenridge, Bringer and Bishopp (2005) mentioned, many different types of abuse, beyond just sexual, had been known for years, but for a variety of reasons had not be labelled as abuse or not been dealt with as misdemeanour. In many other countries terminology is still confused. Fortier et al. (2020) proposed a manifestation that has been developed in reference to the related literature, the identified limitations and some well-recognized relevant work, identifying four different forms of maltreatment: physical, sexual, psychological and neglect. Distinguishing harassment from abuse is, according to Stirling (2009), the critical nature of the relationship in which the behavior occurs. However, in practice it is very difficult to distinguish harassment from abuse on the basis of severity (Kerr, Kidd, & Donnely (2020). Harassment and abuse have been conceptualized by many researchers as existing on a continuum of harmful behaviors (Brackenridge, 2001). Though it is suggested that harassment refers to what may be considered less severe behaviors and abuse as more severe behaviors in practice the distinction is difficult to make (Kerr, et al., 2020). Abuse is defined as a pattern of physical, sexual, emotional or negligent ill-treatment by a person in a caregiver capacity that results in actual or potential harm to the athlete (Stirling, 2009). On the other hand, harassment is defined as a single or multiple acts of unwanted or coerced behaviors by a person within a prescribed position of authority over the athlete that have the potential to be harmful; it occurs outside the context of a caregiving relationship and refers to behaviors that are in violation of individual’s human rights (Stirling, Bridges, Cruz, & Mountjoy, 2011).

A growing area of interest is women in sport, as researchers examine a wider range of aspects to ensure that sport is a healthy environment for girls and women of all ages. It is well documented that sport can be, in fact, a healthy context; however, for some participants, especially young athletes in elite high performance sports it can be unhealthy (UNICEF et al., 2010). More specifically, sport participation, especially for women, includes risks and protective elements. For example, participation provides physical and psychological benefits (Smolak, Murnen, & Ruble, 2000) but can also include potential risks for developing eating disorders (Garner & Rosen, 1991; Smolak et al., 2000). Female athletes experience not only general societal pressure regarding thinness, but sport-specific too (Thompson & Sherman, 1999).

In sports, a lot of attention has been paid to winning and very little to the methods involved in achieving winning results (Gervis & Dunn, 2004). Athletes are vulnerable to the general risk factors of eating disorders, as well as genetics, socio-cultural ideals, interactions with family members, trauma and personality characteristics (Striegel-Moore & Cachelin, 2001) but also to the sport specific influences (Arthur-Cameselle & Baltzell, 2012). A fact is that coaches do not want to harm or injure their athletes, since the athlete’s performance reflects the efficacy of the coaching process (Gervis & Brierely, 1999). Athletes and coaches are close, so close that their relationship is often significant and influential for athletes (Gervis & Dunn, 2004). An exclusive and exceptional group, based on their young age and athletic ability, are elite child athletes (Brackenridge & Kirby, 1997). During athletes’ childhood, this relationship is particularly significant (Chow, Murray, & Feltz, 2009; Guivernau & Duda, 2002). It seems that this relationship in competitive sports is a decisive factor as the athlete and the coach are mutually dependent (Philippe & Seiler, 2006). Athletes need the knowledge, competence and experience of the coaches, and coaches, on the other hand, need to transfer their competences and skills into athlete’s performance and success (Philippe & Seiler, 2006). Coaches and athletes spend a great deal of time every day together (Jowett, 2003) and as the athlete competes on higher level, the time he or she spends with his/her coach increases (Donnelly, 1997; 1993). Coaches represent a significant interpersonal relationship to female athletes (Beckner & Record, 2016); have a great deal of influence on athletes' self-perception (Turman, 2008; Weinstein, Smith, & Wiesental, 1995), and have the power to positively or negatively influence their athletes' perceptions of body image (Biesecker & Martz, 1999; Coppola, Ward, & Freysinger, 2014; Weinstein et al., 1995). Based on the Communication Theory of Identity, Beckner and Record (2016) concluded that coaches could influence the internalized body image and health choices made by their female athletes. Indeed, the coaching style can create an increased vulnerability to poor body image and eating problems in athletes (Biesecker & Martz, 1999). Brackenridge, Bringer and Bishopp (2005) mentioned that the physical demands of training, emotional toughness and a culture of resilience acted as masks to the suffering that some athletes faced as part of their sports experience. After dropping out, is athletes' body image still influenced by this experience? There is evidence that former female athletes' feelings and thoughts about their bodies are based on their former competitive athletic bodies (Greenleaf, 2002). Some athletes perceive their body changes after retirement as negative, but there are also athletes (although a minority) that become more satisfied with their bodies post-retirement (Papathomas, Petrie, & Plateau, 2017).

Body dissatisfaction is a symptom of a disorder or target of interventions, but also plays a role as a risk factor for developing eating disorder and depression (Smolak & Thompson, 2020). In other words, body dissatisfaction is not only a diagnostic criterion but also an important maintenance factor of ED (Fortes & Ferreira, 2011). Also, it is associated with depressive symptoms and dysphoria (Lautenbacher, Thomas, Roscher, Strian, Pirke, & Krieg, 1992). Athletes report lower levels of body dissatisfaction than non-athletes (DiBartolo & Shaffer, 2002; Hausenblas & Symons Downs, 2001; Robinson & Ferraro, 2004; Soulliard, Kauffman, Fitterman-Harris, Perry, & Ross, 2019). On the other hand, there is evidence that after retirement from competitive sport, there are body composition changes that lead to adaptive or maladaptive behaviors (Buckley, Hall, Lassemill, Ackerman, & Belski, 2019; Fortes & Ferreira, 2011). On the other hand, rhythmic gymnasts report a higher dissatisfaction between their perceived body and the body considered ideal from early on (Zacccari, Rinaldo, & Gualdi-Russso, 2019). In the study by the aforementioned authors, all participants wanted to be thinner.

Drive for thinness

Social physique anxiety is a feeling or an emotion people experience in response to other's evaluations of their physique (SPA; Hart, Leary & Rejeski, 1989) and emerged from body image and body esteem literature. SPA is based on theories of self-presentation and impression management (Mülazımoğlu, Erturan-İlker & Arslan, 2014). An individual may choose to either engage in or avoid physical activity in order to improve her/his chances of making positive impressions; or maybe to avoid circumstances in which the physique could potentially be evaluated negatively by others (Crawford & Eklund, 1994; Hart at al., 1989). Females report higher SPA than males, and athletes and sport practitioners have lower SPA than non-practitioners (Mülazimoğlu-Balli, Koca, & Aşçi, 2010). Predictors of SPA are personal characteristics, type of physical activity, environmental triggers, and social triggers. SPA, on the other hand, can predict physical self-perceptions, competitive anxiety, disordered eating stress, depression, enjoyment and adherence to physical activity (for review Sabiston, Pila, Pinsonnault-Bilodeau, & Cox, 2014). Maltreatment by coaches could be a social trigger. Using the Coaching Behavior Scale for Sports, no significant correlation between previous coaching behaviors and SPA was found in adolescent female athletes, but there was a significant correlation between SPA and competition strategies (Fishback, 2018). The instrument used to assess coaching behavior is probably an issue that needs further consideration.

Although the relation between body dissatisfaction, drive for thinness and social physique anxiety is well examined, maltreatment by coaches has recently been in focus. The purpose of the present study was, first of all, to examine the differences in maltreatment by coaches between female athletes participating in rhythmic gymnastics and in other sports; secondly, to examine whether there was a relation or, indeed, a predictive relation between maltreatment (psychological and/or physical) by coaches and eating disorders, and especially body dissatisfaction and drive for thinness, and social physique anxiety. The study included former female athletes, in rhythmic gymnastics and other sports. Primarily and for ethical reasons, all participants had to be adults.

METHODS

The present study included only female adult former athletes (N=250) with mean age 26.10 years (SD=6.35) and mean training age 10.07 years (SD=3.40). 160 participants (64%) were former rhythmic gymnastics athletes (RG), while 90 participants (36%) were former athletes in other sports (OS). Regarding their sport carrier level, 31.2% had no significant winning, but 12.8% had won the 1st to 8th place in either an Olympic, World or European championship. 52.8% of the participants were a Greek National Champion. The participants were asked to declare when they dropped out from organized sport: 14.1% dropped out before 2000, 27% between 2001-2010 and 58.4% between 2011 and 2019. Also, 45.1% (N=111) had coaching experience of less than 10 years and 54.9% (N=135) had 10 years or more.

Self-reported questionnaires were used assessing demographic and personal characteristics (age, training age, year of sport disengagement, body height and weight for calculating Body Mass Index [kg/m^2]), maltreatment (psychological and physical), body dissatisfaction (BD), drive for thinness (DfT), and social physique anxiety scale.

Body mass index (BMI) was defined as the body mass divided by the square of the body height ($weight/height^2$). Commonly accepted BMI ranges are as follows: underweight under 18.5, normal weight 18.5 to 25, overweight 25 to 30, and obese over 30.

Maltreatment by coaches was assessed by the questionnaire used in a previous study (Michailidou, 2005) and was based based on “Questionnaire sur le harcelement” (Hirigoyen, 2002). The questionnaire assessed psychological and physical maltreatment using 12 items. Participants responded to a five-point Likert type scale, from 1 (never) to 5 (very often).

Social physique anxiety was assessed by social physique anxiety (SPA) measures that evaluate the degree of anxiety that an individual experiences when he she or perceives that others are or may be negatively evaluating her or his physique (Hart et al., 1989; Psychountaki, Stavrou, & Zervas, 2004). The SPA scale has 12 items. Participants responded to a five-point Likert type scale from 1 (not at all) to 5 (extremely). Higher scores indicate greater SPA.

Body dissatisfaction was assessed by the 8-item body dissatisfaction subscale of the Eating Disorder Inventory. Each item was rated from 0 (never) to 5 (always). Higher scores indicated greater body dissatisfaction. Drive for thinness was assessed by the 6-item subscale of Eating Disorder Inventory. Each item was rated from 0 (never) to 5 (always). Higher scores indicated greater drive for thinness.

The study took place during 2019. This was a cross-sectional study. Researchers were part of the gymnastics family since

1984, so they were aware of all the athletes who competed at the highest national and international level in Greece. Each participant was informed of the purpose of the study and asked to participate via e-mail or personal contact. After consent, the link was given. In this way, all the former rhythmic gymnasts who competed on the medium or high level, participated. Former athletes from other sports were approached at the Department of Physical Education. They were, again, informed about the purpose of the study and asked to participate voluntarily via personal contact. This was a convenience sample. There was no missing data from former rhythmic gymnastics. From other sports, 4 questionnaires had missing data and were not included.

Questionnaires were completed in a Google form and data were analysed by SPSS 23. Exploratory factor analyses were conducted separately for maltreatment by coaches, social physique anxiety and EDI. For each factor, internal consistency was examined using Cronbach's alpha. After examining the assumptions independent t-tests, paired t-tests and linear regression analyses (outliers, Cook's distance, collinearity, normality) were conducted.

Our exploratory factor analysis for maltreatment by coaches revealed 2 factors explaining 67.4 9 % of the variance (*KMO* = .93, *Bartlett's Test chi-square*= 2068.45, p < .001). The first factor (psychological maltreatment) included 8 items explaining 59.10% of the variance, while the second factor (physical maltreatment) included 4 items explaining 9.55 % of the variance. Internal consistency for psychological maltreatment was α=.92 and for physical maltreatment α= .86. For social physique anxiety, our exploratory factor analysis revealed one factor explaining 48.95 % of the variance (*KMO* = . 90, *Bartlett's Test chi-square* = 817.25, p < .001). Internal consistency was assessed by Cronbach's alpha coefficient, α=.89. Finally, for EDI (Body Dissatisfaction, Drive for Thinness), our exploratory factor analysis revealed two factors, explaining 32.48 % of the variance (*KMO*= . 92, *Bartlett's Test chi-square*= 1279.43, p < .001). The first factor was body dissatisfaction, explained 52.16 % of the variance and had internal consistency by Cronbach's alpha, α = .84 The second factor was drive for thinness that explained 10.31 % of the variance and had internal consistency α = .84.

RESULTS

Differences between former athletes in rhythmic gymnastics and in other sports

The assumptions for independent t-tests and paired t-tests were examined (outliers, normality, homogeneity of variances). Then, independent t-tests were conducted to examine possible differences in maltreatment (psychological and physical) between RG and OS. There were significant differences both in psychological maltreatment, $t(248) = 6.07$, $p < .001$, $d = .80$) and physical maltreatment, $t(248) = 5.39$, $p < .001$, $d = .71$. RG reported higher means in both forms (Table 1). For body dissatisfaction, drive for thinness and social physique anxiety, the differences were not significant: t(248) = -1.53, $p = .13$; $t_{248} = .11$, $p = .91$; $t_{248} = -1.79$, $p = .07$ respectively). For BMI, the differences were significant, $t(247) = -5.78$, $p < .001$, $d = .47$, and RG had lower mean than the other group (Table 1).

Paired t-tests were used to examine each group's (RG, OS) differences between psychological and physical maltreatment. For both groups, the differences were significant, and psychological maltreatment was higher than physical (RG: $t(105) = 15.8928$, $p < .001$, $d = 1.21$, OS: $t(89) = 9.01$, $p < .001$, $d = .95$).

Correlations between maltreatment and eating disorders (body dissatisfaction and drive for thinness)

The relation between maltreatment by coaches (psychological and physical) and eating disorders (body dissatisfaction, drive for thinness) were examined by using

Pearson correlation analysis. It revealed that for all participants there was a significant correlation between the two forms of maltreatment (r = .71, p < .01); between body dissatisfaction and physical maltreatment (r = .19, p < .01), and between body dissatisfaction and psychological maltreatment (r = .15, p < .05). Separately for RG, the same relations were found as above, whereas for OS, no significant correlation between physical maltreatment and body dissatisfaction was found, only a significant correlation between maltreatment and drive for thinness (psychological maltreatment-drive for thinness: r = -.30, p < .005; physical maltreatment-drive for thinness: r = -.22, p < .05).

Prediction of body dissatisfaction and drive for thinness

After checking assumptions (outliers, Cook's distance, collinearity, normality) (Ntoumanis, 2001; Tabachnick and Fidell, 1996), a regression analysis was conducted to predict body dissatisfaction and drive for thinness by training age, BMI, social physique anxiety, and psychological maltreatment and physical maltreatment by coaches. The enter method was used. Correlations between independent variables were not high (.02 < r < .61). For all participants, the linear combination of measures significantly predicted body dissatisfaction (Table 2) and drive for thinness (Table 3). Analyses were calculated for all participants and for each sport separately (rhythmic gymnastics vs. other sports). Also, regression analyses were calculated for athletes who dropped out before 2010 and after 2011.

Prediction of body dissatisfaction

For all participants, a significant regression equation was found with an R^2 of .44, R = .66, F (5,239) = 37.28, p < .001. Social physique anxiety, BMI and physical maltreatment contributed to the prediction (Table 2). For both groups, the prediction was significant but for RG, the above variables were relevant (Table 2), while for OS only BMI and social physique anxiety contributed significantly (Table 2). Separate regression analyses were conducted for athletes who dropped out before 2011 and athletes who dropped out after 2011. For dropouts before 2011, a significant regression equation was found: R = .61, R^2 = .37, F(4,96) = 14.05, p < .001. A predictive variable was only social physique anxiety, B = .80, t = 6.85, p < .001. For dropouts in 2011 and later, a significant regression equation was also found (R = .66, R^2 = .44, F(4,140) = 27.24, p < .001). Predictive variables were physical maltreatment, B = .46, t = 3.01, p < .005, and social physique anxiety, B = .97, t = 9.47, p < .001.

Prediction of drive for thinness

For all participants a significant regression equation was found with an R^2 of .37 (R = .61, F(5,239) = 28.74, p < .001). Only social physique anxiety contributed significantly (Table 3). For both groups, the prediction was significant and also only social physique anxiety contributed significantly (Table 3). Separate regression analyses were also conducted for athletes who dropped out before 2011 and athletes who dropped out after 2011. The prediction of drive for thinness was also significant for both groups and there were, also, differences in the predictive variables. For dropouts before 2011 (R = .60, R^2 = .36, F(3,98) = 18.56, p < .001), predictive variables were psychological maltreatment (B = .34, t = 2.08, p < .05) and social physique anxiety (B= -.97, t = -7.19, p < .001). For dropouts after 2011 (R = .64, R^2 = .40, F(3,98) = 32.08, p < .001), a predictive variable was only social physique anxiety (B = -.92, t = -9.50, p < .001).

Prediction of social physique anxiety

For all participants, it was examined whether social physique anxiety could be predicted by maltreatment (psychological and physical) by using the linear regression analysis: it was not significant. For RG the prediction was not significant, F(2,157) = .74, p > .05, but for OS the prediction was significant, R = .31, R^2 = .10, F(2,87) =

4.75, $p < .01$, although no variable contributed separately to the significant prediction (psychological maltreatment: $B = .24$, $t = 1.93$, $p = .06$, physical maltreatment: $B = .19$, $t = 1.05$, $p = .30$). The prediction of social physique anxiety separately for athletes who dropped out before 2010 and athletes who dropped out after 2011 was not significant for either group.

DISCUSSION AND CONCLUSIONS

The present study examined whether maltreatment by coaches, psychological and physical, had an effect on body dissatisfaction, drive for thinness and social physique anxiety.

The present study examined whether maltreatment by coaches, psychological and physical, had an effect on body dissatisfaction, drive for thinness and social physique anxiety. Only former female athletes participated (rhythmic gymnastics athletes and other athletes), primarily for ethical reasons. The results revealed that RG reported both higher psychological and physical maltreatment than others, but there were no differences in body dissatisfaction, drive for thinness and social physique anxiety. Although there were significant relations between maltreatment and body dissatisfaction, drive for thinness, it was predictive only for OS athletes and not RG athletes.

The present study is one of the few attempts to look at maltreatment by coaches in Greece. Most attention has been given to sexual harassment, but it is well documented worldwide that other types of maltreatment are harmful for athletes too. Abuses of many kinds have been known for years but had not been labelled as abuse or not been dealt with as misdemeanor, so abuse in sports is a relatively recent topic in the relevant research (Brackenridge, et al., 2005).

Table 1
Means (Standard deviations) for training age, BMI maltreatment (psychological and physical, Social Physique Anxiety, body dissatisfaction and drive for thinness for all participants, and separately for RG and OS.

	Total participants *M (SD)*	Rhythmic gymnasts (RG) *M (SD)*	Athletes in other sports (OS) *M (SD)*
Training age	10.07 (3.40)	10.14 (3.13)	9.94 (3.87)
BMI	20.49 (2.13)	19.94 (1.75)	21.46 (2.38)
Psychological maltreatment	2.53 (1.05)	2.82 (1.03)	2.03 (.89)
Physical maltreatment	1.70 (.92)	2.08 (.95)	1.99 (.95)
Social Physique Anxiety	2.55 (.84)	2.48 (.79)	2.67 (.92)
Body dissatisfaction	2.17 (1.30)	2.05 (1.33)	2.31 (1.22)
Drive for thinness	3.02 (1.30)	3.03 (1.30)	3.01 (1.33)

Table 2
Summary of hierarchical regression analysis for variables predicting BD.

Participants		*Variable*	*β*	*t*	*Sig*
All	R = .66, R^2 = .44, F(5,239) = 37.28, p < .001				
		Training age	.19	.99	.32
		BMI	.14	4.43	.000*
		Social Physique Anxiety	.80	9.98	.000**
		Psychological maltreatment	-.01	-.01	.99
		Physical maltreatment	.26	2.66	.01*
RG	R =. 64, R^2 = .41, F(5,151) = 21.22, p < .001				
		Training age	.02	.64	.52
		BMI	.18	3.40	.001**
		Social Physique Anxiety	.80	7.05	.000**
		Psychological maltreatment	-.02	-.18	.85
		Physical maltreatment	.33	2.64	.009*
Other	R = .671, R^2 = .50, F(5,82) = 16.41, p < .001				
		Training age	.02	.84	.40
		BMI	.10	2.38	.02*
		Social Physique Anxiety	.81	7.09	.000**
		Psychological maltreatment	.07	.53	.60
		Physical maltreatment	.08	.09	.93

**: p < .001, *: p < .05

Table 3
Summary of hierarchical regression analysis for variables predicting DfT.

Participants		*Variable*	*β*	*t*	*Sig*
All	R = .61, R^2 = .37, F(5,239) = 28.74, p < .001				
		Training age	.00	-.01	.98
		BMI	-.05	-1.51	.13
		Social Physique Anxiety	-.88	-10.49	.000***
		Psychological maltreatment	.04	.42	.67
		Physical maltreatment	-.10	-1.01	.31
RG	R = .57, R^2 = .32, F(5,151) = 14.02, p < .001				
		Training age	.01	.48	.63
		BMI	-.06	-1.06	.29
		Social Physique Anxiety	-.84	-7.18	.000**
		Psychological maltreatment	.20	1.61	.11
		Physical maltreatment	-.17	-1.32	.19
Other	R = .73, R^2 = .53, F(5,82) = 18.36, p < .001				
		Training age	-.02	-.56	.58
		BMI	-.07	-1.56	.12
		Social Physique Anxiety	-.93	-7.76	.000**
		Psychological maltreatment	-.12	-.87	.39
		Physical maltreatment	-.05	-.25	.81

**: p < .001, *: p < .05

World Health Organization (1999) claimed that the highest potential for maltreatment occurs at the hands of individuals who are closest to the child. The coach-athlete relationship is one of the most common relations in which maltreatment can occur (Gervis & Dunn, 2014; Kerr & Stirling, 2012). Coaches are individuals that are present in child's day-to-day life (Kerr & Stirling, 2019) and in some sports they are closer than parents, as training takes many hours per day and athletes often live in training centers. For rhythmic gymnasts, childhood and adolescence is a period of intensive training, since the selection of elite gymnasts for the national team takes place at that age (Cupisti, D' Alessandro, Castrogiovanni, Barale, & Morelli, 2000). The few selected young gymnasts train for many days per week and for many hours every day (Bobo-Arce & Méndez-Rial, 2013). Perhaps that is the reason why RG athletes reported higher levels of maltreatment than other athletes, both psychological and physical.

Another interesting finding of the present study was that psychological maltreatment was higher than physical in both groups, rhythmic gymnastics and other sports. Emotional maltreatment is often normalized by many cultural sport insiders, as coaches see it as necessary to produce successful athletic performance (McMahon, Penny, & Dinan-Thompson, 2012; Stirling & Kerr, 2014). Given the normalization of emotional maltreatment in sport, Stirling and Kerr (2014) observed that coaches and athletes both seem to view the use of these harmful behaviors as a part of the coaching process required to produce high-performance sporting success. Taylor, Piper and Garratt (2016) argue that the prevailing discourse has redefined coaching and individuals involved in such a way that it is nowconsidered as potentially dangerous. As a consequence, whoever has a duty of care towards children should adopt consistently protective strategies and behaviours (Taylor, Piper, & Garratt, 2016). On the other hand, physical maltreatment is low for many reasons. Currently, coaches are former athletes who experienced physical maltreatment as athletes and do not support such behaviors, therefore they do not include them in their coaching behavior. Also, coaches are more educated than they used to be in the past. Many have a bachelor's degree or a coaching diploma obtained through coaching education by the relevant Federations, both national or international. Although there are studies indicating that the phenomenon of 'fast-tracking' former elite athletes into coaching roles is related to harassment (McMahon, Zehntner, McGannon, & Lang, 2020), it would be interesting to find out whether the coaches in the present study were educated or not. In the aforementioned study, the fast-tracking of an athlete into the swimming coach role meant that she contributed to the perpetuation of physical and psychological abuse in sport (McMahon et al., 2020).

Kerr and her colleagues (Kerr, Willson, & Stirling, 2019) illustrated that most of the forms of harm (psychological, physical, neglect and sexual) were correlated significantly with health outcomes. Our findings partly support this, as body dissatisfaction was related to physical maltreatment and drive for thinness was related to psychological maltreatment. These findings were more intense for RG athletes. Drive for thinness includes perceptual, behavioural and attitudinal parts, and as Sands (2000) mentioned, it is probably triggered when there is a discrepancy between the actual and the ideal body weight that exceeds idealized preference for cultural thinness and involves body image dissatisfaction. Former Greek RG athletes reported higher pressure to be thin by coaches, parents and friends than current RG athletes (Kosmidou, Giannitsopoulou, & Proios, 2018). This pressure could be recognized as psychological maltreatment. Indeed, Pinheiro and her colleagues (2014) considered issues of weight control as abuse in female artistic gymnastics. Such issues exist also in rhythmic gymnastics. It is interesting that one of the greatest rhythmic gymnastics coaches, the Bulgarian Neska Robeva, in her book ”Champions’ school“, included a chapter titled “The terrible war against weight” (Robeva & Rangelova, 1989). In it, some coaches’ behaviors to control athletes’ weight are described and most of them could be defined as maltreatment. Rhythmic gymnastics is a modern sport, as it was included in the Olympic Games for the first time in 1984. The effect and the results of such coaching behaviors are not well documented. So, as Donnelly (1997) observed, many coaches may believe they are working in the best interests of the athletes and tend to place great emphasis on the athletes’ body and its performance.

Rhythmic gymnasts have been identified as being more at risk for eating disorder as they scored higher on drive for thinness than other athletes in other subtypes of gymnastics, artistic and acrobatics (Nordin, Harris, & Cumming, 2003). In our study there were no differences in body dissatisfaction and drive for thinness between rhythmic gymnastics and other sports. This can be due to the sports in which the participants participated. Another possible explanation could be that after their disengagement from sports, former RG athletes are no longer at risk, as disengagement could minimize the possible effects of sport participation. A third possible explanation could lie in the pressure by media on women. Perhaps media creates so much pressure on women that this neutralizes the differences between athletes from different sports. It would be important to design and implement similar studies that would include current athletes.

It is interesting whether and how maltreatment by coaches could predict body dissatisfaction and drive for thinness. There is no other study so far, and the present study found some evidence but this issue needs to be further examined. Only for former RG athletes, physical maltreatment could predict body dissatisfaction.

Social physique anxiety was not predicted by maltreatment by coaches. This probably shows that variables other than coaching behaviour, after disengagement, play a role, such as pressure arising from cultural variables, perhaps from media and/or significant others. These issues should be examined.

The present study is an attempt to examine maltreatment by coaches and eating disorders. As mentioned above, for ethical reasons, only former athletes participated. Although they give us insights, all these issues should also be examined in current athletes. Also, participants from all kinds of sports should participate, and male athletes should also be included. Maltreatment is not a phenomenon in female sports only but in male sports also. It would be interesting to examine whether there is correlation to coaches’ sex. According to similar studies, directions for Federations should be issued in order to design intervention programs of safeguarding both athletes and coaches, and intervention programs of sport disengagement for all athletes.

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SHORT HISTORICAL NOTES XXIV

Anton Gajdoš, Bratislava, Slovakia

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

Aljaž PEGAN (June 2, 1974 Ljubljana, Slovenia)

Aljaž Pegan started his career at TVD Partizan Vič under his the first coach Boris Pavliha. Before puberty he moved to TVD Partizan Trnovo where he worked with Jože Mešl, who was also coach of Alojz Kolman. Aljaž Pegan since his first appearances at gymnastics competitions showed elegance and technical mastership. In junior and beginning of his senior days, he competed in all around. Those who were in TVD Partizan Trnovo knew that his gymnastics had greatly depended on gymnastics hall, which was approximately 12m x 12m. Mostly horizontal bar and parallel bars were in focus of Aljaž. Since 1992 FIG started with specialist's competitions and according to conditions he had, that was something for his acrobatics knowledge on horizontal bar and parallel bars.

Code of Points sometimes did not gave him any bonus, despite his atractive figure (he was slightly taller than other gymnasts) and smooth, elegant movements and very difficult exercise.

With Jože Mešl they mastered two elements with Pegan's name. The first was on high bar: doble salto forward tucked over bar with half turn – Gaylord with half turn – Pegan. At the beginning it was D difficulty in Code and it took many years before FIG raised difficulty. Not many gymnasts performed Pegan in his exercise, but Vlasios Maras even upgraded Pegan's element into piked position. The second element was on parallel bars: from handstand Diamidov on one rail and one turn on one rail. Also element on parallel bars had no many repetitions with other gymnasts, the most famous was Epke Zonderland. In the present Code of Points Pegan's element on parallel bars is not anymore evaluated as difficulty element as it is sum of thwo independent elements.

In 2013 he finished with competing, but is still involved in gymnastics as vice president of Slovene Gymnastics Federation, technical adviser for Turkish Gymnastics Federation and serves as elected athletes representative in FIG.

As he was apparatus specialist he could not qualify for Olympic Games. The closest he was in 2007, when he was 2nd at World Championship, but to qualify for Being 2008 he should win. Despite he was not at OG, his case was one of which made FIG to start changing qualifyng criteria for OG.

European Championship

1994 Prague (CZE)	Horizontal bar 1.
2000 Bremen (GER)	Horizontal bar 3.
2004 Ljubljana (SLO)	Horizontal bar 1.
2007 Amsterdam (NED)	Horizontal bar 2.
2008 Lausanne (SUI)	Horizontal bar 3.

World Cup

2000 Glasgow (UK)	Horizontal bar 2., Parallel bars 3.
2002 Stuttgart (GER)	Horizontal bar 1.
2006 Sao Paulo (BRA)	Horizontal bar 3.

World Championships

1994 Brisbane (AUS)	Horizontal bar 4.
1996 Puerto Rico (PUR)	Horizontal bar 4.
2002 Debrecen (HUN)	Horizontal bar 2.
2005 Melbourne (AUS)	Horizontal bar 1.
2006 Arhus (DEN)	Horizontal bar 2.
2007 Stuttgart (GER)	Horizontal bar 2.

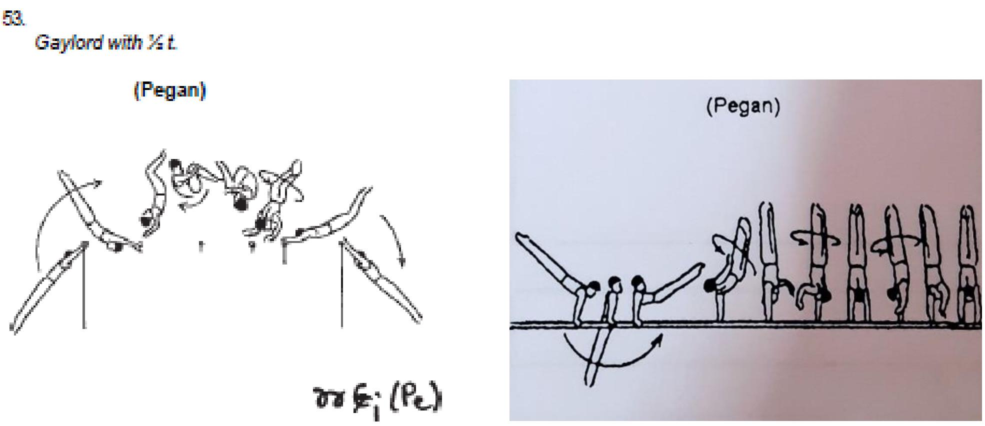

Figure 1. Element Pegan on horizontal bar and parallel bars (FIG Code of points, 2021, 1999).

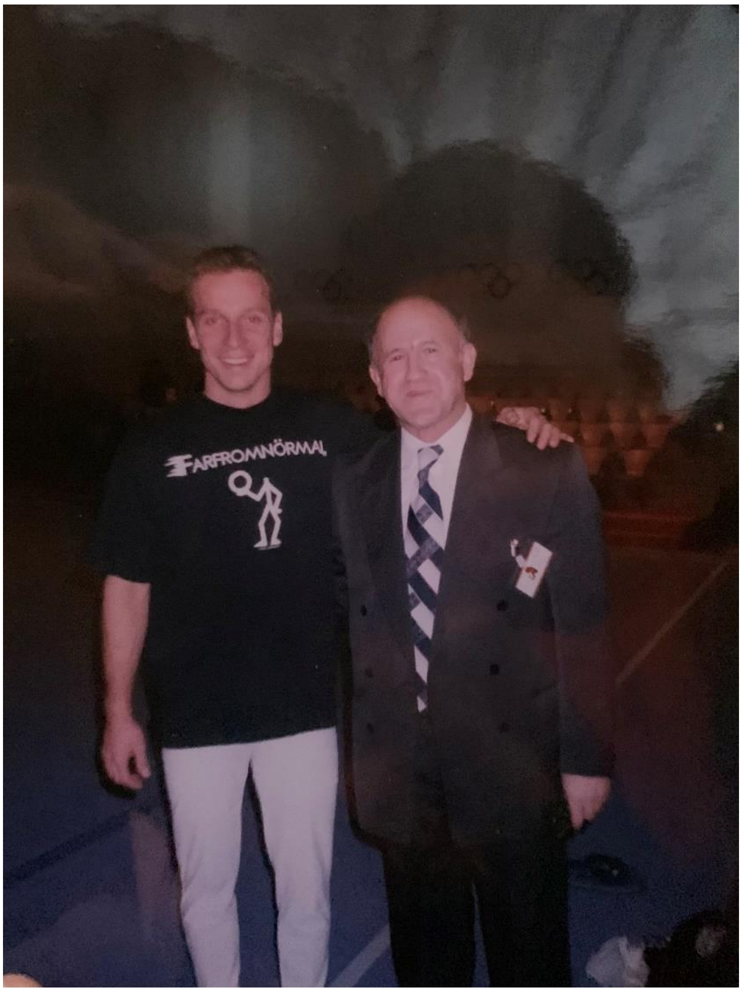

Figure 2. Aljaž Pegan and Anton Gajdoš.

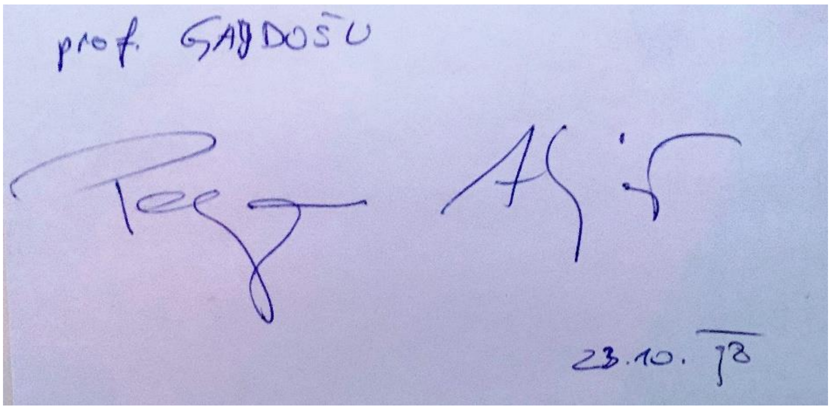

Figure . Aljaž Pegan signature.

Slovenski izvlečki / Slovene Abstracts

K OLIMPIJSKEMU ZLATU: NAČRT VADBE NA KROGIH

Marcos Goto, Paulo Carrara, Hugo Lopes, Myrian Nunomura

Cilj sestavka je opisati načrt vadbe in strategije, ki so jih razvili z olimpijskim prvakom, telovadcem na krogih. V Londonu 2012 je brazilski in tudi južno ameriški telovadec postal prvi olimpijski zmagovalec na olimpijskih igrah. Na olimpijskih igrah v Riu 2016 je telovadec ponovno stal na stopničkah in osvojil srebrno medaljo. Vendar še nismo videli predstavitve poti, ki bi osvetlile pripravo športnika, ki je dosegel vrhunec s tako neverjetnimi dosežki na celinski ravni. Predstavljamo strukturo načrtovanja in izvedbe tega telovadca za obdobje, ki je vključevalo olimpijske igre. Za podrobnejšo obdelavo vadbe procesa smo razčlenili vadbene liste s testi moči, veliko obdobje ter telesno in tehnično pripravo, razporejenimi na tri pod obdobij. Načrt, ki so ga izvajali vaditelji, je telovadca pripeljala do povečanja težavnosti tehničnih prvin sestave, kar je omogočilo povečanje končne uspešnosti. Glavni dejavniki, ki so omogočili olimpijski rezultat, sta bila načrtovanje treh obdobij priprave in tekmovalna taktika v pripravljalnemu ocenjevanju.

Ključne besede: orodna telovadba, vadba, mišična moč, tekmovalna uspešnost.

LEPOTNA RAZMERJA LETA - KAKO SO POVEZANE STROKOVNOST OPAZOVALCEV IN ZAZNAVANJE LEPOTE S KINEMATIKO LETA

Pia M. Vinken, Vincent Stirling in Thomas Heinen

Zaznavanje (gibalne) lepote je povezano z okoliščinami predmeta, opazovalca in okolja. Osrednje vprašanje te študije je, ali je zaznavanje lepote gibanja povezano z razmerjem gibalnih sposobnosti med kinematiko letenja in opazovalčevimi čutno-gibalnimi izkušnjami. Predvideva se, da gibalne sposobnosti, ki jih dojemamo kot bolj lepotne, kažejo kinematična razmerja letenja blizu zlatega reza. Predpostavlja se, da gibalne sposobnosti, ki jih dojemamo kot manj lepe, kažejo kinematična razmerja letenja dlje od zlatega reza. Poleg tega se domneva, da je to razmerje povezano z opazovalčevo čutno-gibalno izkušnjo. Zato je bilo 36 oseb (12 odličnih premagovalcev ovir, 12 začtnikov premagovalcev ovir in 12 oseb, ki nimajo izkušnje s premagovanjem ovir) pozvanih, da navedejo svoje dojemanje lepote gibanja ob gledanju video posnetkov različnih predstav premagovanja ovir. Rezultati kažejo, da so kinematična razmerja letenja in čutno-gibalna izkušnja opazovalca povezana z zaznavanjem lepote veščine premagovanja ovir. Kot je domnevno, so kinematična razmerja predstav, ki jih dojemamo kot lepše, bližje zlatemu rezu; predstave, ki se dojemajo kot grše, pa so dlje od zlatega reza; to je pomembno za premagovalce ovir, ne pa za tiste, brez izkušenj. Tako sklepamo, da je lepotna zaznava gibalnih sposobnosti povezana s kinematičnimi razmerji letenja in čutno-gibalnim znanjem opazovalca. Prihodnje delo bi moralo vključevati takšno znanje o kinematskih razmerjih in o tem, kako jih obravnavati med predstavami gibalnih veščin, da bi ustvarili in izvajali lepe, prijetne, zahtevne gibalne veščine.

Ključne besede: lepota; zaznavanje gibanja; Likertova lestvica; zlata sredina; videografija.

VPLIV MIŠIČNE SILE NA USPEH TELOVADCEV PRI IZVAJANJU PRESKOKA

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Namen raziskave je bil ugotoviti vpliv absolutne in relativne mišične sile nog, nadlahti in ramenskega obroča na uspešnost izvajanja preskoka pri telovadcih, starih od 13 do 16 let, ki se ukvarjajo z orodno telovadbo od 5 do 12 let. Za oceno absolutne mišične sile noge, nadlahti in ramenskega obroča smo uporabili japonski digitalni dinamometer IMADAZ2H-1100 s programsko opremo WinWedge 3.4. Vrednosti, prikazane na digitalnem merilniku, so predstavljale absolutno vrednost največje sile, in ko smo absolutno vrednost sile delili z maso udeleženca, smo dobili vrednost relativne sile. Z regresijsko analizo smo ugotovili vpliv absolutne in relativne mišične sile nog, nadlakti in ramenskega obroča na uspešnost izvedbe preskoka. Rezultati so pokazali, da čeprav obstaja vpliv zgoraj navedenih mišic, ni statistično pomemben. Natančneje, za uspešen nastop na preskoku imajo največji vpliv (brez statističnega pomena) mišice ramenskega obroča. Razlog za tako pridobljene rezultate je v tem, da sta let in doskok odvisna od opore na mizi. Ker je raziskav na temo prispevka malo, ne glede na dobljene rezultate predstavljajo te raziskave dober temelj in podlago za nekatere prihodnje raziskave absolutne in relativne sile v orodni telovadbi.

Ključne besede: preskok, telovadci, absolutna sila, relativna sila

GIBALNE SPOSOBNOST UČENCEV AKROBATSKIH ŠPORTNIH RAZREDOV - DVOLETNO SPREMLJANJE

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Predšolsko obdobje je zelo pomembno v športih zgodnje usmeritve (kot so različne oblike telovadbe). Smiselno usmerjena vadba v tem obdobju zagotavlja podaljšanje razvoja in uravnavanje pri oblikovanju otrokovih gibalnih sposobnosti. Da lahko telovadci učinkovito in natančno izvajajo različne prvine in sestave, je nujna primerna raven njihove telesne pripravljenosti. Raziskovalno gradivo sestavljajo rezultati dvoletnega spremljanja deklic in dečkov, starih 7-9 let. V raziskavi je sodelovalo 253 učencev. V njem je sodelovalo 167 učencev splošnih razredov (75 deklet in 92 fantov) in 86 učencev športnih razredov – razredov akrobatike (50 deklet in 36 fantov). V okviru študije so bile izvedene 3 zaporedja meritev, ki zajemajo 2-letno obdobje predšolske vzgoje (1.-3. razred osnovne šole). Dekleta in fantje iz športnih razredov (7, 8, 9 let) so pri preizkusih telesne pripravljenosti (razen dinamometrične sile desne in leve roke) dosegli v povprečju boljše rezultate kot njihovi vrstniki iz splošnih razredov. Pri obeh spolih (starih 7, 8 in 9 let) so bile največje razlike v stopnji razvitosti opažene pri gibljivosti, moči rok in okretnosti. V nadaljnjem obdobju so se razlike v stopnji telesne pripravljenosti med športnimi in splošnimi razredi poglobile. V vsakem delu študije je bilo povečanje določene gibalne sposobnosti v skupinah športnih razredov večje kot na splošno (razen dinamometrične sile desne in leve roke).

Ključne besede: akrobatika, športni tečaji, telesna pripravljenost, razvoj

PRIMERJAVA STOPNJE UPOGIBA STOPALA MED MLADIMI TELOVADKAMI IN MLADIMI ŠPORTNICAMI - PILOTNA RAZISKAVA

Dávid Líška, Juraj Kremnický

Telovadba razvija moč, gibljivost, pozornost, ravnotežje, natančnost in hitrost. Namen raziskave je ugotoviti, ali telovadba vodi do povečanja razpona gibanja upogiba stopala v zaprti kinematični verigi pri mladih telovadcih v primerjavi z drugo vrsto športa. Izvedba z obremenitvijo je bila izbrana za merjenje obsega upogiba stopala. Prvo skupino sestavljajo člani slovaške mladinske vrste pri telovadbi (26). Drugo skupino sestavljajo člani slovaške vrste v ritmiki (13). Nadzorno skupino sestavljajo mladi športniki (22). Povprečni obseg gibljivosti upogiba stopala pri telovadcih je bil 47,32° v desnem gležnju in 44,75° v levem gležnju. Povprečni obseg pri ritmičarkah je bil 44,32° v desnem gležnju in 43,41° v levem gležnju. Povprečni obseg pri mladih športnikih je bil 44,27° v desnem gležnju in 42,32° v levem gležnju. Rezultati kažejo na statistično značilno razliko v korist telovadk v primerjavi z ritmičarkami v desnem skočnem sklepu (p-0,04). V levem gležnju se skupini nista bistveno razlikovali med seboj (p-0,38). Med telovadkami in športnicami ni bilo bistvene razlike v desnem gležnjem (p-0,09) in levem gležnjem (p-0,19). Med ritmičarkami in športnicami ni bilo bistvene razlike v desnem gležnjem (p-0,38) in levem gležnjem (p-0,24). Pri mladih telovadkah v primerjavi z ritmičarkami smo zaznali večji obseg gibljivosti upogiba stopala v zaprti kinematični verigi.

Ključne besede: meritev z obremenitvijo, obseg gibanja, umetnost, ritmika, šport

KINEMATSKA ANALIZA DVEH NAČIN IZVEDBE PREMETA NAZAJ – ŠTUDIJA PRIMERA

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Namen raziskave je bil primerjati izbrane kinematične spremenljivke premeta nazaj iz stoječega položaja (Bh) in premeta nazaj iz zaporedja akrobatskih skokov premet vstran z obratom nazaj, premet nazaj, stegnjeni salto nazaj (RBhS). Študija je vključevala 4 telovadce (povprečna starost: 19,5 let), ki so opravili 6 ponovitev Bh in RBhS. Vse prvine so bile posnete. Sodniki so za vsakega telovadca izbrali najboljšo izvedbo Bh in RBhS, ki sta bili nato kinematično razčlenjena. Na podlagi posnetih prvin je razčlenjena časovna struktura gibanja, spremembe premikov in hitrosti težišča športnikov (CG) ter spremembe položaja njihovega trupa glede na tla. Pri Bh in RBhS se je vodoravna hitrost CG (vx) zmanjšala od začetka prvega leta do konca opore na nogah. V Bh so se mediane vrednosti (Me) vx zmanjšale z 1,94 m/s na 0,8 m/s, pri RBhS pa s 4,85 m/s na 2,24 m/s. V primeru navpične hitrosti (vy) so bile najvišje vrednosti Me za oba premeta nazaj ob koncu opore na nogah (za Bh in RBhS: 3,27 m/s in 4,79 m/s oziroma). Tako v Bh kot RBhS se je vrednost CG hitrosti v vodoravni smeri zmanjševala od začetka gibanja do njegovega zaključka.

Ključne besede: kinematika, telovadba, premet nazaj, tehnika.

PREGLED ČLANKOV Z VSEBINO MERITEV SILE PRI TELOVADBI

Zadriane Gasparetto, Adenizia Luciana Julião, Mabliny Thuany, Paula Felippe Martinez, Sarita de Mendonça Bacciotti in Silvio Assis de Oliveira-Junior

Namen je bil razčleniti posebne vire o poteku meritev, merilnih napravah in tehnikah, ki se uporabljajo za vadbo in ocenjevanje sile pri telovadcih, ki jih zastopa Mednarodna telovadna zveza (Fédération Internationale de Gymnastique – FIG). Pregled je bil opravljen v skladu s smernicami o prednostnih postavkah poročanja za preglede in metaanalize (PRISMA). Načrtna iskanja v zbirkah podatkov PubMed, Web of Science, Scopus, LILACS, SciELO in SPORTDiscus so bila izvedena z uporabo naslednjih ključnih besed: »ocenjevanje«, ALI »merjenje«, ALI »evalvacija« IN »otrok*« ALI »mladi, ” ALI »mladostnik*«, IN »športnik*«, ALI »vaditelj«, ALI »telovadka*«, IN »telovadka*«, ALI »ponjava« IN »mišična moč«, ALI »mišična sila« ALI »moč ," ALI "sila", ALI "koncentrično", ALI "zmogljivost", ALI "eksplozivna moč", ALI "preizkusi gibalnih sposobnosti". Raziskave, vključene v ta pregled, obravnavajo oceno in vadbo moči pri telovadcih ali športnikih. Temelj tega pregleda je štirinajst raziskav, ki so ocenjevale moč. Ti članki opisujejo poceni, enostavne za uporabo naprave in poteke meritev, ki se izvajajo v telovadnici. Vključeni članki so se osredotočili na ocenjevanje stopnje moči mladostnikov in športnic za izbiro in odkrivanje nadarjenih ter zmanjšanje poškodb. Kljub prednostim vadbe moči, kot so boljša zmogljivost in manj poškodb, se moč na splošno ne ocenjuje redno. Najdene so bile le študije, ki so vključevale orodno telovadbo ali ritmiko.

Ključne besede: telovadba, ponjava, mišična moč, mišična sila

ZAKAJ JE PRESKOK POSTAL NAJPOMEMBNEJŠE ORODJE PRI ŽENSKI ORODNI TELOVADBI?

Jun He, Jeffrey Montez de Oca in Lei Zhang

Kritiki trdijo, da discipline v ženski orodni telovadbi niso enakovredne in da je preskok na splošno ocenjen veliko višje od dvovišinske bradlje, gredi ali parterja. Namen raziskave je razumeti, zakaj je preskok postal pomembnejši od drugih orodij. Zbrani podatki so uradni rezultati za 586 telovadk v predtekmovanju na olimpijskih igrah od leta 2000 do 2020. Enosmerna ANOVA je bila uporabljena za razčlenitev spremenljivosti rezultatov D, E in F za telovadke na vsakem orodju. Rezultati kažejo, da discipline niso bile enakovredne za telovadke, ko so poskušale doseči visoke F-rezultate na zadnjih 6 olimpijskih igrah. Med štirimi ženskimi disciplinami je preskok postal tisti, na katerem bodo telovadke po olimpijskih igrah leta 2000 bolj verjetno dosegle visoke ocene F. Navajamo, da je moč preskoka posledica uvedbe novega orodja – mize – leta 2001 in novih odprtih pravil leta 2006. Čeprav sta bili dve veliki spremembi, ki ju je Mednarodna telovadna zveza uvedla v začetku novega tisočletja, usmerjeni v izboljšanje varnosti preskoka in pravičnosti sojenja je preplet dveh velikih sprememb nenamerno spodbudil preskok, da je postal najpomembnejši. Takšna nepričakovana posledica namenskega delovanja je lahko najpomembnejši vzrok (tj. neravnovesje disciplin) v športu. V skladu s tem ima ta raziskava potencial, da osvetli ne le to pomembno temo enakosti med disciplinami, temveč tudi širše trende v sodobni orodni telovadbi.

Ključne besede: preskok, disciplina, enakopravnost, olimpijske igre.

UČINEK OBRNJENE SORAZMERNE STAROSTI PRI KOREJSKIH TELOVADCIH IN TELOVADKAH

Jiwun Yoon in Jae-Hyeon Park

Učenci, rojeni v zgodnejših mesecih, imajo verjetno višje akademske uspehe kot tisti, rojeni pozneje, čeprav so v istem razredu (učinek sorazmerne starosti, RAE). Nekatere študije niso poročale o RAE v telovadbi. Cilj te študije je bil določiti RAE pri korejskih telovadcih in telovadkah. Zbrani so bili podatki o mesecu rojstva 806 korejskih telovadcev: 482 osnovnošolskih (181 moških; 301 žensk) in 324 srednješolskih telovadcev (189 moških; 135 žensk), včlanjenih pri Korejski telovadni zvezi. Uporabljena so bila štiri četrtletja: Q1 (januar–marec), Q2 (april–junij), Q3 (julij–september) in Q4 (oktober–december). Za preverjanje domneve smo uporabili test $\chi 2$ in njegovo verjetnost. Skupno se je v prvem četrtletju rodilo 164 (20,3 %) telovadcev, v drugem 191 (23,7 %), v tretjem 220 (27,3 %) in v četrtem 231 (28,7 %). Nismo mogli potrditi, da je pogostnost rojstva Q1 visoka. Opisni podatki RAE so pokazali, da je bila frekvenca Q1 najnižja med četrtinami udeležencev. V nasprotju s pričakovanji RAE je Q4 pokazal najvišjo frekvenco tako pri osnovnošolskih telovadcih kot srednješolskih ($\chi 2$ osnovni=2,431, p-vrednost=0,487; $\chi 2$ srednja visoka=17,827, p-vrednost=0,001), kar je izgledalo kot “obrnjeni učinek sorazmerne starosti”. Obrnjeni RAE je bil bolj izrazit pri srednješolskih telovadcih.

Ključne besede: učinek obrnjene sorazmerne starosti; korejski telovadci; RAE; mesec rojstva.

SAMOURAVNAVANJE ZAČETNEGA UČENJA TELOVADNIH PRVIN: STRATEGIJE, OSREDINJENE NA ŠTUDENTE

Alejandra Ávalos-Ramos in Ángeles Martínez Ruiz

V okviru pogledov samoodločanja, samonadzora in samouravnavanje se v tej raziskavi razčlenjuje obvladovanje težav, ki se pojavljajo pri izvajanju strategij za podporo samostojnemu in sodelovalnemu učenju telovadbe. Pristop je kakovosten in temelji na izkušnjah študentov telesne vzgoje in športa, ki uporabljajo osebne dnevnike med obiskovanjem predmeta kot podatkovno orodje. Razčlenitev podatkov se je izvedla s računalniškim orodjem AQUAD 7. Rezultati kažejo, da študenti med učenjem doživljajo težave, povezane s strahom, zlasti v zadnjih trenutkih izobraževanja, skupaj z zaznavo telovadne nesposobnosti, ki se z iztekom vadbenega obdobja zmanjšuje. Kot odgovor na spopadanje z učnimi težavami se študenti večinoma zatekajo k osebnemu zrcalu, prevzemajo stališča žrtve in se v manjši meri obračajo na vrstnike, da jim med drugim pomagajo pri reševanju težav. Visoka stopnja občutka žrtve v položaju visokega pritiska razkriva potrebo po oblikovanju strategij čustvenega upravljanja, da bi zmanjšali odpor študentov do ocenjevalnih nalog, ki lahko poškodujejo in izkrivijo doseženo dejanje pri učenju ter zmanjšajo samonadzor.

Ključne besede: visokošolsko izobraževanje, odločanje, telovadba, podpora samostojnosti, sodelovanje.

NASILJE (OSEBNOSTNO, TELESNO), DRUŽBENA TESNOBA, TELESNO NEZADOVOLJSTVO IN TEŽNJA PO SUHOSTI PRI GRŠKIH ŠPORTNICAH (RITMIKA IN DRUGI ŠPORTI) PO PRENEHANJU TEKMOVALNE POTI

Evdoxia Kosmidou, Evgenia Giannitsopoulou, Natalia Kountouratzi in Maria Karatzioti

Nasilje vaditeljev je pomembno vprašanje za vse športnike, zlasti pa za športnice. Namen te raziskave je bil preučiti, ali bi osebnostno in telesno trpinčenje s strani vaditeljev lahko vplivalo na družbene tesnobo, nezadovoljstvo s telesom in željo po vitkosti pri nekdanjih grških športnicah. V raziskavi je sodelovalo dvesto petdeset nekdanjih športnic, nekdanjih športnic v ritmiki (RG) in drugih športih (OS). Izpolnili so vprašalnike, o katerih so poročali sami, v katerih so ocenili nasilje (osebnostno, telesno) s strani vaditeljev, družbeno tesnobo, nezadovoljstvo s telesom in željo po vitkosti. Rezultati so pokazali, da je RG poročala o večjem osebnostnem in telesnem trpinčenju kot drugi, vendar ni bilo razlik v nezadovoljstvu s telesom, težnji po vitkosti in družbeni tesnobi. Čeprav so obstajale pomembne povezave med nasiljem in nezadovoljstvom s telesom ter željo po vitkosti, je bilo napovedovanje za druge športnike in ne za ritmičarke. Te ugotovitve lahko morda pomagajo, da vse vrste športov postanejo okvir, ki spodbuja zdravje športnic, ne pa ga spodkopava.

Ključne besede: vaditelji, tesnoba, nezadovoljstvo s telesom, težnja po vitkosti.