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CONTENTS

Slovenia celebrates 160th anniversary since Južni Sokol have been established. His most known members are dr. Viktor Murnik – father of Slovene physical culture, Peter Šumi (twice World Champion in all around), Miroslav Cerar (twice Olympic Champion on pommel horse) and Mitja Petkovšek (twice World Chamipon on parallel bars). Exhibition prepared by Ivan Čuk is located in Tivoli park in Ljubljana.

Photos: Valentina Horvat and Ivan Čuk

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EDITORIAL

Dear friends,

Last year we moved to open editorial software that is hosted by University of Ljubljana Press. We are still adapting to this new address and the new way of work. We apologise for any inconvenience that this move has created and hope to get everything running smoothly as soon as possible.

Please note that our address is

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

We are still working as volunteers and splitting our duties with our younger coworkers. You may have noticed that the administrator has become very strict when articles are not prepared according to the guidelines. To avoid any prolonged delays in getting your article approved, please read the guidelines carefully and make sure to follow them.

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

This issue covers a diverse range of content, the authors are coming from Taiwan, Spain, Croatia, USA, Brazil, Portugal and the Bosnia and Herzegovina.

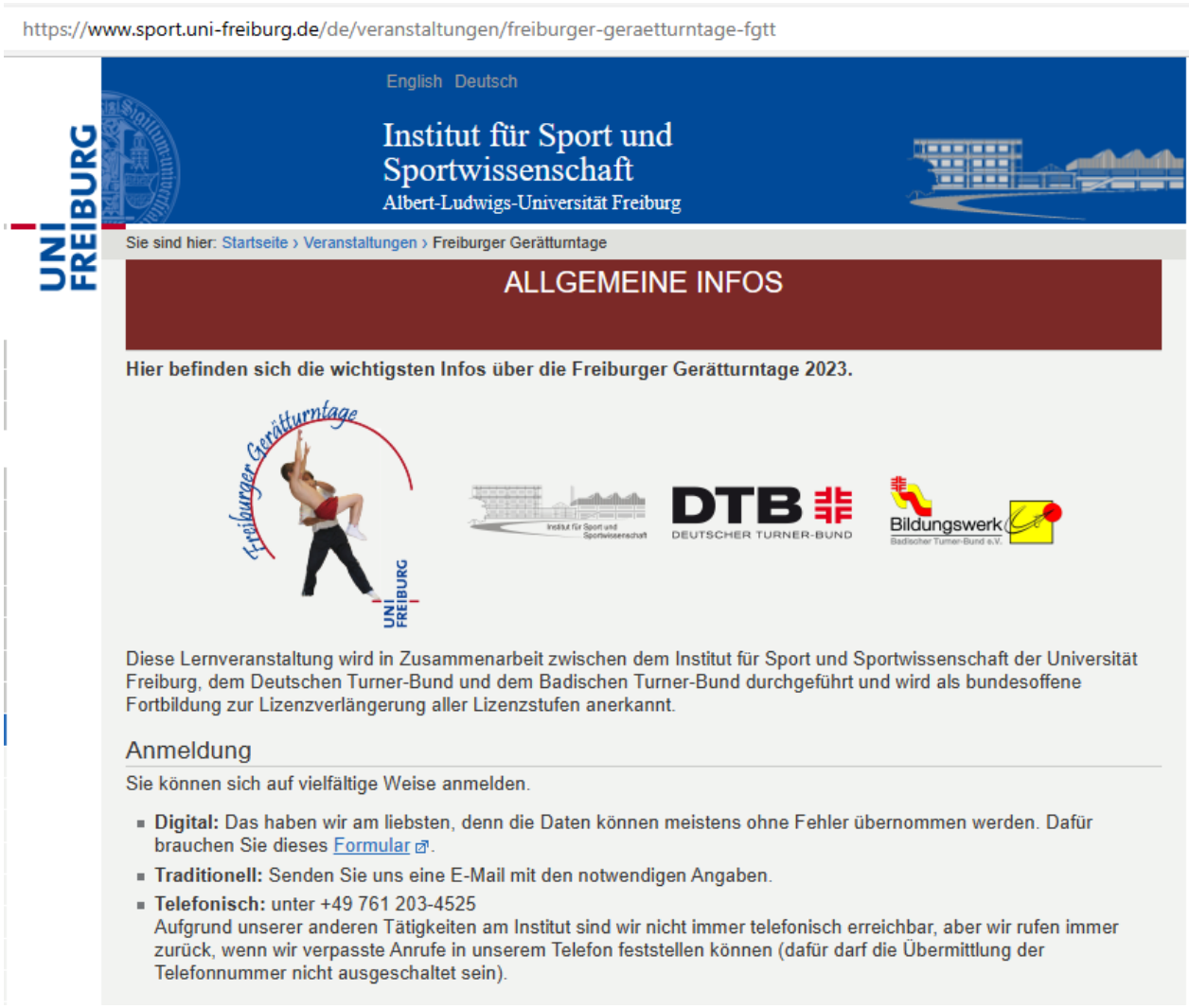
For those, who want more knowledge from different areas of our gymnastics, please join to Freiburger Gerätturntage 2023 from 14.-15.10.23. Lectures will be also in English.

Anton Gajdoš prepared his 27th short historical note introducing Mitsuo Tsukahara from Japan.

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



Dear friends!

We invite you to be part of **Freiburger Gerätturntage 2023 from 14.-15.10.23**.

More info:

https://www.sport.uni-freiburg.de/de/veranstaltungen/freiburger-geraetturntage-fgtt

Prof.in Jana Strahler and Flavio Bessi

WILL ELEVATING THE DIFFICULTY SCORES IMPROVE THE ODDS OF WINNING? THE CASE OF ARTISTIC GYMNASTICS EVENT FINALS

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Abstract

The aim of this study was to compare the difficulty (D) scores and final (F) scores between the qualification round (QR) and the event finals round (EF) for each apparatus in 2018–2020 Individual Apparatus World Cup Series (IAWCS) and 2019 World Artistic Gymnastics Championships (WC). It was also to examine the association between strategy of D scores and winning a medal or not. Both male and female gymnasts who participated the EF in IAWCS and WC were the subject of present investigation. The dependent t test was used to analyze the D scores and F scores. The Chi-square test was selected to test the numbers of distribution of increasing/non-increasing of D scores and wining/losing a medal, and the odds ratio was also calculated. It shows that in all apparatus, there were meaningful differences in D scores between the QR and EF for both male and female gymnasts. The F scores of EF were significantly lower as compared to the QR in men's pommel horse (PH), horizontal bar (HB) and women's balance beam (BB), floor exercise (WFX) events. To elevate D scores in the EF of PH, HB and WFX could significantly improve the odds for getting a medal. To our knowledge, this was the first study to compare the gymnast's performance between the QR and the EF. And we also determine the different D scores and the odds ratio of winning a medal in the EF. When studying PH, HB, BB and WFX, there was a tendency to underestimate the scores if only the result of EF was analyzed but without the QR. Elevating D scores was not always guaranteed to increase the chance of winning. Coaches and gymnasts could refer to the current study to draw up their strategies for different competitions.

Keywords: *artistic gymnastics, final scores, qualification, apparatus finals, odds ratio.*

INTRODUCTION

Artistic gymnastics is a sport in which gymnasts perform various technical elements on various apparatuses (Caine, Russell, & Lim, 2013, pp. 85–97). Women's

artistic gymnastics includes four events, namely the vault (WVT), uneven bars (UB), balance beam (BB), and floor exercise (WFX) events. Men's artistic gymnastics includes six events, namely the floor exercise (MFX), pommel horse (PH), rings (SR), vault (MVT), parallel bars (PB), and horizontal bar (HB) events. Each competition is divided into four rounds, namely a qualification round (QR), a team final, an all-around final, and an apparatus final (EF). The medals (always gold, silver, and bronze for first, second, and third, respectively) are awarded to the gymnasts after the EF. Each gymnast must perform in each event in both the QR and EF. Leskosek, Cuk, and Bucar Pajek (2013) and Looney (2004) have indicated that in aesthetic sports, including gymnastics, diving, and figure skating, a participant receives two scores, namely a difficulty (D) score and an execution (E) score. Judges must, in accordance with the rules of the sport, provide the final (F) score and determine the winner (Cuk, Fink, & Leskosek, 2012). The F score of all the events of an artistic gymnastics competition is the sum of the D score and the E score. The D score judges (D-panel judges) grade the overall performance of the gymnasts and provide a D score. The E score judges (E-panel judges) use a method known as execution deduction to determine a gymnast's E score based on the quality of the performance (Fédération Internationale de Gymnastique [FIG], 2017a, 2017b).

Therefore, the key to winning an artistic gymnastics competition and a medal is striking an effective balance between the D score and the E score to achieve a high F score (Kerwin & Irwin, 2010). In other words, increasing the D score is crucial for gymnasts to increase their F score in each event (Schärer, Lehmann, Naundorf, Taube, & Hübner, 2019). For instance, a coach or gymnast could change their strategy before the EF by increasing their D score from the QR, thereby potentially effectively increasing their F score. However, naturally, the odds of errors leading to E score deduction increase greatly with more difficult and complex movements and combinations of elements. Therefore, it is necessary to investigate the differences between gymnasts' D scores and F scores in the QR and EF and to analyze the relationship between the outcome of a competition and increases in D scores for the EF.

Olympic Qualification System Tokyo 2020 stated that gymnasts could qualify for the Olympics through other competitions, including the 2018–2020 Individual Apparatus World Cup Series (IAWCS) and 2019 World Artistic Gymnastics Championships (WC) (FIG, 2020). In recent years, gymnastics scores in major international competitions have been compared and analyzed to serve as a reference for gymnasts training and preparing for the Olympics. For example, one study investigated variations in the scores of gymnasts in each event in Australian national gymnastics competitions and Olympic women's artistic gymnastics competitions (Bradshaw, Hume, & Aisbett, 2011). Chen, Chen, Lu, and Tang (2021) investigated Taiwanese male gymnasts who had qualified for the Tokyo 2020 Olympics men's team event. However, apart from those two studies, no study has investigated or analyzed gymnasts attempting to qualify for Tokyo 2020 Olympics men's and women's individual events. The eight competitions of the IAWCS and the WC were closely related to the qualification for the Tokyo 2020 Olympics and thus are worth

investigating. Therefore, this study analyzed whether the D scores or F scores of gymnasts in an EF were higher than those in the corresponding QR and whether increasing the D score increased the odds of winning a medal. If this study could prove that a gymnast's score in the EF was no higher than that in the corresponding QR, future studies related to EF would need to consider both the F score in the EF and the F score in the QR. In addition, this study examined the correlation between increasing the D score for the EF and the outcome of the competition, as well as the correlation between the D score and the odds ratio (OR) related to winning a medal, in order to understand whether gymnasts should increase their D score once they have entered an EF to increase their odds of winning a medal. The aim of this study was to provide a reference for male and female gymnasts and their coaches for training and strategy setting in preparation for future EF. Specifically, this study compared the D scores and F scores of gymnasts in the QR and EF of the IAWCS and WC to determine whether increasing or not increasing their D score before the EF affected their OR of winning a medal. The main research objectives were (1) to compare the D scores and F scores of male and female gymnasts (in all the events) between the QR and EF and (2) to investigate the correlation between the D score of a male or female gymnast in the EF and their odds of winning a medal.

METHODS

The subjects of this study were finalists in the MFX, PH, SR, MVT, PB, HB, WVT, UB, BB and WFX in the IAWCS and WC. The IAWCS originally scheduled eight competitions, but the competition to be held in Baku in 2020 was affected by the COVID-19 pandemic. Thus, only the QR was completed for this competition. Therefore, all data of this competition were excluded from this study. The competition in Doha was postponed to March 2021. This study included and analyzed gymnasts who competed in the seven competitions of the IAWCS (gymnasts who competed in the competition in Doha in 2021 were also included) and the WC, as illustrated in Tables 1 and 2.

Table 1
Number of male finalists competing in each event.

	2018 GER	2019 AUS	2019 AZE	2019 QAT	2019 WC	2019 GER	2020 AUS	2021 QAT	Total
Floor exercise	8	8	8	8	8	8	8	8	64
Pommel horse	8	8	8	8	9	8	8	8	65
Rings	8	8	8	8	8	8	8	8	64
Vault	8	8	8	8	8	8	8	8	64
Parallel bars	8	8	8	8	8	8	8	8	64
Horizontal bar	8	8	8	8	8	8	8	8	64

Table 2:
Number of female finalists competing in each event.

	2018 GER	2019 AUS	2019 AZE	2019 QAT	2019 WC	2019 GER	2020 AUS	2021 QAT	Total
Vault	8	8	7	8	8	8	8	4	59
Uneven bars	8	8	8	8	8	8	8	7	63
Balance beam	8	8	8	8	8	8	8	7	63
Floor exercise	8	8	9	8	8	8	8	7	64

The seven competitions of the IAWCS were held in Cottbus in 2018; in Melbourne, Baku, Doha, and Cottbus in 2019; in Melbourne in 2020; and in Doha in 2021. The results of these competitions and the results of male and female competitions at the WC were provided by FIG, whose website URL is https://www.gymnastics.sport/site/events/searchresults.php.

This study did not require a review by an institutional review board because the data of the analyzed competitions were public data accessed online.

The official scores of the IAWCS and WC incorporated the male and female gymnasts' D scores, E scores, and F scores in the QR and EF. These scores were used for statistical analyses in this study. The data were compiled using the method described as follows:

(1) This study arranged the D scores and F scores of the QR and EF of each competition in the following order: the 2018 Cottbus, 2019 Melbourne, Baku, Doha, 2019 WC, 2019 Cottbus, 2020 Melbourne, and 2021 Doha.

(2) This study arranged the scores of the events in the following order: MFX, PH, SR, MVT, PB, HB, WVT, UB, BB and WFX.

(3) This study recorded the D scores, E scores, F scores, and rankings of the event finalists in both the QR and EF. Since the number of gymnasts who competed in each event was different, the D scores, E scores, and F scores were arranged according to the scores of the EF, starting with the winner of the final and ending with the last-placed competitor. This study used Microsoft Excel to compile the data.

(4) After the data of the D score, E score, and F score of each gymnast were compiled, this study compared these data with the official scores listed on the FIG website and confirmed that the data were accurate before compiling the data of the next gymnast.

(5) After the data of the D scores, E scores, and F scores of the finalists of an event were confirmed to be accurate, this study compiled the data for the next event.

This study collected, edited, and processed all the collected data and then conducted a dependent sample *t* test, chi-squared test, and OR test for statistical analyses. This study used SPSS 24.0 for Windows for the following four analyses:

(1) This study used dependent sample *t* test to compare male finalists' D score and F score for the six events in the QR and EF in the eight male competitions.

(2) This study conducted a dependent sample *t* test to compare female finalists' D scores and F scores between the QR and EF in all eight female competitions.
(3) This study conducted a chi-squared test to investigate the correlation between the D score of each male finalist in each of the eight competitions and the corresponding outcome of that competition and calculated the OR for increasing the D score and winning a medal.
(4) This study conducted a chi-squared test to investigate the correlation between the D score of each female finalist in each of the eight competitions and the corresponding outcome of that competition and calculated the OR for increasing the D score and winning a medal.
(5) The OR is a common statistical method used in epidemiological studies. In this method, each case is classified into a case group or a control group depending on whether they had conditions or responses and whether they had exposure to a certain factor. The exposure factor could be viewed as the independent variable of the experiment, whereas the presence of conditions or responses could be viewed as the dependent variable (Weir & Vincent, 2021). Whether the gymnasts analyzed in this study increased their D score before the EF was the factor, or independent variable, in the present study, and whether they won a medal was the condition or response, or dependent variable. This principle was used to calculate the odds of increasing the D score that resulted in winning a medal. Calculations of the OR are illustrated as follows.

	Response	No response
Factor	A	B
No factor	C	D

$$OR = (A / C) / (B / D) = (A \times D) / (B \times C)$$

RESULTS

The data in Table 3 show that regarding the D scores of the male finalists in the six events in the QR and EF, only the D score of the SR was significantly different ($p < .05$). This finding revealed that the male finalists who competed in the SR generally established different D scores in the QR when compared with those of the EF. This study further observed that regarding the average D scores in the SR, the average D score in the SR EF was higher than that in the QR (6.18 > 6.15). According to the rules of men's artistic gymnastics, except for the vault event, the lowest difficulty value (DV) in each of the other five events is 0.1 (FIG, 2017a). However, the average difference between the male gymnasts' D score in the SR EF and the QR was only 0.02. Therefore, this marginal difference was not statistically meaningful, revealing that the male gymnasts used similar D scores in the QR and EF for all six events.

Next, this study conducted a dependent sample *t* test to compare the male finalists' F scores in the six events in the QR and EF, and discovered that the F scores of the PH and the HB were significantly different ($p < .05$). The average F score of the PH QR was higher than that of the PH EF (14.54 > 14.05), and the average F score of the HB QR was higher than that of the HB EF (14.05 > 13.72). These results indicated that the male gymnasts had higher F scores in the QR than in the EF. However, for each of the other four events, the F scores in the QR and EF were not significantly different. In general, the average F score of the male gymnasts in the EF was not higher than that in the QR, and their F scores in the PH and HB EF were significantly lower than the

corresponding scores in the PH and HB QR, respectively.

The data in Table 4 show that regarding the female finalists' D scores in the four items in the QR and EF, only the D scores of the uneven bars event were significantly different ($p < .05$). This result revealed that the female finalists who competed in the UB used different D scores in the QR and EF. This study further observed the average D scores of the UB and discovered that the average D score in the QR was higher than that in the EF (5.85 > 5.80), albeit with a difference of only 0.05. This finding was similar to that of the SR, and the marginal difference was not statistically meaningful. Next, this study conducted a dependent sample *t* test to compare the female finalists' F scores in the Q and in EF and discovered that the F scores of the BB and the WFX were significantly different ($p < .05$). In addition, the average F score of the BB QR was higher than that of the BB EF (13.12 > 12.75), and the average F score of the WFX QR was higher than that of the WFX EF (13.20 > 13.02). These results revealed that the female gymnasts had higher F scores in the Q than in the EF for the BB and the WFX. However, the average F scores of the Q and the EF of the WVT and the UB did not exhibit significant differences. In general, the average F scores of the female gymnasts in the four female events showed that that the F scores in the BB and WFX EF were not necessarily higher than those in the QR, respectively. In fact, the average F scores of the BB and FX QR were significantly higher than those of the BB and FX EF, respectively.

Table 3
Male gymnasts' difficulty scores and final scores in the events during the qualification rounds and apparatus finals in the eight competitions.

	Difficulty score			Final score		
Apparatus	Qualification round M±SD	Final M±SD	*p*	Qualification round M±SD	Final M±SD	*p*
Floor exercise	6.07±.29	6.05±.52	.814	14.34±.33	14.05±1.34	.074
Pommel horse	6.14±.26	6.20±.60	.443	14.54±.40	14.05±1.46	.004*
Rings	6.15±.25	6.18±.24	.011*	14.59±.43	14.56±.49	.402
Vault	5.51±.18	5.53±.22	.381	14.52±.23	14.46±.43	.267
Parallel bars	6.10±.38	6.13±.43	.445	14.51±.46	14.34±.95	.096
Horizontal bar	5.90±.35	5.98±.43	.085	14.05±.64	13.72±.91	.004*

Note: $p < .05$

Table 4
Female gymnasts' difficulty scores and final scores in the various events during the qualification rounds and apparatus finals in the eight competitions.

Event	Difficulty score			Final score		
	Qualification round M±SD	Final M±SD	*p*	Qualification round M±SD	Final M±SD	*p*
Vault	5.31±.39	5.34±.41	.084	14.17±.54	14.10±.57	.057
Uneven bars	5.85±.53	5.80±.56	.041*	13.82±.98	13.66±1.04	.109
Balance beam	5.44±.37	5.40±.41	.221	13.12±.59	12.75±1.15	.005*
Floor exercise	5.25±.44	5.23±.48	.521	13.20±.60	13.02±.92	.006*

Note: $p < .05$

Table 5
Minimum scores required to qualify for men's apparatus finals.

	Floor exercise	Pommel horse	Rings	Vault	Parallel bars	Horizontal bar
Average difficulty score	5.93	6.09	6.00	5.49	5.74	5.68
Average final score	14.01	14.16	14.20	14.31	14.05	13.38

Table 6
Minimum scores required to qualify for women's apparatus finals.

	Vault	Uneven bars	Balance beam	Floor exercise
Average difficulty score	4.88	5.41	5.29	4.96
Average final score	13.61	13.13	12.67	12.74

This study conducted a chi-squared test to test the data shown in Table 7 and discovered that the D scores of the male medalists in the PH and the HB were significantly different ($p < .05$) from the D scores of the male non-medalists in the PH and the HB, respectively. For the PH, the chi-squared score was 9.69, the degrees of freedom (*df*) score was 1, and $p = .002$. For the HB, the chi-squared score was 6.04, the *df* score was 1, and $p = .014$. The number of medalists who increased their D scores and the number of medalists who did not increase their D scores in the PH EF were 20 and 4, respectively. The number of non-medalists who increased their D scores and the number of non-medalists who did not increase their D scores in the PH EF were 18 and 23, respectively. The number of medalists who increased their D scores and the number of medalists who did not increase their D scores in the HB EF were 16 and 8, respectively. The number of non-medalists who increased their D scores and

the number of non-medalists who did not increase their D scores in the HB were 14 and 26, respectively. These results demonstrated that more medalists than non-medalists increased their D scores in the PH and HB EF.

The OR of winning a medal for the male finalists who increased their D scores and the male finalists who did not increase their D scores in the PH EF was 6.39, and the confidence interval (CI) was 3.43–0.32. The OR of winning a medal for the male finalists who increased their D scores and the male finalists who did not increase their D scores in the HB EF was 3.71, and the CI was 3.43–0.32. These results revealed that for the finalists in the PH and HB EF, increasing their D score increased their odds of winning a medal. By contrast, for each of the other four events, increasing the D score in the EF did not have a significant correlation with the outcome of the competition and did not significantly increase the odds of winning a medal.

This study used the chi-squared test to test the data shown in Table 8 and discovered that the D score of the female medalists in the WFX was significantly different ($p < .05$) from the D score of the female non-medalists in the WFX; the chi-squared score was 4.23, the *df* score was 1, and $p = .040$. The number of medalists who increased their D scores and the number of medalists who did not increase their D scores in the WFX EF were 9 and 15, respectively. The number of non-medalists who increased their D scores and the number of non-medalists who did not increase their D scores in the WFX EF were 6 and 34, respectively.

The OR of winning a medal for the female finalists who increased their D scores and female finalists who did not increase their D scores in the WFX EF was 3.40, and the CI was 11.27–1.03. This result demonstrated that for the female finalists in the WFX EF, increasing their D score increased their odds of winning a medal. For the other three events, increasing the D score in the EF did not have a significant correlation with the outcome of the competition and did not significantly increase the odds of winning a medal.

Table 7
Correlation analysis of increasing the difficulty score versus winning a medal for the male gymnasts.

Floor exercise	Medalist	Non-medalist	
Increased difficulty score	6	9	$\chi^2 = 0.01$, $df = 1$, $p = .932$
Did not increase difficulty score	19	30	OR = 1.05, 95% CI = 3.43–0.32, $p > .05$
Pommel horse	**Medalist**	**Non-medalist**	
Increased difficulty score	20	18	$\chi^2 = 9.69$, $df = 1$, $p = .002$*
Did not increase difficulty score	4	23	OR = 6.39, 95% CI = 22.04–1.85, $p < .05$*
Rings	**Medalist**	**Non-medalist**	
Increased difficulty score	4	4	$\chi^2 = 0.61$, $df = 1$, $p = .435$
Did not increase difficulty score	20	36	OR = 1.80, 95% CI = 7.99–0.45, $p > .05$
Vault	**Medalist**	**Non-medalist**	
Increased difficulty score	3	5	$\chi^2 < 0.01$, $df = 1$, $p = 1.000$
Did not increase difficulty score	21	35	OR = 1.00, 95% CI = 4.62–0.22, $p > .05$
Parallel bars	**Medalist**	**Nonmedalist**	
Increased difficulty score	8	7	$\chi^2 = 2.10$, $df = 1$, $p = .148$
Did not increase difficulty score	16	33	OR = 2.36, 95% CI = 7.65–0.73, $p > .05$
Horizontal bar	**Medalist**	**Nonmedalist**	
Increased difficulty score	16	14	$\chi^2 = 6.04$, $df = 1$, $p = .014$*
Did not increase difficulty score	8	26	OR = 3.71, 95% CI = 10.82–1.28, $p < .05$*

Note: χ^2 = chi-squared score; *df* = degrees of freedom score; OR = odds ratio; CI = confidence interval.
*$p < .05$

Table 8
Correlation analysis of increasing the difficulty score versus winning a medal for the female gymnasts.

Vault	Medalist	Non-medalist	
Increased difficulty score	2	7	$\chi^2 = 1.50$, $df = 1$, $p = .221$
Did not increase difficulty score	22	28	OR = 0.36, 95% CI = 1.93–0.07, $p > .05$
Uneven bars	**Medalist**	**Non-medalist**	
Increased difficulty score	5	4	$\chi^2 = 1.36$, $df = 1$, $p = .244$
Did not increase difficulty score	19	35	OR = 2.30, 95% CI = 9.61–0.55, $p > .05$
Balance beam	**Medalist**	**Non-medalist**	
Increased difficulty score	7	11	$\chi^2 = 0.01$, $df = 1$, $p = .935$
Did not increase difficulty score	17	28	OR = 1.05, 95% CI = 3.22–0.34, $p > .05$
Floor exercise	**Medalist**	**Non-medalist**	
Increased difficulty score	9	6	$\chi^2 = 4.23$, $df = 1$, $p = .040$*
Did not increase difficulty score	15	34	OR = 3.40, 95% CI = 11.27–1.03, $p < .05$*

Note: χ^2 = chi-squared score; *df* = degrees of freedom score; OR = odds ratio; CI = confidence interval.
*$p < .05$

DISCUSSION

Tables 3 and 4 show that the D scores of the male and female gymnasts during the QR and the EF were not significantly different. Tables 5 and 6 show the minimum D score required to qualify for each EF and indicate that gymnasts should actively increase their D score in each event, as indicated by the D score threshold used by current international elite gymnasts to formulate their training programs and goals.

Tables 3 and 4 also show that the average F scores in the PH, HB, BB, and WFX EF were significantly lower than the corresponding scores in the QR. Kalinski, Jelaska, and Atikovic (2017) indicated that when the D scores of combinations of elements are similar among multiple competitors, it is the E scores of those competitors that determine the F scores. In other words, the E score was the primary factor causing the average F scores in the PH, HB, BB, and WFX EF to be lower than the corresponding scores in the QR. The PH is considered one of the more difficult men's event because when gymnasts perform technical elements on a PH, they

have to maintain their balance while moving and thus are more likely to make errors due to unstable elements or losing their balance (Prassas, Kwon, & Sands, 2006). In addition, gymnasts have a higher failure rate when it comes to performing two or more flight elements on the HB. Furthermore, if the position of their body is too low after they have performed multiple jumps or twists supported by one hand followed by hanging from the bar and flight elements, they face an E score deduction (FIG, 2017a). In the BB, gymnasts have to maintain their balance while competing on a platform 10 cm wide and 125 cm high. Thus, the gymnasts are at a relatively high risk of making errors while attempting difficult twists or saltos (Massidda & Calo, 2012; Sands, 2000). Rohleder and Vogt (2019) indicated that gymnasts must complete saltos in the MFX by landing on both feet, and this factor increases the uncertainty of landing. The stability of the landing after a salto and the quality of the body posture have a considerable influence on the F score of the gymnast. The present analysis revealed that errors were more likely to occur in PH, HB, BB, and WFX EF than in the other events, resulting in lower F scores in these events. Both the factors that caused more failures in these four events and the pressure of competing in the EF caused the gymnasts to have a higher failure rate. In addition, past analyses of individual artistic gymnastics competitions have focused on scores in EF. The author of the present study served as a coach in the national gymnastics team and discovered that coaches often used scores in previous EF to set goals. The results of this study revealed that the final scores in PH, HB, BB, and WFX EF were lower than the corresponding scores of QR. Therefore, analyzing F scores in finals of these four events alone could lead to an underestimation of the overall standard. In addition, analyzing the scores of gymnasts after they have made errors could lead to inaccurate estimations or misjudgments of their overall scores.

Table 7 shows that the male medalists set different D scores in the PH and the HB, and one OR result demonstrated that the gymnasts who increased their D score in the PH EF were 6.38 times more likely to win a medal than those who did not increase their D score, whereas those who increased their D score in the HB EF were just 3.71 times more likely to win a medal than those who did not increase their D score. In addition, this study discovered that a gymnast must increase their D score in a PH EF or HB EF to significantly increase their odds of winning a medal in an international competition. Rohleder and Vogt (2019) stated that the average execution scores in the WFX EF of the 2013, 2015, and 2017 WC gradually declined, whereas the D scores were volatile; these findings indicated that the international trend was toward stricter deduction standards regarding elements in finals. That study also discovered that a gymnast's E score had a significant negative correlation with the number of times their feet moved after saltos. This finding indicated that if a gymnast performed more saltos to increase their D score, the E-panel judges would deduct their E score by more points if they could not effectively control their performance. To win a medal, gymnasts must incorporate difficult elements into their performance to increase their D score. However, if they cannot control their technique or body posture when performing difficult elements, their F score is affected. The PH and the HB are men's events that are considered the most difficult and where

errors occur most frequently during competitions. George (2014) emphasized that stable performance among artistic gymnasts results from effective daily training and that training lays the foundation for successful performance. Therefore, male gymnasts should practice difficult elements during training in preparation for PH and HB. Koca, Kosova, and Kosova (2021) believed that daily training should be planned carefully and aimed toward increasing a gymnast's D score. Therefore, coaches and gymnasts should formulate routine for the QR and EF of PH and HB so that the gymnasts are able to combine high D scores with stable performance in order to qualify for finals and then increase their D scores before finals to improve their odds of winning a medal. By contrast, increasing the D score in other men's events—such as MFX, SR, MVT, and PB—apparently does not improve a gymnast's odds of winning a medal. Therefore, in these events, male gymnasts do not need to increase their D scores in the EF.

Table 8 shows that for female gymnasts, increasing the D score before a WFX EF improves their odds of winning a medal (OR = 3.40). The rules for international women's artistic gymnastics events state that female gymnasts earn points for completing difficult elements and can earn additional connection points for directly or indirectly connecting skilled elements with dance elements. These guidelines suggest that WFX, UB and BB have relatively many possible combinations available to score points by increasing the overall D score (FIG, 2017b). In addition, Heinen, Vinken, and Velentzas (2012); Pizzera (2012); and Pizzera, Möller, and Plessner (2018) have indicated that gymnastics judges do not rely solely on objective standards to judge gymnastics events. Rather, they tend to use subjective judgements for specific details. When gymnasts exhibit incomplete elements, pause, or make errors between dances, saltos, and twists, D-panel judges do not recognize the set D score and thus do not award connection points, and E-panel judges perform Execution deduction for the errors (Atiković & Smajlović, 2011; FIG, 2017b). The OR of the WVT was 0.36, which indicated that increasing the D score for a WVT EF reduced a gymnast's odds of winning a medal. Although the OR between increasing the D score in a WVT EF and winning a medal was not statistically significant, it suggested that attempting more difficult elements in a final does not increase a gymnast's odds of winning a medal. Therefore, gymnasts should focus on their E scores during their training and should first aim to flawlessly execute an element with the minimum D score required to qualify for a final, as illustrated in Table 6.

In this study, we compared the D, E, and F scores of finalists in different events during the QR and EF of eight competitions in the IAWCS and WC. We also used the statistical method of the OR of winning a medal to analyze the relationship between the high and low D scores of gymnasts during the apparatus finals and their odds of winning a medal. Because no suitable method currently exists for determining how D-panel judges grade gymnasts when they make mistakes while performing, presumably because of high D scores or other factors, and no related studies are currently available, we made inferences regarding the official D, E, and F scores and ranking of event finalists. Generally, after gymnasts qualify for apparatus finals, they must draw lots to determine the starting

order. However, in this study, we did not further analyze each event. Future researchers must therefore determine whether the starting order of EF or all-around finals affects the performance of gymnasts.

CONCLUSIONS

The qualification for the Tokyo 2020 Olympics was unique in terms of Olympic gymnastics qualification in that only scores and rankings in the IAWCS and WC were used as a basis for qualification. Therefore, this study investigated only the competitions that could lead to qualification for individual events. The primary conclusions of this study are described as follows: First, the male and female gymnasts' D scores in QR and EF were similar. However, the average F scores in the QR of the PH, HB, BB, and WFX were higher than those of the corresponding EF. Second, in the ten events analyzed, the male gymnasts were more likely to win medals when they increased their D score in the PH and HB EF, whereas the female gymnasts were more likely to win medals when they increased their D score in the WFX EF.

This paper proposes the following suggestions based on the aforementioned conclusions: First, a gymnast should improve their D score for each event by aiming for the minimum D score that qualifies for the EF, and they should strive to improve their technique in events where they made errors easily. Second, male gymnasts can increase the D scores for the PH and HB in the EF to increase their odds of winning a medal; and female gymnasts can increase the D scores for the WFX in the EF to increase their odds of winning a medal. Third, this study analyzed only the eight gymnastics competitions in the IAWCS and WC. Thus, future studies could perform more detailed analyses on other individual events.

REFERENCES

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

Bradshaw, E., Hume, P., & Aisbett, B. (2011). Performance score variation between days at Australian national and Olympic women's artistic gymnastics competition. *Journal of sports sciences, 30*, 191-199. doi:10.1080/02640414.2011.633927

Caine, D. J., Russell, K., & Lim, L. (2013). *Handbook of Sports Medicine and Science: Gymnastics*: Wiley.

Chen, C. Y., Chen, K. H., Lu, K. H., & Tang, W. T. (2021). Relationships between Taiwanese gymnasts' performance scores at the 2018, 2019 Artistic Gymnastics World Championships and qualification for the Olympic Games Tokyo 2020 *Sports & Exercise Research, 23*(3), 293-306. doi:10.5297/ser.202109_23(3).0005

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

Fédération Internationale de Gymnastique. (2017a). *2017-2020 Code of points men's artistic gymnastics*. Author.

Fédération Internationale de Gymnastique. (2017b). *2017-2020 Code of points women's artistic gymnastics*. Author.

Fédération Internationale de Gymnastique. (2020). *Qualification system-games of the XXXII OLYMPIAD -TOKYO 2020*. Author.

George, G. S. (2014). *Championship gymnastics: Biomechanical techniques for shaping winners*: Designs for Wellness Press.

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

Kalinski, S., Jelaska, G., & Atikovic, A. (2017). Elite female Vault finale from 2008-2016. *Acta Kinesiologica, 11*(1), 62-66.

Kerwin, D. G., & Irwin, G. (2010). Musculoskeletal work preceding the outward and inward Tkachev on uneven bars in artistic gymnastics. *Sports Biomechanics, 9*(1), 16-28. doi:10.1080/14763141003690203

Koca Kosova, M., & Kosova, S. (2021). Evaluation of scores of the 33rd and 34th Junior European Championships in Men's Artistic Gymnastics. *European Journal of Human Movement, 46*. doi:10.21134/eurjhm.2021.46.8

Leskosek, B., Cuk, I., & Bucar Pajek, M. (2013). Trends in E and D scores and their influence on final results of male gymnasts at European Championships 2005–2011. *Science of Gymnastics Journal, 5*(1), 29-38.

Looney, M. A. (2004). Evaluating judge performance in sport. *Journal of Applied Measurement, 5*(1), 31-47. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/14757990

Massidda, M., & Calo, C. M. (2012). Performance scores and standings during the 43rd Artistic Gymnastics World Championships, 2011. *Journal of Sports Sciences, 30*(13), 1415-1420. doi:10.1080/02640414.2012.710759

Pizzera, A. (2012). Gymnastic Judges Benefit From Their Own Motor Experience as Gymnasts. *Research Quarterly for Exercise and Sport, 83*, 603-607. doi:10.1080/02701367.2012.10599887

Pizzera, A., Möller, C., & Plessner, H. (2018). Gaze Behavior of Gymnastics Judges: Where Do Experienced Judges and Gymnasts Look While Judging? *Research Quarterly for Exercise and Sport, 89*(1), 112-119. doi:10.1080/02701367.2017.1412392

Prassas, S., Kwon, Y. H., & Sands, W. A. (2006). Biomechanical research in artistic gymnastics: a review. *Sports Biomechanics, 5*(2), 261-291. doi:10.1080/14763140608522878

Rohleder, J., & Vogt, T. (2019). Changes in Floor Exercise Characteristics in World Elite Male Gymnasts. *Journal of Human Kinetics, 67*, 291-300. doi:10.2478/hukin-2018-0083

Sands, W. A. (2000). Injury prevention in women's gymnastics. *Sports Medicine, 30*(5), 359-373. doi:10.2165/00007256-200030050-00004

Schärer, C., Lehmann, T., Naundorf, F., Taube, W., & Hübner, K. (2019). The faster, the better? Relationships between run-up speed, the degree of difficulty (D-score), height and length of flight on vault in artistic gymnastics. *PLOS ONE, 14*(3), e0213310. doi:10.1371/journal.pone.0213310

Weir, J. P., & Vincent, W. J. (2021). *Statistics in kinesiology*: Human Kinetics Publishers.

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EATING DISORDERS IN SPANISH ACROBATIC GYMNASTS BASED ON SEX AND COMPETITIVE LEVEL

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Abstract

The aim of this study was to assess the body composition and the risk of developing an eating disorder (ED) in two groups of Spanish elite acrobatic gymnasts. A cross-sectional descriptive study was conducted, where 130 acrobatic gymnasts aged 9 to 21 and registered with the Spanish federation voluntarily participated; 56 of them were competing at the international level and 74 at the national level. Height and weight measures were used to calculate body mass index (BMI) and skinfolds were measured to determine the percentage of body fat. The Eating Disorders Inventory (EDI-3-RF) was applied to assess the ED variables. The results revealed that most gymnasts presented normal weight (BMI) and a low % body fat, and the international-level gymnasts showed lower values than national-level ones. However, *52.6% of the gymnasts in this study were at risk of developing an ED. Concerning the scales, the scores related to drive for thinness were noteworthy, especially in women competing at the international level, who reported greater concern about weight and body image. The international-level gymnasts met most of the referring criteria; in particular, most senior gymnasts met criterion 3. There was an average percentage of gymnasts at risk of developing an ED. The risk factors were more noticeable among female international-level gymnasts who presented greater drive for thinness and body dissatisfaction.*

Keywords: *gymnastics, acrobatic gymnastics, eating disorder, anthropometry.*

INTRODUCTION

Acrobatic gymnastics (AcG) was included in the International Gymnastics Federation (FIG) in 1999. It is based on regulated behaviours and, like in the rest of gymnastic disciplines, exercises are artful and composed of multiple independent

skills or elements, performed in stardardised and stable spaces, and regulated by the Code of Points (COP) which defines this modality (Vernetta & López-Bedoya, 2005).

In aesthetic sports, including AcG, high technical complexity combined with some components of physical fitness (including strength, flexibility, speed, coordination and balance), and a good body image (BI) are some determining factors that can lead to sports success (Peláez & Vernetta, 2018). Certain anthropometric measures, such as weight, BMI and percentage of body fat, become important in relation to this BI, as well as the selection process that determines the roles to be performed in this sport: base or top (Taboada-Iglesias et al., 2017; Taboada-Iglesias et al., 2021). For obvious reasons, depending on the motor profile of this discipline, smaller, younger gymnasts with less body weight act as tops gymnasts occupying the upper part of the collective figures and pyramids, performing elements of flexibility, balance and combinations on top of the bases, or large acrobatic jumps in the aerial phase by means of propulsion of the bases in order to land on them or on the floor (Vernetta & López-Bedoya, 2005; Salas-Morillas et al., 2022). Hence, depending on the position or the role played by the gymnast, their morphological characteristics are specific and different, with the bases being heavier and larger, presenting an endo-mesomorphic somatotype, while the tops are smaller in size, weight and percentage of body fat with an ectomorphic tendency (Taboada-Iglesias et al., 2016; Salas-Morillas, et al., 2022).

Excessive concern regarding weight or BI can lead to eating disorders. This can have negative effects on the gymnast's performance and, more importantly, a negative impact on health.

Eating disorders (EDs) are characterised by abnormal eating behaviours, such as trying to control weight, based on a psychological disorder. These EDs are serious mental health issues that mainly affect young women; they are usually chronic severe disorders associated with high dysfunctionality (Dallas et al., 2016; Dallas et al., 2017; Fernández-Rivas, 2021; Herpertz-Dahlmann, 2009). The most frequent ED syndromes are anorexia nervosa (AN), bulimia nervosa (BN) and eating disorders not otherwise specified (ED-NOS), according to the fifth review of the *Diagnostic and statistical manual of mental disorders* (DSM-5) by the American Psychiatric Association (APA, 2013).

There is scientific evidence that most experienced female artistic and rhythmic gymnasts restrict their food intake to stay thin and maintain pubertal looks (Deutz et al., 2000; Jonnalaggada & Benardot, 2000; Papacharalampous et al., 2022). On the other hand, Nordin et al. (2003) assessed EDs in gymnasts who presented normal eating behaviours associated with hypocaloric and reduced nutrient intake. However, they observed that not most of artistic gymnasts were at risk of developing nutritional disorders (Papacharalampous et al., 2022). By contrast, most rhythmic and aerobic gymnasts could be considered at risk of developing an eating disorder (Donti et al., 2021; Jardim et al., 2022; Valles et al., 2020).

Most studies so far have looked at artistic and rhythmic gymnastics, and very few focused on AcGs. That is why our aim was to assess the risk of developing an ED and body composition in Spanish acrobatic

gymnasts based on sex and competitive level.

METHODS

This was a descriptive, cross-sectional, non-experimental study in which 130 acrobatic gymnasts (17 male, 113 female) registered with the Spanish Federation and aged between 9 and 21 (14.14±3.30) volunteered to participate. The participants had at least 4 years (6.18±2.62) of training experience and trained 8-10h/week (13.8%) or more than 10h/week (86.2%). The participants were classified into two groups according to their competitive level: international level (FIG) or national level (RFEG). The RFEG group of gymnasts consisted of 71 women (age= 12.59±1.95 years) and 3 men (age= 14±0 years) with an average training time of 12.32±2.98h per week. The FIG group consisted of 42 women (age= 15.34±2.91 years), and 14 men (age= 18.5±4.75 years) with an average training time of 14.69±6.63h per week.

All procedures applied in this study were approved by the Ethics Committee of the University of Granada (Reference number: 1484/CEIH/2020). The study complied with all ethical research principles outlined in the Declaration of Helsinki.

The Spanish adaptation (Elosua et al., 2010) of the *Eating Disorders Inventory* (EDI-3-RF) (Garner, 2004) was used to assess EDs. It allows for quick assessment through standardised criteria in order to discard or confirm the presence of an ED. An individual score can be obtained from each of the three scales: Drive for Thinness (composed of 7 items), Bulimia (8 items) and Body Dissatisfaction (10 items), as well as a total score by adding up the 25 items:

* Drive for Thinness scale (DT) measures a strong drive for getting thinner or a strong fear of fatness, consequently becoming a good predictor of binge eating or ED development. The direct score ranges from 0 to 20, 12 being the critical value (García et al., 2012).

* Bulimia scale (B) evaluates the tendency towards thoughts related to excessive eating or towards uncontrolled binge eating. The direct score ranges from 0 to 32, the critical value lying between 5 and 8, depending on the gymnast's BMI (García et al., 2012).

* Body Dissatisfaction scale (BD) assesses the individual's dissatisfaction with their general body shape or those body parts about which people with ED are usually most concerned: belly, hips, thighs, buttocks, etc. The direct score ranges from 0 to 40, divided into three levels depending on the body dissatisfaction intensity: 0-6 low, 7-27 average and 28-40 high (García et al., 2012).

Lastly, this questionnaire allows for referral to a specialised service, depending on three standard criteria:

- Criterion 1 is exclusively based on the individual's BMI. Depending on sex and age, it is decided whether the body weight is excessively low.
- Criterion 2 relates BMI to the presence of excessive concern about weight or food, or complicated eating patterns (assessed through DT and B scales).
- Criterion 3 focuses on the presence of behavioural symptoms that could suggest an ED (assessed through the B scale of the questionnaire).

The following instruments were used to measure the anthropometric variables: TEFAL digital scales for body mass, with 0.05kg accuracy; SECA 220 stadiometer for height, 1mm accuracy; and a plicometer for

skinfolds (triceps [TS], biceps [BS], subscapular [SSS], suprailiac [SIS], abdominal [AS] and medial calf [MCS]). BMI was calculated by dividing weight in kilograms by height in metres squared. Two different equations using the measured skinfolds were applied to calculate the percentage of body fat. Firstly, considering that lower-limb measurements are essential due to their high importance in the motor function of children and adolescents when practising gymnastics (Taboada-Iglesias et al., 2017), the equation proposed by Slaughter et al. (1988) was applied using the addition of the triceps and medial calf skinfolds. Subsequently, the formula suggested by Yuhasz (1974) was applied, which used the addition of six skinfolds (TS, BS, SSS, SIS, AS, MCS). This one is specially indicated for high-performance athletes and highly trained individuals.

For gymnasts under 18 years old, the cut-offs proposed by Cole et al. (2007) were used: thinness grade 3 (<16), thinness grade 2 (16.1-17), thinness grade 1 (17.1-18.5), normal weight (18.5-24.9), overweight (25-30) and obesity (≥30). For the 10 gymnasts aged 19 to 21, the WHO criteria were followed: underweight (<18.5), normal weight (18.5-24.9), overweight (25-29.9), obesity grade 1 (30-34.9), obesity grade 2 (35-39.9), obesity grade 3 (>40).

All Spanish clubs were visited. Firstly, a self-registration form was distributed to collect the participants' age, years of AcG practice, club, competitive level, training days and hours/week. Secondly, they were requested to fill in the EDI-3-RF. Lastly, the anthropometric measurements were conducted following the recommendations and protocol established by the International Society for the Advancement of Kinanthropometry (ISAK) (Marfell-Jones et al., 2006). The anthropometric assessment was carried out by ISAK level 1-certified staff following this order: weight, height, and triceps, biceps, subscapular, suprailiac, abdominal and medial calf skinfolds of all participants. During the measurements, all gymnasts were barefoot and wearing training clothes.

A descriptive study of the data was carried out, using an analysis based on contingency tables, observing the independence of the data using Pearson's chi-square statistic.

Given the small size of some of the groups formed, once the sample was distributed according to the levels of the variables Level of competition and Sex, we opted for a non-parametric analysis.

Correlation analysis was approached by calculating Spearman's correlation coefficient.

Differences were considered statistically significant for p-values < .05. Data are shown as observed frequencies and percentages, except for quantitative variables, in which case they are shown as mean values and standard deviation.

The Statistical Package for the Social Sciences (SPSS) v.25.0 (SPSS Inc., Chicago, IL) was used to conduct the statistical analyses.

RESULTS

Descriptive statistics of arthrometric variables are presented in Table 1.

Table 2 shows BMI considering the cut-offs proposed by Cole et al. (2007) for gymnasts under 18.

For the remaining 10 gymnasts aged 18 to 21 years, the criteria of the World Health Organisation (OMS, 2023) were used for the BMI weight classification. 70% presented normal weight and of the remaining athletes, 20% of the women were

overweight (compared to 10% of the men). None were obese or underweight.

Table 3 contains the number and percentage of gymnasts who presented critical values according to the different scales: Drive for Thinness (DT) and Bulimia (B).

Table 4 shows the frequency and percentage of body dissatisfaction levels according to EDI-3-RF, divided by sex and competitive level.

Table 5 shows the frequency and percentage of individuals who were referred to treatment according to the three criteria established by EDI-3-RF.

An analysis based on contingency tables was conducted controlling for the effect of the variables 'Competitive level' and 'Sex' (Table 6) with the purpose of further examining the dependent variables based on the categories. In male, international-level gymnasts, the age group was related to the variables 'drive for thinness' and 'body dissatisfaction' measured through EDI-3-RF ($\chi^2(8, N = 9) = 18.000$, $p = .021$), with moderate ($\eta = .407$) and high ($\eta = .900$) effect sizes, respectively.

Table 1:
Descriptive variable values based on sex and competitive level.

	FIG			***RFEG***			***TOTAL***		
	M (n=14)	*W (n=42)*	*T (n=56)*	*M (n=3)*	*W (n=71)*	*T (n=74)*	*M (n=17)*	*W (n=113)*	*T (N=130)*
Weight (kg)	66.03± 20.87	49.47± 11.68	53.61± 16.03	60.00± 2.74	44.30± 11.04	44.94± 11.26	64.96± 18.99	46.22± 11.51	48.67± 14.14
Height (m)	1.67± 0.16	1.57± 0.09	1.60± 0.12	1.69± 0.03	1.50± 0.11	1.50± 0.11	1.68± 0.14	1.52± 0.11	1.54± 0.12
BMI	22.82± 3.93	19.71± 2.99	20.49± 3.49	21.08± 0.17	19.44± 2.78	19.51± 2.75	22.51± 3.61	19.54± 2.85	19.93± 3.11
MCS	11.89± 3.69	12.40± 3.20	12.28± 3.31	9.00± 1.00	12.05± 3.30	11.93± 3.29	11.38± 3.53	12.18± 3.26	12.08± 3.29
TS	11.46± 3.90	11.51± 3.97	11.50± 3.92	9.83± 0.76	11.58± 3.48	11.51± 3.43	11.18± 3.58	11.56± 3.65	11.51± 3.63
BS	8.00± 3.04	8.38± 2.79	8.29± 2.83	7.33± 0.58	8.37± 2.63	8,32± 2.59	7.88± 2.76	8.37± 2.68	8.31± 2.68
SSS	12.11± 2.68	10.60± 4.92	10.97± 4.49	9.17± 2.25	10.42± 4.37	10.36± 4.31	11.59± 2.80	10.48± 4.56	10.63± 4.38
SIS	12.29± 2.92	11.31± 4.49	11.55± 4.15	9.67± 1.53	11.06± 4.09	11.00± 4,03	11.82± 2.88	11.15± 4.23	11.24± 4.07
AS	11.29± 5.47	12.38± 5.41	12.11± 5.39	8.00± 2.65	12.39± 4.97	12.22± 4.97	10.71± 5,18	12.39± 5.11	12.95± 5.00
Σ6 SKINFOLDS	58.14± 22.42	66.51± 22.91	64.42± 22.88	48.67± 14.47	67.61± 20.45	66.84± 20.52	56.47± 21.18	67.20± 21.30	66.61± 19.36
% BF Slaughter	14.10± 5.22	20.15± 4.56	18.63± 5.38	13.62± 3.33	20.78± 4.09	20,49± 4.28	14.01± 4.85	20.54± 4.26	19.78± 4.23
%BF 6 skinfolds Yuhasz	12.77± 13.19	14.07± 3.28	13.75± 7.03	8.36± 1.40	14.23± 2.92	13.99± 3.10	11.99± 12.02	14.17± 3.05	13.71± 3.08
DT	11.71± 7.49	11.05± 6.94	11.21± 7.02	10.67± 8.02	10.80± 7.75	10.80± 7.71	11.53± 7.33	10.89± 7.43	10.98± 7.39
B	6.14± 7.42	8.21± 7.22	7.70± 7.26	7.00± 6.56	6.28± 5.90	6.31± 5.88	6.29± 7.09	7.00± 6.46	6.91± 6.52
BD	16.71± 3.12	15.79± 6.62	16.02± 5.93	16.33± 4.04	17.72± 4.87	17.66± 4.82	16.65± 3.16	17.00± 5.63	16.95± 5.37

BMI= Body mass index; TS=Triceps, BS= Biceps; SSS= Subscapular; SIS= Suprailiac; AS= Abdominal; MCS= Medial calf; DT=Drive for Thinness scale; B= Bulimia scale; BD= Body Dissatisfaction scale

Table 2
Frequency (percentage) of BMI values.

COMPETITIVE LEVEL	SEX	T-1	T-2	T-3	NORM	OVER	OB
FIG	M (n=7) %	-	1 (14.3)	2 (28.6)	3 (42.9)	1 (14.3)	-
	W (n=39) %	5 (12.8)	5 (12.8)	3 (7.7)	25 (64.1)	1 (2.6)	
	T (n=46) %	5 (10.9)	6 (13.0)	5 (10.9)	28 (60.9)	2 (4.3)	-
RFEG	M (n=3) %	-	-	-	3 (100.0)	-	-
	W (n=71) %	9 (12.7)	9 (12.7)	6 (8.5)	45 (63.4)	2 (2.8)	-
	T (n=74) %	9 (12.2)	9 (12.2)	6 (8.1)	48 (64.9)	2 (2.7)	-
TOTAL	M (n=10) %	-	1 (10.0)	2 (20.0)	6 (60.0)	1 (10.0)	-
	W (n=110) %	14 (12.7)	14 (12.7)	9 (8.2)	70 (63.6)	3 (2.7)	-
	T (N=120) %	14 (11.7)	15 (12.5)	11 (9.2)	76 (63.3)	4 (3.3)	-

T-3: Thinness grade 3; T-2: Thinness grade 2; T-1: Thinness grade 1; NORM: Normal weight; OVER: Overweight; OB: Obesity.
* Depending on the competitive level for participants under 18 years old.

Table 3
Frequency (percentage)of Drive for Thinness (DT) and Bulimia (B) scales.

COMPETITIVE LEVEL	SEX	DT	B
FIG	M (n=14) %	5 (35.7)	4 (28.6)
	W (n=42) %	24 (57.1)	28 (66.7)
	T (n=56) %	29 (51.8)	32 (57.1)
RFEG	M (n=3) %	1 (33.3)	2 (66.7)
	W (n=71) %	29 (40.8)	44 (62.0)
	T (n=74) %	30 (40.54)	46 (62.2)
TOTAL	M (n=17) %	6 (35.2)	6 (35.3)
	W (n=113) %	53 (46.9)	72 (63.7)
	T (N=130) %	59 (45.38)	78 (60.0)

* Gymnasts who presented critical values according to Drive, divided by sex and competitive level.
DT=Drive for Thinness scale; B= Bulimia scale

Table 4
Frequency (percentage) of body dissatisfaction levels (EDI-3-RF).

COMPETITIVE LEVEL	SEX	LOW	MEDIUM	HIGH
FIG	M (n=14) %	5 (35.7)	9 (64.2)	-
	W (n=42) %	3 (7.1)	38 (90.4)	1 (2.3)
	T (n=56) %	8 (14.2)	47 (83.9)	1 (1.7)
RFEG	M (n=3) %	3 (100.0)	-	-
	W (n=71) %	6 (8.4)	65 (91.5)	-
	T (n=74) %	6 (8.1)	68 (91.8)	-
TOTAL	M (n=17) %	4 (23.5)	13 (76.4)	-
	W (n=113) %	9 (7.9)	103 (91.1)	1 (0.9)
	T (n=130) %	13 (10.0)	116 (89.2)	1(0.8)

***** Divided by sex and competitive level.

Table 5
Frequency (percentage) of individuals who met the referring criteria.

COMPETITIVE LEVEL	SEX	Crit 1	Crit 2	Crit 3
FIG	M (n=14) %	1 (7.1)	6 (42.9)	4 (28.6)
	W (n=42) %	3 (7.1)	33 (78.6)	9 (21.4)
	T (n=56) %	4 (7.1)	39 (69.6)	13 (23.2)
RFEG	M (n=3) %	-	1 (33.3)	-
	W (n=71) %	2 (2.8)	46 (64.7)	10 (14.1)
	T (n=74) %	2 (2.7)	47 (63.5)	10 (13.5)
TOTAL	M (n=17) %	1 (5.9)	7 (41.1)	4 (5.2)
	W (n=113) %	5 (4.4)	79 (69.9)	19 (16.8)
	T (N=130) %	6 (4.6)	92 (66.1)	23 (17.7)

***** Divided by sex and competitive level.

Table 6

Pearson's chi-squared test and coefficient of association between pairs of variables.

Variables dependientes		**FIG**			**RFEG**			**Total**		
		M	*W*	*Total*	*M*	*W*	*Total*	*M*	*W*	*Total*
DT (drive for thinness)	χ^2	18.000	82.044	72.457	19.200	56.721	70.156	41.083	92.237	95.934
	gl	8	57	60	15	69	75	27	81	84
	N	9	39	48	8	74	82	17	113	130
	p	.021	.017	.130	.205	.855	.637	.040	.185	.176
	CA	.407(c)	.241(c)	.236(c)	.487(c)	.101(c)	.120(c)	.353(c)	.152(c)	.140(c)
B (bulimia)	χ^2	18.000	54.702	71.688	16.800	71.059	75.353	42.500	68.899	76.300
	gl	10	42	54	12	63	66	27	69	75
	N	9	39	48	8	74	82	17	113	130
	p	.055	.090	.054	.157	.227	.202	.029	.481	.436
	CA	.297(c)	.095(c)	.147(c)	.451(c)	.318(c)	.250(c)	.303(c)	.185(c)	.149(c)
BD (body dissatisfaction)	χ^2	18.000	57.435	68.674	14.400	77.882	64.467	36.243	102.965	105.983
	gl	8	45	45	15	57	57	24	66	66
	N	9	39	48	8	74	82	17	113	130
	p	.021	.101	.013	.495	.495	.232	.052	.002	.001
	CA	.900(c)	.389(c)	.342(c)	.597(c)	.101(c)	.121(c)	.623(c)	.186(c)	.186(c)
Dissatisfaction in EDI 3RF	χ^2	(*)	2.273	2.369	(*)	5.189	4.864	(*)	3.999	3.491
	gl	--	3	3	--	6	6	--	6	6
	N	9	39	48	8	74	82	17	113	130
	p	--	.518	.499	--	.520	.561	--	.677	.745
	CA	(*)	.235	.217	(*)	.256	.237	(*)	.185	.162
			p = ,518	*p* = .499		*p* = .520	*p* = .561		*p* = .677	*p* = .745
Criterion 1	χ^2	.321	.975	.775	(a)	4.773	4.067	1.195	3.037	3.174
	gl	2	3	3	--	3	3	3	3	3
	N	9	39	48	8	74	82	17	113	130
	p	.852	.807	.855	--	.189	.254	.754	.386	.366
	CA	1.86(a)	.156(a)	.126(a)	(*)	.246(a)	.217(a)	.256(a)	.162(a)	.154(a)
		p =.852	*p* = .807	*p* = .855		*p* = .189	*p* = .254	*p* = .754	*p* = .386	*p* = .366
Criterion 2	χ^2	2.057	2.333	1.200	3.200	.825	1.989	1.613	2.435	1.623
	gl	2	3	3	3	3	3	3	3	3
	N	9	39	48	8	74	82	17	113	130
	p	.358	.506	.753	.362	.843	.575	.656	.487	.654
	CA	.431(a)	.238(a)	.156(a)	.534(a)	.105(a)	.154(a)	.294(a)	.145(a)	.111(a)
		p = .358	*p* = .506	*p* = .753	*p* = .362	*p* = .843	*p* = .575	*p* = .656	*p* = .487	*p* = .654
Criterion 3	χ^2	2.100	2.982	8.888	.686	2.376	1.762	3.068	2.448	5.525
	gl	2	3	3	3	3	3	3	3	3
	N	7	38	45	8	73	81	15	111	126
	p	.350	.394	.031	.877	.498	.623	,381	.485	.137
	CA	.480(a)	.270(a)	.406(a)	.281(a)	.178(a)	.146(a)	.412(a)	.147(a)	.205(a)
		p = .350	*p* = .394	*p* = .031	*p* = .877	*p* = .498	*p* = .623	*p* = .381	*p* = .485	*p* = .137

(*) The statistic has not been calculated as the variable analysed is a constant.

CA = Coefficient of association

a = Contingency ratio; b = Association coefficient Gamma; c = Association coefficient Eta

*On one side, age group, competitive level and sex and, on the other, drive for thinness, bulimia, body dissatisfaction, Dissatisfaction in EDI-3-RF and Referring criteria 1, 2 and 3.

Table 7
Correlation analysis through Spearman's Rho based on competitive level and sex.

		Sex	CL	Role	We.	He.	BMI	Σ6SF	%BF S.	%BF Y.	DT	B	BD	C1	C2	C3
Sex	CC	1.000	-.308**	0.096	.359**	.380**	.278**	0.038	-0.116	-.186*	-0.029	-0.089	-0.086	0.023	-.202*	0.059
	p		0.000	0.276	0.000	0.000	0.001	0.665	0.189	0.034	0.744	0.312	0.329	0.791	0.021	0.503
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
CL	CC	-.308**	1.000	0.006	-.272**	-.368**	-0.136	-0.046	-0.011	0.038	-0.131	-0.058	.206*	-0.105	0.022	-0.126
	p	0.000		0.946	0.002	0.000	0.122	0.600	0.899	0.667	0.138	0.514	0.019	0.235	0.808	0.154
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
Role	CC	0.096	0.006	1.000	.801**	.744**	.749**	.298**	0.164	.211*	.455**	.361**	0.086	-.297**	.373**	.217*
	p	0.276	0.946		0.000	0.000	0.000	0.001	0.063	0.016	0.000	0.000	0.332	0.001	0.000	0.013
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
We.	CC	.359**	-.272**	.801**	1.000	.906**	.901**	.367**	.200*	.225*	.543**	.361**	0.083	-.238**	.264**	.273**
	p	0.000	0.002	0.000		0.000	0.000	0.000	0.023	0.010	0.000	0.000	0.346	0.006	0.002	0.002
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
He.	CC	.380**	-.368**	.744**	.906**	1.000	.674**	.296**	0.142	0.153	.450**	.303**	-0.091	-0.101	.204*	.200*
	p	0.000	0.000	0,000	0,000		0,000	0,001	0,106	0,082	0,000	0,000	0,305	0,254	0,020	0,023
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
BMI	CC	,278**	-0.136	.749**	.901**	.674**	1.000	.399**	.234**	.279**	.527**	.323**	0.162	-.319**	.253**	.254**
	p	0.001	0.122	0.000	0.000	0.000		0.000	0.007	0.001	0.000	0.000	0.065	0.000	0.004	0.004
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
Σ6SF	CC	0.038	-0.046	.298**	.367**	.296**	.399**	1.000	.809**	.884**	.210*	0.083	0.094	-0.152	0.142	0.107
	p	0.665	0.600	0.001	0.000	0.001	0.000		0.000	0.000	0.017	0.347	0.290	0.084	0.106	0.224
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
%BFS	CC	-0.116	-0.011	0.164	.200*	0.142	.234**	.809**	1.000	.839**	0.141	-0.018	0.113	-.191*	0.069	0.058
	p	0.189	0.899	0.063	0.023	0.106	0.007	0.000		0.000	0.109	0.836	0.202	0.029	0.435	0.51
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
%BFY	CC	-.186*	0.038	.211*	.225*	0.153	.279**	.884**	.839**	1.000	0.157	0.042	0.144	-0.154	0.102	0.075
	p	0.034	0.667	0.016	0.010	0.082	0.001	0.000	0.000		0.074	0.636	0.101	0.080	0.249	0.398
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
DT	CC	0.032	-0.077	.421**	.521**	.433**	.479**	0.167	0.122	0.112	.774**	.610**	0.021	-.180*	.586**	.321**
	p	0.720	0.386	0.000	0.000	0.000	0.000	0.057	0.168	0.203	0.000	0.000	0.811	0.040	0.000	0
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
B	CC	-0.089	-0.058	.361**	.361**	.303**	.323**	0.083	-0.018	0.042	.625**	1.000	0.021	-.205*	.741**	.466**
	p	0.312	0.514	0.000	0.000	0.000	0.000	0.347	0.836	0.636	0.000		0.811	0.020	0.000	0
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
BD	CC	-0.086	.206*	0.086	0.083	-0.091	0.162	0.094	0.113	0.144	-0.096	0.021	1.000	-0.073	0.051	.215*
	p	0.329	0.019	0.332	0.346	0.305	0.065	0.290	0.202	0.101	0.277	0.811		0.406	0.566	0.014
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
C1	CC	0.023	-0.105	-.297**	-.238**	-0.101	-.319**	-0.152	-.191*	-0.154	-.174*	-.205*	-0.073	1.000	-.342**	-0.102
	p	0,791	0,235	0,001	0,006	0,254	0,000	0,084	0,029	0,080	0,048	0,020	0,406		0,000	0,248
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
C2	CC	-.202*	0.022	.373**	.264**	.204*	.253**	0.142	0.069	0.102	.500**	.741**	0.051	-.342**	1.000	.298**
	p	0.021	0.808	0.000	0.002	0.020	0.004	0.106	0.435	0.249	0.000	0.000	0.566	0.000		0.001
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
C3	CC	0.059	-0.126	.217*	.273**	.200*	.254**	0.107	0.058	0.075	.388**	.466**	.215*	-0.102	.298**	
	p	0.503	0.154	0.013	0.002	0.023	0.004	0.224	0.51	0.398	0	0	0.014	0.248	0.001	.
	N	130	130	130	130	130	130	130	130	130	130	130	130	130	130	

CL= Competitive level; We. = Weight; He.= Height; BMI= Body mass index; Σ6SF= Σ6Skin folds; %BF S. = %Body fat Slaugther; %BF Y.= % Body fat Yuashz; DT=Drive for Thinness scale; B= Bulimia scale; BD= Body Dissatisfaction scale

Lastly, the correlation analysis of all variables for the whole sample yielded significant positive relationships between sex and role and most of the anthropometric variables, as well as between many pairs of anthropometric variables. Likewise, the relationships between DT, B and BD scales, and the anthropometric variables were noteworthy. Similarly, relationships were found between the referring criteria and the ED subscales, as well as between the criteria and some anthropometric variables like BMI, weight and height (Table 7).

Some relevant negative relationships were sex-competitive level; Crit 2-sex; weight-competitive level; weight-age group; height-competitive level; Crit 1-DT, role, weight, BMI, Slaughter's percentage of body fat, B.

DISCUSSION

The analysis of the anthropometric variables revealed that more than half of the sample (63% of women and 60% of men) presented a healthy BMI, with gymnasts who competing at a higher level presented an increased BMI associated with their older age. Furthermore, no gymnasts presented obesity.

In the present study, women showed higher BMI values (19.54 kg/m2) than men, which agrees with Valles et al. (2020), who found that men had lower BMI values than women. This is contrary to the results of Papacharalampous et al. (2022) where males had a higher BMI than females (19.53 vs. 18.69).

As regards the under-18 group of gymnasts, more than half of the sample showed a BMI indicating normal weight or underweight with thinness grades 3 and 2. Only 2.7% of them presented overweight according to the indicators proposed by Cole et al. (2007). These results were similar to those obtained in other groups of gymnasts (Salas-Morillas & Vernetta, 2020; Taboada et al., 2016; Vernetta et al., 2018). Several authors have stated that, in many cases, such characteristics are due to a 'natural selection' process (Jonnalaggada et al., 2000), since light weight is beneficial in these highly technical sports and a determining factor of performance (Kaur & Koley, 2019). With regard to the 10 gymnasts aged 18 to 21, all competing at the international level (FIG), 70% presented normal weight and 30% were underweight, while overweight or obesity was not found in any of them.

International-level gymnasts showed statistically lower percentage of body fat compared to the national-level gymnasts (18.3 vs. 20.49) when using the formula proposed by Slaughter (1988). The percentages decreased when applying Yuhashz's (1974) equation: 13.75 vs. 13.99. Our results are similar to those obtained by Salas-Morillas et al. (2021) with junior and senior tops that correspond to the international level of our study and whose percentage body fat was 18.08, calculated using Slaughter's (1988) formula.

Female gymnasts presented higher values than men when using both formulas. These data are in keeping with the values obtained for female AcGs of different age groups (Taboada-Iglesias et al., 2021).

One factor that may affect these low results is the weekly training load, which could lead to a reduction in their adipose mass (Martins & Rodríguez Dos Santos, 2004; Peláez & Vernetta; 2020).

In general, the low percentages of body fat shown by our gymnasts support the findings by Salas-Morillas et al. (2022) in regard to performance in different competition exercises, where the gymnast's

body is thrown or supported against gravity during many elements. Therefore, it is beneficial to have a low percentage of body fat, like in some other disciplines (Kaur & Koley, 2019). The different levels of body fat are not only confirmed among other male and female gymnasts, but mainly result from sexual dimorphism which has a genetic and hormonal basis.

When analysing the ED risk factors, it was detected that the gymnasts of this study were vulnerable to developing this type of disorder. This finding agrees with the results obtained in previous studies (Anderson et al., 2011; De Bruin et al., 2007; Donti et al., 2021; Jardim et al., 2022; Valles et al., 2020; Vieira et al., 2009).

52.6% of the gymnasts were at risk of developing an ED. Previous studies have reported similar percentages in female gymnasts (Fortes et al., 2013ab; Laffitte et al., 2013; Martínez-Rodríguez et al., 2018).

The vulnerability to developing an ED has been assessed in this study through two risk scales:

1. Drive for thinness. Prevailing among women and at the international level in the majority of studies (Fortes et al., 2013ab; Iannidou & Venetsanou, 2019; Laffitte et al., 2013; Martínez-Rodríguez et al., 2020).
2. Bulimia. It was higher among international-level gymnasts. Actually, the competitive level is considered to be an important risk factor (Fortes et al., 2013ab; Laffitte et al., 2014).

The results revealed that the gymnasts competing at the international level met at least one referring criterion. Only 4.6% of the whole sample met criterion 1, which is exclusively related to low BMI values and entails a warning but not a referral to a specialist. The highest percentages in both levels corresponded to referring criterion 2, with slightly higher values for international-level and female gymnasts (78.6% vs. 64.7%, female international-level vs. female national-level gymnasts). They should be preventively referred, given the presence of a drive for thinness and problematic eating patterns. With regard to criterion 3, 16.8% of the gymnasts (5.2% of men and 16.8% of women) should be referred due to the existence of at least one extreme weight-control behaviour in the last three months (binge eating, vomiting, laxative, exercise) or due to a substantial weight loss in the last nine months. It was noteworthy that it was mostly international-level gymnasts who met criterion 3, which involves behavioural symptoms that indicate an ED and mandatory referral. Many of these gymnasts also reported excessive concerns regarding weight and eating as well as problematic eating patterns.

The referring percentages described in the present study may seem high in some cases, being above those described by Martínez-Rodríguez et al. (2020) where only two rhythmic gymnasts presenting an ED, or by Harriguer et al. (2014) who brought to light a relationship between training hours and ED presence, meaning that EDs decreased when training hours increased. Nonetheless, these comparisons must be made with care, since none of these studies applied the EDI-3-RF and the referring possibilities were not analysed.

In general, all studies examined the risk of developing an ED, but did not analyse in detail the symptoms prior to the ED. It must be highlighted that in ED studies with these athletes, it has been widely accepted that the higher the competitive level, the higher the dietary restriction or the presence of an inadequate food intake in order to stay thin (Anderson et al., 2011; De Bruin et al., 2007; Laffitte

et al., 2013). Although this variable was not analysed in our study, it was a direct consequence of one of the variables included, drive for thinness, which was pronounced at the highest competitive level. Various authors have considered such obsession to be the consequence of the thin-ideal internalisation and the pressure from parents and trainers to be thin (Fortes et al., 2014; Kosmidou et al., 2018; Valles et al., 2020).

Fortes et al. (2014) presented the thin-ideal internalisation as a potential bulimia predictor. In our study, female international-level gymnasts showed a higher risk of bulimia, as well as higher values on the drive for thinness scale. In the study by Laffitte et al. (2013), 63.5% of the gymnasts were at risk of developing bulimia, which was very similar to the 63.7% of female gymnasts in our study.

Looking at sex, EDI-3-RF scores related to the drive for thinness scale were slightly higher for female than for male gymnasts, but with no significant differences. Despite research involving male gymnasts being scarce, previous studies have confirmed an increased body dissatisfaction in this population, showing values that are similar to those of female gymnasts (Andersen, 2005).

A particularly concerning result of the present study was that the relationship between BMI and the behaviours corresponding to referring criterion 2 (bulimia and drive for thinness) applied to the vast majority of the sample of both levels, it is important to underline that the presence of pathologies in any of the items of part B of the questionnaire as a weight-control strategy was reason enough to refer the gymnast to a specialised centre. The results obtained reveal that Spanish gymnasts present an actual risk of developing an ED, which needs to be accepted and addressed.

The correlation analysis yielded significant associations between BMI and all variables except BD, as well as between percentage of body fat calculated using both formulas (Slaughter, 1988; Yuhasz, 1974) and referring criterion 1. These results were similar to the study by Laffite et al. (2013), where the gymnasts with lower percentages of body fat and inadequate dietary intake presented a higher tendency toward bulimia and anorexia. As regards the referral to treatment, criterion 1 was associated with Slaughter's percentage of body fat and BMI (which is logical, since this criterion is based on BMI), as well as with body dissatisfaction, drive for thinness and bulimia. Additionally, criterion 2 was associated with BMI, DT, B and criterion 1, which seems consistent, since this criterion is based on the association between BMI and DT, B. Lastly, referring criterion 3 was associated with BMI, drive for thinness and bulimia. This shows that behavioural symptoms that indicate the presence of an ED are caused by factors like dissatisfaction, which lead to obsessive behaviours and EDs. It is difficult to compare these results with previous research since no study involving gymnasts was found to have applied this questionnaire.

A later analysis was conducted, examining both sexes and both competitive levels (FIG and RFEG: Royal Spanish Gymnastics Federation) separately.

With regard to anthropometric variables in women, associations were found between the sum of 6 skinfold thicknesses and BMI, hip circumference and Slaughter's % body fat, as well as between both % body fat, in both competitive levels. These results are

obvious since the calculation of the variables is closely related. Similarly, the men's group showed associations between both % body fat and between them and the sum of 6 skinfold thicknesses.

When looking for potential associations and causes of the EDs, DT and B were observed to be related to BMI in women. By contrast, in men, DT and B were associated with each other but not with BMI. Various studies have reported a higher risk of ED in elite than in non-elite gymnasts (De Bruin et al., 2007; Dallas et al., 2016; Dallas et al., 2017; Donti et al. 2021; Dosil et al., 2012; Papacharalampous et al. 2022; Valles et al., 2020).

When examining the referring criteria in women of both levels, criterion 1 was associated with BMI, while criteria 2 and 3 were associated with BMI, DT and B, which is normal, as the criteria are built based on these variables. In men, only at the international level criteria 2 and 3 were associated with DT and B.

CONCLUSIONS

Overall, it can be concluded that there was an average percentage of gymnasts at risk of developing an ED, and body dissatisfaction was confirmed to be the major cause of these disorders. Female gymnasts competing at a higher level presented a higher risk of ED since they showed higher values in the variables drive for thinness, bulimia and body dissatisfaction. A significant relationship was found between low BMI and both bulimia and drive for thinness. Furthermore, the main causes of mandatory referral to a specialist in EDs of senior female international-level gymnasts were low BMI, low percentage of body fat, body dissatisfaction, drive for thinness and bulimia.

As a practical application, it is suggested to implement prevention and intervention strategies that are specifically aimed at AcGs, such as programmes to promote healthy eating habits, improve perceived body image and reduce the obsession with thinness.

This information should focus not only on gymnasts, but also on their family environment. Both trainers and families should be aware of the risk factors involved in the development of this type of issue and be able to contribute to the prevention and early detection of those gymnasts at a higher risk. After that, gymnasts should immediately start with therapy.

Among the main limitations, we can highlight, firstly, the lack of studies that analyse EDs in Spanish gymnasts in this discipline and the inequality of the sample in terms of gender. Another limitation lies in the lack of variables such as family context, pressure from coaches, parents and peers, as previous studies confirm the relationship between the risk of suffering from ED and these variables.

Likewise, the questionnaire used has been applied to gymnasts for the first time. However, it is a questionnaire that has validity and reliability to assess the constructs studied (Garner, 2004) and in our study the reliability with Cronbach's alpha was DT= 0.77 B= 0.79 and CI= 0.62.

In addition, a strength of the present study was that the gymnasts self-administered the questionnaire, they were offered, by those responsible for the study, privacy, anonymity and confidentiality, which may have helped them not to underestimate or overestimate their responses.

As a final limitation, it is worth highlighting the need for a larger sample to be able to segment it by categories and competitive modalities, as well as by the different roles that are assumed in this sport.

REFERENCES

Andersen, A. (2005). Eating disorders in males. En C.G. Fairburn & K. D. Brownell (Eds.). *Eating disorders and obesity*, (2a. Ed.). A comprehensive handbook. NY: The Guildford Press.

Anderson, C. M., Petrie, T. A., & Neumann, C. S. (2011). Psychosocial correlates of bulimic symptoms among NCAA Division-I Female Collegiate Gymnasts and Swimmers/Divers. *Journal of Sport and Exercise Psychology, 33*(4), 483–505. https://doi.org/10.1123/jsep.33.4.483

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th. Ed.). Washington, DC: APA.

Cole, T., Flegal, K., Nicholls, D., & Jackson, A. (2007). Body mass index cut offs to define thinness in children and adolescents. *International Survey*, 335, 194–197.

Dallas, G., Dallas, C., Simatos, J., & Simatos, J. (2016). Nutritional status and dietary assessment of elite female artistic and rhythmic gymnasts-a case study. *Science of Gymnastics Journal*, *8*(3), 255-269.

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

De Bruin, A. K., Oudejans, R. R., & Bakker, F. C. (2007). Dieting and body image in aesthetic sports: a comparison of dutch female gymnasts and non-aesthetic sport participants. *Psychology of Sport and Exercise, 8*(4), 507–520. https://doi.org/10.1016/j.psychsport.2006.10.002

Deutz, R. C., Benardot, D., Martin, D. E., & Cody, M. M. (2000). Relationship between energy deficits and body composition in elite female gymnasts and runners. *Medicine and Science in Sports and Exercise*, 32(3):659-68. https://doi.org/10.1097/00005768-200003000-00017

Donti, O., Donti, A., Gaspari, V., Pleksida, P., & Psychountaki, M. (2021). Are they too perfect to eat healthy? Association between eating disorder symptoms and perfectionism in adolescent rhythmic gymnasts. *Eating Behaviors*, *41*, 101514. https://doi.org/10.1016/j.eatbeh.2021.101514

Dosil, J., Díaz, I., Viñolas, A. & Díaz, O. (2012). Prevención y detección de los trastornos de alimentación en deportistas de alto rendimiento (CAR, CEARE y CTD). [Prevention and Detection of the Disorders of Food in Athletes of High Performance (CAR, CEARE and CTD). *Cuadernos de Psicología del Deporte*, *12*(1), 163-166. https://scielo.isciii.es/scielo.php?script=sci_arttext&pid=S1578-84232012000100019

Fernández Rivas, A. (2021). Anorexia nerviosa del adolescente y COVID-19: la pandemia colateral. [Anorexia nervosa in adolescents and COVID-19: the collateral pandemic]. *Revista Española de Endocrinología Pediátrica*, *12*(2). 10.3266/RevEspEndocrinolPediatr.pre2021.Nov.705

Fortes, L. S., Neves, C. M., Filgueiras, J. F., Almeida, S. S., & Ferreira, M. E. C. (2013a). Body dissatisfaction,

psychological commitment to exercise and eating behavior in young athletes from aesthetic sports. *Revista Brasileira de Cineantropometría y Desempenho Humano, 15*(6), 695–704. https://doi.org/10.5007/1980-0037.2013v15n6p695

Fortes, L. S., Almeida, S. S., & Ferreira, M. E. C. (2013b). Influência da ansiedade nos comportamentos de risco para os transtornos alimentares em ginastas. [Influence of anxiety on risk behaviors to eating disorders in gymnasts]. *Revista Brasileira de Atividade Física y Saúde, 18*(5), 546-553 https://doi.org/10.12820/rbafs.v.18n5p546

Fortes, L. S., Almeida, S. S., & Ferreira, M. E. C. (2014). A internalização do ideal de magreza afeta os comportamentos alimentares inadequados em atletas do sexo feminino da Ginástica Artística?. [The internalization of the thin ideal affects the inappropriate eating Behaviors in artistic gymnastic female athletes?]. *Revista Da Educacao Fisica, 25*(2), 181–191. https://doi.org/10.4025/reveducfis.v25i2.21866

García, J., Solbes, I., Expósito, E. & Navarro, E. (2012). Imagen corporal y riesgo de trastornos de la conducta alimentaria en población universitaria española: Diferencias de género. *Revista de Orientación Educacional*, *26*(50), 31-46.

Garner, D. M. (2004). Eating Disorder Inventory–3 Professional manual. Odessa, *Fl: Psychological Assessment Resources.*

Harriger, J. A., Witherington, D. C., & Bryan, A. D. (2014). Eating pathology in female gymnasts: potential risk and protective factors. *Body Image, 11*(4), 501-508. https://doi.org/10.1016/j.bodyim.2014.07.007

Herpertz-Dahlmann, B. (2009). Adolescent eating disorders: definitions, symptomatology, epidemiology and comorbidity. *Child* and *Adolescent Psychiatric Clinics of North America 18*(1), 31–47. https://doi.org/10.1016/j.chc.2008.07.005

Ioannidou, C., & Venetsanou, F. (2019). Social physique anxiety, disturbed eating attitudes and behaviors, and perceived pressure for thin body in competitive Rhythmic and Aerobic Gymnasts. *Science of Gymnastics Journal, 11*(3), 331-342. https://www.fsp.uni-lj.si/mma/-/20191027171537/

Jardim, M. L., Valencio, A. C. J., Menegassi, L. N., Da Silva, R. A., & Carteri, R. B. (2022). Risks of eating and image disorders are correlated with energy and macronutrient inadequacies in youth rhythmic gymnastics. *Science of Gymnastics Journal*, *14*(1), 85-96.

Jonnalaggada, S. S., Benardot, D., & Dill, M. N. (2000). Assessment of Under-Reporting of Energy Intake by Elite Female Gymnasts. *International Journal of Sport Nutrition and Exercise Metabolism, 10*(3)315-25. https://doi.org/10.1123/ijsnem.10.3.315

Kaur, K., & Koley, S. (2019). Anthropometric determinants of competitive performance in gymnastics: a systematic review. *International Journal Health Science and Research*, *9*(7), 249-256. https://www.ijhsr.org/IJHSR_Vol.9_Issue.7_July2019/38.pdf

Kosmidou, E., Giannitsopoulou, E., & Proios, M. (2018). Are body esteem, eating attitudes, pressure to be thin, body mass index and training age related in rhythmic gymnastics athletes?. *Science of Gymnastics Journal, 10*(2), 189–201. http://humanperformancelab.phed.aut

h.gr/wp-content/uploads/2018/08/Kosmidou-et-al.-2018.pdf

Laffitte, A. M., Zap, M., Leandro, P. P., & Colleon, P. G. K. (2013). Relationship between body composition, dietary intake and tendency to eating disorders in Rhythmic Gymnastics athletes from Paraná. RBNE-*Revista Brasileira de Nutrição Esportiva,* *7*(38), 99–107. http://www.rbne.com.br/index.php/rbne/article/view/375

Marfell-Jones M., Olds T., Stewart A., & Carter L. (2006). *International standards for anthropometric assessment.* ISAK: Potchefstroom, South Africa.

Martínez-Rodríguez, A., Leyva-Vela, B., Cuestas-Calero, B. J., & Reche, C. (2018). Deporte escolar y trastornos de la conducta alimentaria [School sports and eating disorders]. *Retos*, *34*, 236–239. https://doi.org/10.47197/retos.v0i34.59671

Martínez-Rodríguez, A., Reche-García, C., Martínez Fernández, M. C., & Martínez Sanz, J. M. (2020). Assessment of dietary-nutritional status, body composition, eating behaviour and image perception in rhythmic gymnastics athletes. *Nutrición Hospitalaria, 37*(6), 1217–1225. https://doi.org/10.20960/nh.03141

Martins, F. R., & Rodríguez Dos Santos, J. (2004). Leisure-time physical activity, diet and body composition. *Revista Brasileira de Educaçao Física e Esporte*, *18*(2), 159–167. https://doi.org/10.1590/S1807-55092004000200004

Nordin, SM., Harris, G., & Cumming, J. (2003). Disturbed Eating in Young, Competitive Gymnasts: Differences Between Three Gymnastics Disciplines. *European Journal of Sports Science, 3*(5), 1-14. https://doi.org/10.1080/174613903000735

02

OMS (2023), Clasificación Índice de Masa Corporal.

Papacharalampous, K. E., Dallas, C., & Dallas, G. (2022). Detection of eating disorders in male and female artistic gymnasts. *Science of Gymnastics Journal*, *14*(3), 421-433. https://doi.org/10.52165/sgj.14.3.421-433

Peláez-Barrios, E. M., & Vernetta-Santana, M. (2018). Estima corporal y factores antropométricos en adolescentes practicantes de acrobática. [Body esteem and anthropometric factors in acrobatic teenage gymnasts]. *TRANCES: Revista de Transmisión Del Conocimiento Educativo y de La Salud*, *10(*1), 511-526.

Peláez-Barrios, E. M., & Vernetta-Santana, M. (2020). Effects of sports practice on body image in male adolescents. ESHPA - Education, Sport, Health and Physical Activity. *ESHPA - Education, Sport, Health and Physical Activity*, *4*(3), 362–372. http://doi.org/10.5281/zenodo.4118376

Salas-Morillas, A., Gutiérrez-Sánchez, A., & Vernetta-Santana, M. (2022). Body composition and sports performance in acrobatic gymnasts. *International Journal of Morphology, 40*(1), 220–227. http://www.intjmorphol.com/wp-content/uploads/2022/02/art_32_401.pdf

Salas-Morillas, A., Gutiérrez-Sánchez, A., & Vernetta-Santana, M. (2021). Insatisfacción corporal y trastornos de conducta alimentaria en gimnastas: revisión sistemática**.** **[**Body dissatisfaction and eating disorders in gymnasts: a systematic review]. *Retos, 44,* 577-585. https://doi.org/10.47197/retos.v44i0.91042

Salas-Morillas, A., & Vernetta, M. (2020). Imagen corporal en adolescentes masculinos sedentarios y practicantes de gimnasia acrobática. Body image in

sedentary male adolescents who practice acrobatic gymnastics. En Marín, J. A. et al. (Ed). *Inclusión, Tecnología y Sociedad.* (pp. 548-562). Editorial Dykinson, S.L.

Slaughter, M., Lohman, T., Boileau, R., Horswill, C., Stillman, R., van Loan, M., & Bemben, D. (1988). Skinfold equation for estimation of body fatness in children and youth. *Human Biology, 60*(5), 709-23. https://pubmed.ncbi.nlm.nih.gov/3224965/

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

Taboada-Iglesias, Y., Vernetta Santana, M., & Gutiérrez-Sánchez, A. (2017). Anthropometric profile in different event categories of Acrobatic Gymnastics. *Journal of Human Kinetics*, *57*, 169-179. https://doi.org/10.1515/hukin-2017-0058

Taboada-Iglesias, Y., Vernetta-Santana, M., Alonso-Fernández, D., & Gutiérrez-Sánchez, Á. (2021). Phantom model and proportionality indices in acrobatic gymnastics age categories: a cross-sectional and descriptive study. *Revista Española de Nutrición Humana y Dietética*, *25*(Supl. 1), e1091-e1091. https://doi.org/10.14306/renhyd.25.S1.1091

Valles Verdugo, G., Hernández Armas, E., Baños, R., Moncada-Jiménez, J., & Rentería, I. (2020). Distorsión de la imagen corporal y trastornos alimentarios en adolescentes gimnastas respecto a un grupo control de adolescentes no gimnastas con un IMC similar**.** [Body image distortion and eating disorders in adolescent gymnasts compared to a control group of non-gymnasts with similar BMI]. *Retos*, *37*, 297–302. https://doi.org/10.47197/retos.v37i37.67090

Vernetta, M., & López Bedoya, J. (2005). Perfil motor de la gimnasia acrobática: características y planteamiento taxonómico [Motor profile of acrobatic gymnastics: Characteristics and taxonomic approach]. *Lecturas: EF y Deportes. Revista Digital, 10* (81). https://efdeportes.com/efd81/acrob.htm

Vernetta, M., Montosa, I., & Peláez, E. (2018). Estima corporal en gimnastas adolescentes de dos disciplinas coreográficas: gimnasia rítmica y gimnasia acrobática [Body esteem in adolescent gymnasts in two choreographic disciplines: rhythmic gymnastics and acrobatic gymnastics]. *Psychology, Society, y Education*, *10*(3), 301-314. https://doi.org/10.25115/psye.v10i1.2216

Vieira, J. L. L., Amorim, H. Z., Vieira, L. F., Amorim, A. C., & Rocha, P. G. M. da. (2009a). Distúrbios de atitudes alimentares e distorção da imagem corporal no contexto competitivo da ginástica rítmica. Eating disorders and body image distortion in the rhythmic gymnastics competitive context. *Revista Brasileira de Medicina Do Esporte, 15*(6), 410-414. https://doi.org/10.1590/s1517-86922009000700001

Vieira, J. L. L., Vieira, L. F., Amorim, H. Z., Amorim, A. C., & Rocha, P. G. M. da. (2009b). Distúrbios de atitudes alimentares e sua relação com o crescimento físico de atletas paranaenses de Ginástica Rítmica. Eating disorders and the relationship with the physical growth in Paranaenses rhythm gymnastic athletes. *Motriz, 15*(3), 552-561. https://www.periodicos.rc.biblioteca.unesp.br/index.php/motriz/article/download/2180/2472

Yuhasz, M. (1974). Physical Fitness Manual. London: Ontario

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IDENTIFICATION OF TOPOLOGICALLY CHARACTERISTIC MUSCULOSKELETAL PAIN OCCURRENCE AMONG YOUNG FEMALE ATHLETES

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Abstract

The purpose of this study was to identify pain occurrence among young female athletes in aesthetic sports by defining the proportions of pain status of fourteen body regions. Three groups of young female athletes (artistic gymnasts, rhythmic gymnasts and contemporary dancers) were analysed and compared. The sample consisted of overall 99 competitive athletes. Using the "Self-estimated functional inability because of pain" (SEFIP) questionnaire, athletes were asked to assess their current pain status in 14 body regions on a 5-point scale, with 0 being no pain and 4 being pain so severe that they are unable to practice. According to the Wilk's test there was a significant multivariate effect ($F= 4.60$; $p<0.001$) between artistic gymnasts, rhythmic gymnasts and compulsory dancers in training experience and body status. The most common locations for incidence of pain on the total sample of subjects were in the lower back (44%), knees (35%) and ankles/feet (31%). Artistic gymnasts mostly report pain in the ankles/feet (51.43%), and lower (37.14%) and upper back (34.29%). Rhythmic gymnasts of the same age mostly report pain in lower back area (46.42%), knees (42.86%) shins, ankles and feet (28.57%), while dancers experience pain mostly in lower back (50%), upper back (44%) and knees (38.89%). According to the results of the Chi-square test, artistic gymnasts reported significantly higher pain incidence in ankles/feet region ($p<0.01$). Early detection of even low intensity pain, accompanied with the adjustment of training load and usage of appropriate safety requirements, can prevent the occurrence of injuries among young athletes.

Keywords: *artistic gymnastics, rhythmic gymnastics, dance, health care, back pain.*

INTRODUCTION

Young female athletes in aesthetic sports are subjected to intensive training very early in life while they master the demanding techniques of performance, which can cause musculoskeletal pain. Due to differences in training content, one could expect different incidence and risk of injury in aesthetic sports such as artistic gymnastics, rhythmic gymnastics and contemporary dance. Differences are expected even within different types of dance with different topological characteristics and occurrences of pain (Miletić, Kostić, Božanić & Miletić, 2009).

Artistic, as well as rhythmic gymnasts, start with systematic competitions at the age of 7. High level of training demands at an early age can lead to various injuries which become a serious obstacle in development of future competitive career.

Artistic gymnastics is reported to have some of the highest injury rates in sports (Campbell et al. 2019). According to recent studies, most frequently, musculoskeletal pain among gymnasts may occur in lower extremities (Thomas & Thomas, 2019; Kerr, Hayden, Barr, Klossner & Dompier, 2015), wrists (Di Fiori, 2006), lower-back (Cugusi et al. 2020) and shoulder (Gerhardt, Doyscher, Boschert & Scheibel, 2014) regions. Other possible risk factors of musculoskeletal pain among gymnasts are identified as overuse and repetition of the same gestures several times for every type of training (Wyatt, Gittoes & Irwin, 2020), maturity phases of rapid growth (Notarnicola et al. 2019), age, body mass, body size, training duration and life stress (Campbell et al. 2019), and duration of sport practice (Farri et al. 2021). According to Thomas & Thomas (2019), the most common injury types in gymnast Olympians were sprains (35%) followed by tendinopathy/arthritis/impingements 17%), contusions (10%), and fractures (7%). Researches on young gymnasts (ages 6 to 10) show that they are most likely to experience a lower arm fracture, while those over the age of 10 years were most likely to experience an ankle sprain (Albright, Meghani, Lemme, Owens, & Tabaddor, 2022). In order to be able to prevent such injuries caused by training, it is advisable to start with the systematic monitoring of the occurrence of pain of very low intensity as early as possible.

In rhythmic gymnastics, there is a prevailing attitude that reduced body weight will positively affect performance (Kaur & Koley, 2019), and thus the overall competitive result. Therefore, eating disorders and lower caloric intake are more common in aesthetic sports such as rhythmic gymnastics and figure skating, and endurance sports such as cycling, distance running and swimming (Coelho, Gomes, Ribeiro & Soares, 2014). In order to achieve the desired external appearance, which includes a below-average body weight, female athletes often do not have adequate nutrition, optimal for the heavy, multi-hour training sessions they carry out on a daily basis (Amorim, 2019). An additional problem is that rhythmic gymnasts enter the competition system very early, and the high requirements of physical appearance with below-average body weight, especially for girls in the developmental phase, can negatively affect the physical and mental health of young athletes. The higher the competitive level, the greater is the prevalence of eating disorders and risky dietary behaviors (Francisco, Alarcão, & Narciso, 2012). Some authors (de Oliviera et al., 2021) indicate the need for action by the main gymnastics institution (FIG) in order to prevent training methods that include inadequate nutrition of athletes, which will negatively affect the health of gymnasts. It is all the more important for rhythmic gymnasts to frequently monitor the appearance of pain caused by training, which can be directly related to exhaustion, overtraining and caloric deficit. The most common injuries among rhythmic gymnasts, according to previous research, are in the area of the lower extremities and back (Gulati, Rychlik, Wild, & LaBella, 2022; Oltean, Rusu, Copoiu, & Calin, 2017.). Overuse injuries are mostly seen in the knees, lower back and hip/groin (Gram,

Clarsen, & Bø, 2021). Some authors (Gulati, Rychlik, Wild, & LaBella, 2022) report that the most common injury types were strain (20.7%), nonspecific pain (15.5%), and tendinitis/tenosynovitis (10.36%); and the most common injured body parts were foot (24.9%), ankle (15.5%), knee (15.0%), lower back (14.0%), and hip (13.0%).

Generally, dance is an activity that causes intense pain, especially in the lower back (Miletic, Miletic, & Milavic, 2015; Henn, Smith, Ambegaonkar, & Wyon, 2020; Miletic, Miletic, Lujan, Kezic, & Erceg, 2015). McMeeken reported that 52% of Australian dancers suffer from back pain injuries before they are 18 and 75% by the time they are 25.

Contemporary dance, according to research so far, causes pain predominantly in the lower extremities due to specific dance techniques, especially intense jumps. Most pain in contemporary dancers is in the area of knees, ankles, and shin (Van Winden, Van Rijn, Richardson, Savelsbergh, Oudejans, & Stubbe, 2019) and contemporary dancers are at high risk for lower-extremity injuries (van Seters, van Rijn, van Middelkoop, & Stubbe, 2020). In modern dance, it is important to regularly monitor the occurrence of pain because the occurrence of a higher incidence of characteristic painful areas is possibly related to physical fitness, incomplete mastery of mechanical movements and incorrect movements (Sun, 2020). According to Angioi, Metsios, Koutedakis, Twitchett, & Wyon (2009) a reduced level of lower body muscular power is associated with increased severity of injuries in female contemporary dancers. Injury rates in contemporary dance are high; notably, 89% of dancers reported one or more injuries. This problem is particularly evident in the lower limb (Baker, Scott, Watkins, Keegan-Turcotte, & Wyon, 2010). Research on the incidence of pain in contemporary dancers is still insufficient (Fuller, Moyle, Hunt, & Minett, 2019).

Generally, frequent monitoring of the occurrence of pain in young female athletes needs to be carried out in order to: (1) determine the characteristic critical points of occurrence of pain in certain sports activities, (2) prevent the occurrence of more serious chronic injuries related to the training content, (3) extended the careers of young female athletes. In this paper, we analyze and compare the incidence of pain in female athletes who actively train in different aesthetic sports, in order to be able to relate the characteristic topological pain occurrence in each special group to the training content. Knowing the characteristics of topologically defined occurrence of pain for each of the analyzed sports is the first step to the complex process of protecting young female athletes from sports injuries caused by training. Namely, the characteristic occurrences of pain in some sports lead to acute ones, and if they are ignored, it is possible that they become serious chronic injuries that seriously threaten the careers of young female athletes. Prevention of the occurrence of characteristic injuries in female athletes is a complex process that, in addition to the female athletes and coaches, also encompasses the wider environment. It is especially important for young athletes that their parents, coaches, doctors and therapists, choreographers, fitness trainers and everyone involved in the training and education processes are educated and informed in this sense.

The purpose of this study was to identify pain experience among young female athletes by defining the proportions

of pain status of fourteen body regions. Accordingly, three groups of young female athletes (artistic gymnasts, rhythmic gymnasts and contemporary dancers), defined by type of athletic training were analyzed and compared.

METHODS

The sample of subjects for the investigation consisted of 99 young female athletes who participated in aesthetic sports. Their mean age was 12.3 years (range 8 to 18). The coaches and parents were thoroughly familiar with aims and methods of this research. The study was performed following standard ethical guidelines of the University of Split, Croatia, and was approved by the Faculty of Kinesiology's Ethics Committee. The subjects were divided into three groups according to their training programs: artistic gymnasts (AG), rhythmic gymnasts (RG) and dancers (D). The artistic gymnasts (N=35) are competitors in compulsory and free programs, who have participated in national competitions and have a training load of approximately 10 hours per week of training. The rhythmic gymnasts (N=28) have participated in national and international competitions and have approximately 12 hours per week of training. The dancers (N=36) have participated in national compulsory dance competitions and have approximately 18 hours per week of training.

The experiment was conducted in two phases. In the first phase, coaches and parents were introduced to the methods and objectives of the research, and the athletes, with the assistance of the coaches, filled out a questionnaire about their sports status, which included; a) previous training experience; b) training characteristics; c) hours of training per week; d) number of years of current sports participation; e) competition level and sport success. Then, subjects who changed training activities in the past three years, and who trained less than 7 hours a week in the past 6 months, were excluded from the research. Out of a total of 251 female athletes included in the first phase of the research, 99 of them met the conditions for inclusion in the second phase of the experiment.

In the second phase, the subjects were asked to complete a questionnaire, and anthropometric measurements were taken. "Self-estimated functional inability because of pain" (SEFIP) questionnaire is a simple and valuable tool in defining the pain status in certain regions, approved to be of high applicability among young athletes involved in aesthetic activities (Ramel, Moritz & Jarnlo 1999; Miletić, Kostic, Bozanic & Miletic, 2009). SEFIP is an instrument that asks the subjects to assess their current pain on a 5-point scale. The questionnaire covers 14 body regions (neck, shoulders, elbows, wrists/hands, upper back, lower back, hips, thighs (front), thighs (back), knees, shins, calves, ankles/feet, and toes). A sum score (range, 0-56) can be achieved where 0 represents no pain and 4 represents maximal pain. Everything above zero is regarded as a positive finding. Subject reports pain intensity on the five-point scale as follows: 0 – if they report no pain at all; 1 – if they report some pain but not much problem; 2 – if they report some pain but can handle it; 3 – if they report much pain and must avoid some movements; 4 – if the absence of practice is reported because of pain. The 99 subjects from three aesthetic sports were asked to answer the questions of the questionnaire sincerely, based on their own observations and experience. An online questionnaire

was posted on a specialized server *SurveyMonkey* with permission of the Faculty of Kinesiology, University of Split. *SurveyMonkey* is specialized for collecting and analyzing data electronically on a global level. The server and the application enabled a password level of access security and automatic identification of subjects when filling out the questionnaire from a computer identified by the IP address and personal information. Data collection was conducted in the period from April to June, 2022. The anthropometric measurements included body height and body weight. Body mass index (BMI) was calculated as BMI = body weight (kg)/ body height $(m)^2$.

The basic parameters of the distribution of variables were calculated (mean value and standard deviation) for the three groups of athletes: (1) number of years of training; (2) body height (BH); (3) body weight (BW); and (4) body mass index (BMI). A multivariate analysis of variance (one–way MANOVA) with the post-hoc Tukey's test was used to test the differences between the three groups of subjects in the mentioned variables. Pearson's Chi-square test was applied for the comparison of the proportions of pain experience in the 14 body regions between the groups of athletes. The statistical level of significance of 95% ($p < 0.05$) was applied.

RESULTS

Basic data of body status and years of training, separately for each group, are presented in Table 1. One-way MANOVA was calculated in order to determine the differences between the groups in these six variables.

According to Wilks' test, there was a significant multivariate effect (F= 4.60; p<0.001) meaning that the whole set of composites could significantly discriminate the groups. In order to define which of the analyzed dependent variables contributes the most to the defined differences, a post-hoc Tukey's HDS test was calculated. The results show that there are no significant differences between the groups if we analyze the total sum of the results achieved by applying the SEFIP questionnaire and the occurrence of pain in young female athletes. Furthermore, the post-hoc Tuckey test determined that there are significant differences in the years of training between sports gymnasts and dancers and between rhythmic gymnasts and dancers. Differences in body height and weight were determined between artistic gymnasts and dancers and between rhythmic gymnasts and dancers, which was also reflected in significant differences in BMI between rhythmic gymnasts and dancers.

Percentages of reported intensity of pain or absence of pain for each body region separately and for total sample of athletes are presented in Table 2. According to these results, young female athletes in aesthetic sports most often report the appearance of pain of low intensity in the knees (as many as 29 of them), followed by the upper and lower back (26 athletes) and in the area of the ankle joints and feet (20 athletes). When it comes to the occurrence of pain of greater intensity that young athletes feel but can still exercise and correctly follow the training requirements and correctly perform the given elements, such pain most often appears in the upper and lower back and in the area of the ankle joints and feet. It is characteristic that the pain of high intensity, due to which female athletes' proper performance is impaired in training and they avoid performing some elements, most often occurs in ankle joints and feet.

Table 1.
Descriptive statistics for groups of artistic gymnasts (AG), rhythmic gymnasts (RG), and dancers (D) and results of One-way MANOVA (Post-hoc Tukey's Test)

Sports	SEFIP (Σ)	Yrs (t)	Age (yrs)	Height (cm)	Weight (kg)	BMI
AG (n = 35)	4.09±4.66	5.46±2.74[2]	11.86±2.64	145.69±14.74[2]	39.20±12.90[2]	17.95±2.81
RG (n = 28)	2.57±2.59	5.61±2.94 [3]	11.85±2.58	149.53±12.86[3]	37.89±10.99[3]	16.54±2.12[3]
D (n = 36)	3.75±3.14	7.67±2.96	13.08±1.25	162.03±11.73	49.56±10.58	18.67±2.63

[1]differences between AG and RG, [2]differences between AG and D, [3]differences between RG and D

Table 2.
Percentages of reported intensity of pain (1, 2, 3 or 4) or reported absence of pain (0) for total sample of athletes (N=99) for each body region separately

Body region	*No pain* (0)	*Some pain but not much problem* (1)	*Pretty much pain but can handle it* (2)	*Much pain, must avoid some movements* (3)	*Cannot practice because of pain* (4)
Neck	85.9%	12.1%	2%	0.0%	0.0%
	85	12	2	0	0
Shoulders	82.8%	13.2%	4%	0.0%	0.0%
	82	13	4	0	0
Elbow	93.9%	4.1%	1%	0.0%	1%
	93	4	1	0	1
Wrists/hands	85.9%	10.1%	4%	0.0%	0.0%
	85	10	4	0	0
Upper back	64.6%	26.3%	9.1%	0.0%	0.0%
	64	26	9	0	0
Lower back	55.6%	26.3%	15.1%	3%	0.0%
	55	26	15	3	0
Hips	89.9%	9.1%	1%	0.0%	0.0%
	89	9	1	0	0
Thighs (front)	86.9%	8.1%	5%	0.0%	0.0%
	86	8	5	0	0
Thighs (back)	90.9%	8.1%	1%	0.0%	0.0%
	90	8	1	0	0
Knees	64.7%	29.3%	4%	2%	0.0%
	64	29	4	2	0
Shins	89.9%	10.1%	0.0%	0.0%	0.0%
	89	10	0	0	0
Calves	70.7%	24.3%	4%	1%	0.0%
	70	24	4	1	0
Ankles/feet	68.6%	20.2%	6.1%	5.1%	0.0%
	68	20	6	5	0
Toes	98%	2%	0.0%	0.0%	0.0%
	97	2	0	0	0

For a better insight into the occurrence of pain of low, medium and high intensity in the area of ankle joints and feet by research groups, the results are shown in Figure 1.

The results in the category (4) *Cannot practice because of pain* are not shown in the figure because the highest level of pain in the total sample of young female athletes was not identified by the SEFIP questionnaire. However, the most frequently reported occurrences of pain by subsamples of female athletes are identified. In the sub-sample of artistic gymnasts, only 48.60% of them do not report any occurrence of pain. This means that every other gymnast at the age of 12 reports some musculoskeletal pain caused by training, regardless of its intensity. A total of 71.40% of rhythmic dancers at the age of 12 do not report any occurrence of pain, and 86.10% of female dancers at the age of 13.

The results of the Chi square test for each body region between the three groups of athletes are presented in Table 3. According to the results, young female athletes in aesthetic sports most often report the occurrence of characteristic musculoskeletal pain in the lower back area (44.44 %) followed by the upper back and knees (35.35%), while in third place is the occurrence of pain in the area of the ankle joints and feet (31.31%). By analyzing the appearance of characteristic musculoskeletal pain for each research group separately, we see how the characteristic appearance of topological pain in young female athletes differs depending on the type of training activity. Thus, in artistic gymnasts, the occurrence of pain is most common in the area of the ankle joints (up to 51.43%), followed by the area of the lower back (37.14%) and upper back (34.29%).

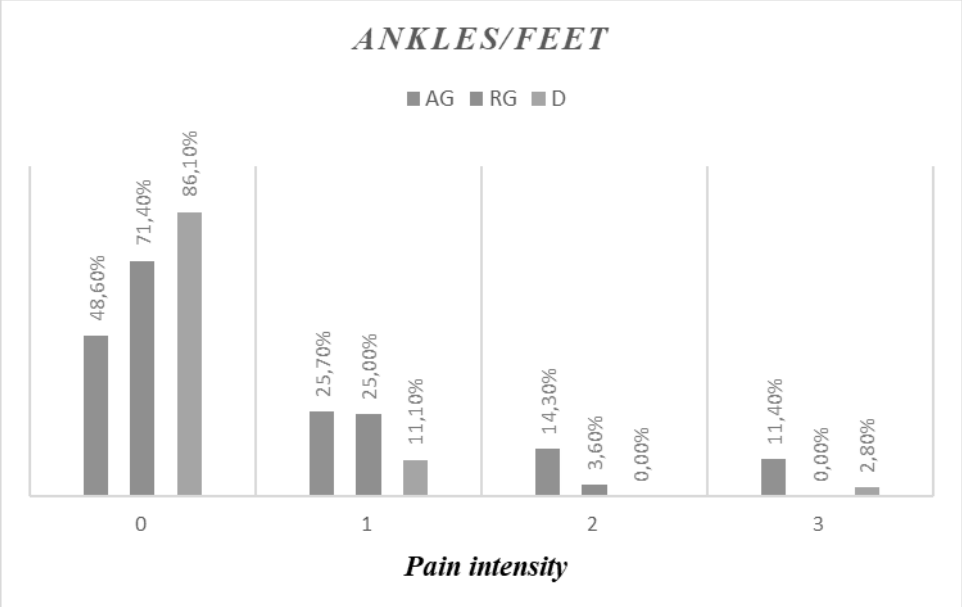

Figure 1. Intensity of pain prevalence among groups of artistic gymnasts (AG), rhythmic gymnasts (RG) and dancers (D) in ankles/feet region: (0) *No pain*; (1) *Some pain but not much problem*; (2) *Pretty much pain but can handle it*; (3) *Much pain, must avoid some movements*.

Table 3.
Differences between groups of artistic gymnasts, rhythmic gymnasts and dancers in pain incidence: Chi square test results (χ^2) for each body region between three groups

Body region	*AG N= 35*	*RG N=28*	*D N=36*	*TOTAL N=99*	χ^2	*df*
Neck	7	2	5	14.14%	4.76	4
	20%	7.14%	13.89%	14		
Shoulders	7	3	7	17.17%	1.95	4
	20%	10.71%	19.44%	17		
Elbow	2	1	3	6.06%	3.96	6
	5.71%	3.57%	8.33%	6		
Wrists/hands	8	2	4	14.14%	8.16	4
	22.86%	7.14%	11.11%	14		
Upper back	12	7	16	35.35%	5.03	4
	34.29%	25%	44.44%	35		
Lower back	13	13	18	44.44%	3.48	6
	37.14%	46.42%	50%	44		
Hips	1	4	5	10.10%	4.55	4
	2.86%	14.28%	13.89%	10		
Thighs (front)	4	1	8	13.13%	5.31	4
	11.43%	3.57%	22.22%	13		
Thighs (back)	4	1	4	9.09%	3.07	4
	11.43%	3.57%	11.11%	9		
Knees	9	12	14	35.35%	7.93	6
	25.71%	42.86%	38.89%	35		
Shins	3	2	5	10.10%	.93	2
	8.57%	7.14%	13.89%	10		
Calves	10	8	11	29.29%	5.04	6
	28.57%	28.57%	30.56%	29		
Ankles/feet	18	8	5	31.31%	16.98**	6
	51.43%	28.57%	13.89%	31		
Toes	2	0	0	2.02%	3.73	2
	5.71%	0.0%	0.0%	2		

*Denotes significant coefficients on the level $p<0.05$;
**Denotes significant coefficients on the level $p<0.01$.

In rhythmic gymnasts, the occurrence of characteristic musculoskeletal pain is most common in the lower back (46.42%), followed by the knees (42.86%) and in the area of ankles and feet (28.57%). In female dancers, the occurrence of characteristic musculoskeletal pain is most common in the lower back (50%), upper back (44%) and in the area of the knees (38.89%). According to the results of the Pearsons Chi-square test, we found significant differences between the three investigated groups in the occurrence of characteristic musculoskeletal pain in the area of the ankle joints and feet. Artistic gymnasts most often report pain in the area of the ankle joints and feet (51.43%), followed by rhythmic gymnasts (28.57%) and dancers (13.89%).

DISCUSSION

Results have shown that there are differences in training experience between artistic gymnasts and dancers. Respondents in the sub-sample of female dancers, with an average age of 13.8 years, are slightly older than the gymnasts (11.8 years), which is expected because gymnasts enter the competition system earlier and therefore start systematic training very early, already at the age of 5. In relation to their age, it is expected that there are more dancers than gymnasts because they are already in the phase of accelerated growth. The differences in weight and BMI, which show that rhythmic gymnasts have the lowest BMI values and below average body weight, are in accordance with previous research (Purenović-Ivanović, Popović, Bubanj, & Stanković, 2019; Batista, Garganta, & Ávila-Carvalho, 2019) according to which we expect a characteristic physique from female competitors in rhythmic gymnastics: lean body, long limbs, and low body weight. It is a common opinion that in female rhythmic gymnasts, reduced body weight is a prerequisite for better performance of body elements (Kaur & Koley, 2019) and already at an early competitive age, girls with such a physique and below-average BMI will be positively selected. In recent scientific literature (Oliviera, Costa, Antualpa, & Nunomura, 2021) the question is increasingly being asked how justified this is, i.e., whether such a physique really promotes good performance and whether it justifies dietary restrictions that can have a bad effect on the overall mental and physical health of young female athletes. We can assume that insufficient nutrition will make it more difficult to cope with the great training demands of this sport, and that the problems of rhythmic gymnasts will also be reflected in the appearance of musculoskeletal pain. That is why it is necessary to react seriously to the appearance of musculoskeletal pain even of the smallest intensity and to adjust the training loads and diet.

According to the obtained results, young female athletes in aesthetic sports most often report the appearance of pain in the area of the upper and lower back and knees, followed by ankles and feet in third place. The results are in line with previous research and the general occurrence of pain in young athletes in the phase of growth and development (Müller, Müller, Stoll, Fröhlich, Otto, & Mayer, 2017; Schmidt et al. 2014; Hall, Foss, Hewett, & Myer, 2015).

By analyzing the occurrence of characteristic musculoskeletal pain in subgroups of artistic gymnasts, rhythmic gymnasts and dancers in this research, we come to more detailed information regarding pain caused by specific sports training. In artistic gymnasts, a characteristic occurrence of musculoskeletal pain was identified, most often in the area of the ankle joints and feet, as well as the upper and lower back. Artistic gymnastics is a physically demanding sport that requires flexibility, agility, and extreme upper and lower body strength. The specific biomechanics of the sport leads to a unique injury profile (Desai, Vance, Rosenwasser, & Ahmad, 2019). According to Edouard, Steffen, Junge, Leglise, Soligard, & Engebretsen (2018), the most common injury in female artistic gymnasts is ankle sprain, which is in line with the results of this research. Understanding the aetiology, prevention and treatment protocol by coaches and athletes is a necessary prerequisite for injured athletes to return to

training under full load. This is why it is important to frequently monitor the occurrence of musculoskeletal pain and identify the intensity of the occurrence of pain in order to be able to adjust training contents and loads. This can be done by, for example, reducing intensive training of explosive strength such as jumps and flexibility, especially in the back area, after the identification of characteristic pain.

In a sub-sample of female rhythmic gymnasts, a characteristic occurrence of musculoskeletal pain in the area of the lower back, knees, lower legs, ankles and feet was identified. For rhythmic gymnasts, the training is based on the intensive development of extreme flexibility, mobility, while the body elements of balances mainly contain elements related to back flexibility, which can be the cause of significant pain in the back. The obtained results are in accordance with previous research (Gulati, Rychlik, Wild, & LaBella, 2022; Oltean, Rusu, Copoiu, & Calin, 2017), and it is recommended to adjust the training in order to reduce the execution of high-risk elements to a minimum (Oltean, Rusu, Copoiu, & Calin, 2017).

In a subsample of female dancers, a characteristic occurrence of musculoskeletal pain in the back and knee area was identified. Dancers in the contemporary dance style, when compared to gymnasts and rhythmic gymnasts, do not have pronounced jumping training, and there is no intense pain in the area of the ankle joints, while the dominant pain appears in the back and knees. The results of the Pearsons Chi-square test show significant differences in the occurrence of musculoskeletal pain in the area of the ankle joints, which can be directly related to the content of the training, especially when it comes to intensive training during which the take-off is practiced, whether it is a group of jumps or acrobatic elements. It is clear that such trainings in artistic gymnastics are the most intense due to its acrobatic elements.

The most common causes of chronic injuries in female gymnasts are poor technique, improper training methodology for learning gymnastic elements and overtraining (Kolar, Pavletič, Smrdu, & Atiković, 2016). Possible prevention of acute painful conditions that progress to chronic ones include better education of coaches, athletes, parents, physiotherapists, doctors and others involved in the training protocol of young female athletes. Better education also includes recent knowledge such as the identification of the characteristic occurrence of pain in certain sports disciplines, and a more effective transfer of knowledge between conducted research and coaches who directly affect the health status of young female athletes.

This paper once again proved that there is a clear need for adoption of universal standards for injury prevention screens and injury reporting (Liederbach, 1997) and, therefore, scientists and experts are making great efforts to develop these standards in their sports. However, as the results of this research show, the main problem in most aesthetic sports are the back, knees, feet and ankles areas. Fortunately, the importance of injury prevention for these body areas is well researched and includes core and knee stability exercises, as well as strengthening the feet & ankle muscles (Thacker et al., 2003; Huxel Bliven & Anderson, 2013; van Der Merwe, Shultz, Colborne & Fink, 2021). Coaches and experts need to realize that injury prevention exercises are crucial for athlete's development and their long-term wellbeing and that they are to be practised on a daily basis. Also, to minimize

the injury risk, all the professionals working with athletes need to be devoted to improving training facilities, as well as training equipment and apparatus that athletes use.

CONCLUSIONS

According to the results presented and discussed in this research, it can be concluded:

- The most common occurrence of musculoskeletal pain in young female athletes in aesthetic disciplines is in the lower back, followed by the upper back and knees, and in the ankles and feet.
- Characteristic musculoskeletal pain caused by training in artistic gymnasts is mainly in the area of the ankle joints, then in the lower and upper back; in rhythmic gymnasts in the lower back, knees and shins, ankles and feet; and in dancers in the area of the lower and upper back and in knees.
- It is recommended to monitor the occurrence of musculoskeletal pain in young female athletes and to modify training in accordance with the obtained results, so that the acute occurrence of pain does not have chronic consequences and thus directly negatively affect the careers of young female athletes.
- The use of the SEFIP questionnaire is recommended for monitoring the occurrence of musculoskeletal pain in young female athletes.
- Injury prevention program should be an integral part of every sport-related activity, since it not only helps in achieving training goals but also keeps athletes healthy.

REFERENCES

Albright, J. A., Meghani, O., Lemme, N. J., Owens, B. D., & Tabaddor, R. (2022). Characterization of Musculoskeletal Injuries in Gymnastics Participants From 2013 to 2020. *Sports Health*, 19417381221099005.

Amorim, M. G. A. (2019). *Perturbações do comportamento alimentar e a ginástica de alta competição Perturbações do comportamento alimentar e a ginástica de alta competição*. Universidade do Porto.

Angioi, M., Metsios, G. S., Koutedakis, Y., Twitchett, E., & Wyon, M. (2009). Physical fitness and severity of injuries in contemporary dance. *Medical Problems of Performing Artists*, *24*(1), 26-29.

Baker, J., Scott, D., Watkins, K., Keegan-Turcotte, S., & Wyon, M. (2010). Self-reported and reported injury patterns in contemporary dance students. *Medical problems of performing artists*, *25*(1), 10-15.

Batista, A., Garganta, R., & Ávila-Carvalho, L. (2019). Morphological Characteristics and Biological Maturation of Brazilian and Portuguese Gymnasts. *International Journal of Morphology*, *37*(2).

Campbell, R. A., Bradshaw, E. J., Ball, N.B., *et al.* (2019). Injury epidemiology and risk factors in competitive artistic gymnasts: a systematic review. *British Journal of Sports Medicine*; 53**:**1056-1069.

Coelho, G. M. D. O., Gomes, A. I. D. S., Ribeiro, B. G., & Soares, E. D. A. (2014). Prevention of eating disorders in female athletes. *Open access journal of sports medicine*, 105-113.

Cugusi, L., Manca, A., Sarritzu, S., Bergamin, M., et al. (2020). Risk factors associated with low back pain in competitive female gymnasts: A meta-analytic approach. *Journal of Sport science*, 38, 2543–2552.

Desai, N., Vance, D. D., Rosenwasser, M. P., & Ahmad, C. S. (2019). Artistic gymnastics injuries; epidemiology, evaluation, and treatment. *JAAOS-Journal of the American Academy of Orthopaedic Surgeons*, *27*(13), 459-467.

Di Fiori, J. P. (2006). Overuse injury and the young athlete: The case of chronic wrist pain in gymnasts. *Curr. Sports Med. Rep.* 2006, 5, 165–167.

Edouard, P., Steffen, K., Junge, A., Leglise, M., Soligard, T., & Engebretsen, L. (2018). Gymnastics injury incidence during the 2008, 2012 and 2016 Olympic Games: analysis of prospectively collected surveillance data from 963 registered gymnasts during Olympic Games. *British journal of sports medicine*, *52*(7), 475-481.

Farì, G., Fischetti, F., Zonno, A., Marra, F., Maglie, A., Bianchi, F. P., Messina, G., et al. (2021). Musculoskeletal Pain in Gymnasts: A Retrospective Analysis on a Cohort of Professional Athletes. *International Journal of Environmental Research and Public Health*, *18*(10).

Francisco, R., Alarcão, M., & Narciso, I. (2012). Aesthetic sports as high-risk contexts for eating disorders—Young elite dancers and gymnasts perspectives. *The Spanish journal of psychology*, *15*(1), 265-274.

Fuller, M., Moyle, G. M., Hunt, A. P., & Minett, G. M. (2019). Ballet and contemporary dance injuries when transitioning to full-time training or professional level dance: a systematic review. *Journal of Dance Medicine & Science*, *23*(3), 112-125.

Gerhardt, C., Doyscher, R., Boschert, H. P. & Scheibel, M. (2014). Die Turnerschulter (The gymnastics shoulder). *Orthopade,* 43, 230–235.

Gram, M. C. D., Clarsen, B., & Bø, K. (2021). Injuries and illnesses among competitive Norwegian rhythmic gymnasts during preseason: a prospective cohort study of prevalence, incidence and risk factors. *British journal of sports medicine*, *55*(4), 231-236.

Gulati, R., Rychlik, K., Wild, J. T., & LaBella, C. R. (2022). Rhythmic gymnasts' injuries in a pediatric sports medicine clinic in the United States: a 10-year retrospective chart review. *The Physician and Sportsmedicine*, 1-7.

Hall, R., Foss, K. B., Hewett, T. E., & Myer, G. D. (2015). Sport specialization's association with an increased risk of developing anterior knee pain in adolescent female athletes. *Journal of sport rehabilitation*, *24*(1), 31-35.

Henn, E. D., Smith, T., Ambegaonkar, J. P., & Wyon, M. (2020). Low back pain and injury in ballet, modern, and hip-hop dancers: a systematic review. *International journal of sports physical therapy*, *15*(5), 671.

Huxel Bliven, K. C., & Anderson, B. E. (2013). Core stability training for injury prevention. *Sports health*, *5*(6), 514-522.

Kaur, K., & Koley, S. (2019). Anthropometric determinants of competitive performance in gymnastics: a systematic review. *Int J Health Sci Res*, *9*(7), 249-256.

Kerr, Z. Y., Hayden, R., Barr, M., Klossner, D. A., & Dompier, T. P. (2015). Epidemiology of National Collegiate Athletic Association women's gymnastics injuries, 2009–2010 through 2013–

2014. *Journal of athletic training*, *50*(8), 870-878.

Kolar, E., Pavletič, M. S., Smrdu, M., & Atiković, A. (2016). Athletes' perception of the causes of injury in gymnastics. *The Journal of sports medicine and physical fitness*, *57*(5), 703-710.

Liederbach, M. (1997). Screening for functional capacity in dancers designing standardized, dance-specific injury prevention screening tools. *Journal of Dance Medicine & Science*, *1*(3), 93-106.

McMeeken, J., Tully, E., Stillman, B., Nattrass, C., Bygott, I. L., & Story, I. (2001). The experience of back pain in young Australians. *Manual therapy*, *6*(4), 213-220.

Miletic, A., Kostic, R., Bozanic, A., & Miletic, D. (2009). Pain status monitoring in adolescent dancers. *Medical problems of performing artists*, *24*(3), 119-123.

Miletic, D., Miletic, A., & Milavic, B. (2015). Age-related progressive increase of lower back pain among male dance sport competitors. *Journal of Back and Musculoskeletal Rehabilitation*, *28*(3), 551-560.

Miletic, D., Miletic, A., Lujan, I. K., Kezic, A., & Erceg, M. (2015). Health care related problems among female sport dancers. *International Journal of Athletic Therapy and Training*, *20*(1), 57-62.

Müller, J., Müller, S., Stoll, J., Fröhlich, K., Otto, C., & Mayer, F. (2017). Back pain prevalence in adolescent athletes. *Scandinavian journal of medicine & science in sports*, *27*(4), 448-454.

Notarnicola, A., Farì, G., Maccagnano, G. Riondino, A., Covelli, I., at al. (2019). Teenagers' perceptions of their scoliotic curves. An observational study of comparison between sports people and non-sports people. *Muscles Ligaments Tendons J. (MLTJ)*, 9, 225–235.

de Oliveira, L., Costa, V. R., Antualpa, K. F., & Nunomura, M. (2021). BODY AND PERFORMANCE IN RHYTHMIC GYMNASTICS: SCIENCE OR BELIEF? *Science of Gymnastics Journal*, *13*(3).

Oltean, A., Rusu, M. M., Copoiu, N., & Calin, M. F. (2017). Incidence of injuries in rhythmic gymnastics. *Ovidius University Annals, Series Physical Education and Sport/Science, Movement and Health*, *17*(2), 427-433.

Purenović-Ivanović, T., Popović, R., Bubanj, S., & Stanković, R. (2019). Body composition in high-level female rhythmic gymnasts of different age categories. *Science & Sports*, *34*(3), 141-148.

Ramel, E. M., Moritz, U., & Jarnlo, G. B. (1999). Validation of a pain questionnaire (SEFIP) for dancers with a specially created test battery. *Medical problems of performing artists*, *14*, 196-203.

Schmidt, C. P., Zwingenberger, S., Walther, A., Reuter, U., Kasten, P., Seifert, J., ... & Stiehler, M. (2014). Prevalence of low back pain in adolescent athletes–an epidemiological investigation. *International journal of sports medicine*, *35*(08), 684-689.

Thacker, S. B., Stroup, D. F., Branche, C. M., Gilchrist, J., Goodman, R. A., & Kelling, E. P. (2003). Prevention of knee injuries in sports. *Journal of Sports Medicine and Physical Fitness*, *43*(165-179).

van Seters, C., van Rijn, R. M., van Middelkoop, M., & Stubbe, J. H. (2020). Risk factors for lower-extremity injuries among contemporary dance students. *Clinical journal of sport medicine*, *30*(1), 60-66.

Sun, W. (2020). Injuries in Contemporary Dance. *Advances in Physical Education*, *10*(03), 282.

Thomas, R. E., & Thomas, B. C. (2019). A systematic review of injuries in gymnastics. *The Physician and sportsmedicine*, *47*(1), 96-121.

van Der Merwe, C., Shultz, S. P., Colborne, G. R., & Fink, P. W. (2021). Foot Muscle Strengthening and Lower Limb Injury Prevention. *Research Quarterly for Exercise and Sport*, *92*(3), 380-387.

van Winden, D. P., Van Rijn, R. M., Richardson, A., Savelsbergh, G. J., Oudejans, R. R., & Stubbe, J. H. (2019). Detailed injury epidemiology in contemporary dance: a 1-year prospective study of 134 students. *BMJ Open Sport & Exercise Medicine*, *5*(1), e000453.

Wyatt, H. E., Gittoes, M. J. R. & Irwin, G. (2020). Sport-specific musculoskeletal growth and postural control in female artistic gymnasts: A 12 month cohort study. *Sports Biomech*., 19, 258–270.

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CONCERNS ABOUT WEIGHT AND MENTAL HEALTH AMONG ADOLESCENT GYMNASTS: A PILOT STUDY

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Abstract

Weight concerns can have an effect on gymnasts' quality of life. We examined the association between concerns about weight with self-reported anxiety levels and other psychosocial and menstrual health characteristics among child and adolescent gymnasts. Gymnasts between 8- and 18-year-old completed an online questionnaire distributed by their gymnastics clubs. They also completed the Generalized Anxiety Disorder (GAD-7) questionnaire. Of the 73 gymnasts who completed the questionnaire, 15% reported worrying about their weight; they were significantly older and reported higher GAD-7 scores than those who did not worry about their weight. After adjusting for the independent effect of age, worrying about weight was no longer significantly associated with GAD-7 scores (adjusted odds ratio= 1.13, 95% CI=0.98, 1.30, p=0.10), beliefs about their body size (adjusted odds ratio=6.48, 95% CI=0.84, 50.1; p=0.07), or menarche (adjusted odds ratio=0.40, 95% CI=0.04, 4.14, p=0.44). We found an association between age, anxiety, and weight concerns in child and adolescent gymnasts. Healthcare providers should screen for weight concerns and increased anxiety in older gymnasts

Keywords: *Gymnastics, mental health, weight concerns, adolescence, anxiety.*

INTRODUCTION

Eating disorders, conditions characterized by disordered eating behaviors, and excessive preoccupation with weight and body size, are more prevalent among athletes relative to non-athletes.(Kong & Harris, 2015; Nicholls & Viner, 2005; J. Tan et al., 2014) This may be particularly evident in sports in which lower body weight or "thinness" is viewed as more favorable, such as gymnastics.(Kong & Harris, 2015; Nicholls & Viner, 2005; J. Tan et al., 2014; J. O. A. Tan et al., 2016) Individuals with eating disorders or disordered eating habits tend to deny or not understand their symptoms, conceal their illness, and may be resistant to treatment.(Bonci et al., 2008; Kong & Harris, 2015; Meroño et al., 2019) This, in combination with the significant physiologic harm of pathological eating habits, makes eating disorders difficult to diagnose and treat, requiring

comprehensive physical and mental health care over a long period of time.(Bonci et al., 2008; *IOC Consensus Statement on the Female Athlete Triad*, 2005) In the past 20 years, numerous organizations (e.g., International Olympic Committee, National Athletic Trainers Association) have released position statements identifying the need for early detection and comprehensive treatment for athletes who are at risk for the development of eating disorders.(Bonci et al., 2008; *IOC Consensus Statement on the Female Athlete Triad*, 2005)

Past studies have examined the factors that predispose athletes to developing an eating disorder and/or ways to identify if an athlete has already begun to develop one of these conditions. (Bonci et al., 2008; Davison et al., 2003; *IOC Consensus Statement on the Female Athlete Triad*, 2005; Killen et al., 1996; Kong & Harris, 2015; Ohring et al., 2002) One such factor is whether an athlete is concerned about their weight.(Davison et al., 2003; Killen et al., 1996; Ohring et al., 2002) Existing studies document a significant association between weight concern and the risk of developing eating disorders later in life in both general and athlete populations. (Davison et al., 2003; Killen et al., 1996; Ohring et al., 2002) Gymnasts are especially at risk for disordered eating. (Kontele et al., 2022; Leonkiewicz & Wawrzyniak, 2022) While this evidence may help identify athletes at risk of developing an eating disorder, there is opportunity for exploration into how an individual's concern about their weight might relate to other facets of life, especially athletes who participate in gymnastics, a sport known for its emphasis on athlete's body shape and weight. (Kong & Harris, 2015; J. Tan et al., 2014; J. O. A. Tan et al., 2016) To further explore this topic, we examined the association between concerns about weight with self-reported anxiety levels and other psychosocial and menstrual health characteristics among adolescent gymnasts.

METHODS

Following approval from the local Institutional Review Board, we contacted each gymnastics club in our geographic area using contact information obtained via a public database. We asked each club to send a questionnaire to the gymnasts who participated in their organized club activities. If they were willing to distribute the survey, the club then emailed the questionnaire to the parent or guardian for the athlete to complete.

Inclusion criteria included being 8-18 years of age and participating in USA Gymnastics Xcel or Junior Olympic (Developmental) programs. Gymnasts who participated in high school or other gymnastics programs were excluded, along with retired gymnasts, and those who were unable to read or write. After the guardians provided consent and the gymnasts provided assent, participants provided information about their demographics, basic health, and experience with anxiety. All questionnaires were completed via a REDCap electronic database.

We collected demographic information including participant age, sex, height, weight, and school grade. We calculated BMI based on reported height and weight (Table 1). We also asked participants to describe information about their gymnastics experience, competition group (Junior Olympic vs Xcel), current level, and their age when they started gymnastics. Participants then provided information about their weight perceptions, and whether

they had a history of disordered eating. The questions used in this survey were taken from the Female Athlete Triad Consensus Panel Screening Questions. (De Souza et al., 2014) These questions asked participants (1) "do you worry about your weight," (2) "are you trying or has anyone recommended that you gain or lose weight," (3) "are you on a special diet or do you avoid certain types of foods or food groups," (4) and "have you ever had an eating disorder."

We assessed bone health by asking participants to report any history of stress fracture or low bone density. We collected information about menstrual function by asking female participants (1) whether they have ever had a menstrual period, (2) how old they were when they had their first period, (3) how many periods they have had in the past 12 months, (4) whether they have experienced 3 or more months without menstruation, (5) if they are taking female hormones, or (6) if they view losing their period as a normal response to high-level athletic training. We assessed anxiety using the Generalized Anxiety Disorder (GAD-7) questionnaire, a 7-item instrument that provides a valid and reliable measure of self-reported anxiety.(Löwe et al., 2008) To construct our grouping variable, we asked participants the question: "Do you worry about your weight?" We then grouped participants whether they responded "yes" or "no" to address our primary purpose.

Data are presented as mean (standard deviation) for continuous variables and the number within group (corresponding percentage) for categorical variables. We compared continuous variables between groups using independent samples t-tests or Mann-Whitney U tests given the normality of the variable tested, and compared categorical variables between groups using chi-squared analyses or Fisher's exact tests (if cell sizes were <5). We then constructed a multivariable logistic regression model, where the outcome variable was whether the participant worried about their weight (yes/no), and GAD-7 total and age were the predictor variables. Adjusted odds ratios and 95% confidence intervals (95% CI) were calculated to provide interpretation for multivariable logistic regression results. All analyses were two-sided, statistical significance was defined as $\alpha=0.05$, and analyses were performed using Stata version 15 (StataCorp, College Station, TX).

RESULTS AND DISCUSSION

We analyzed data from 73 gymnasts who completed all data elements related to the current investigation. Fifteen percent (n=11) reported worrying about their weight. Those who reported worrying about their weight were significantly older and taller than those who did not (Table 1). Other demographic characteristics such as sex, competition type, body mass index (BMI), BMI-for-age percentile, and training volume were not significantly different between groups. Those who reported worrying about their weight reported significantly higher GAD-7 scores (Figure 1) than those who did not (Figure 1). A significantly higher proportion of those who reported worrying about their weight also reported they thought they were fat when others say they are thin and had experienced menarche compared to those who did not worry about their weight (Table 1). After adjusting for the independent effect of age, worrying about weight was no longer significantly associated with GAD-7 scores (adjusted odds ratio= 1.13, 95% CI=0.98, 1.30, p=0.10), beliefs about their

body size (adjusted odds ratio=6.48, 95% CI=0.84, 50.1; p=0.07), or menarche (adjusted odds ratio=0.40, 95% CI=0.04, 4.14, p=0.44).

Table 1.
Characteristics of the two participant groups.

Variable	**Worried About Their Weight (n=11)**	**Not Worried About Their Weight (n=62)**	**P value**
Demographic and Training Characteristics			
Age (years)	13.3 (2.9)	10.9 (2.8)	0.01*
Sex (female)	10 (91%)	50 (81%)	0.68
Junior Olympic Competition Type athletes	7 (64%)	44 (72%)	0.72
Height (cm)	153.0 (12.3)	140.9 (16.1)	0.02*
Weight (kg)	44.7 (13.6)	37.0 (13.3)	0.10
BMI (kg/m^2)	19.0 (3.0)	18.4 (3.5)	0.62
BMI (percentile rank)	61.0 (24.8)	50.4 (23.0)	0.21
Age began gymnastics (years)	5.1 (1.8)	4.3 (2.1)	0.27
Average days spent training/week	4.3 (1.3)	4.1 (1.4)	0.72
Average hours spent training/week	15.7 (7.5)	15.0 (7.5)	0.82
Consider gymnastics more important than other sports	9 (82%)	53 (85%)	0.67
Psychosocial, medical, and menstrual health characteristics			
Believe yourself to be fat when others say you are too thin	3 (27%)	2 (3%)	0.02*
Food dominates your life	1 (9%)	0 (0%)	0.15
History of stress fracture	3 (27%)	6 (10%)	0.13
Female gymnast questions	***N = 10***	***N = 50***	
Reported having a menstrual period previously	5 (50%)	10 (20%)	0.04*
Presently taking any female hormones (e.g., estrogen, progesterone, birth control pills)	2 (20%)	1 (2%)	0.07
Believe losing your period is a normal response to a high level of athletic training	6 (60%)	22 (44%)	0.36

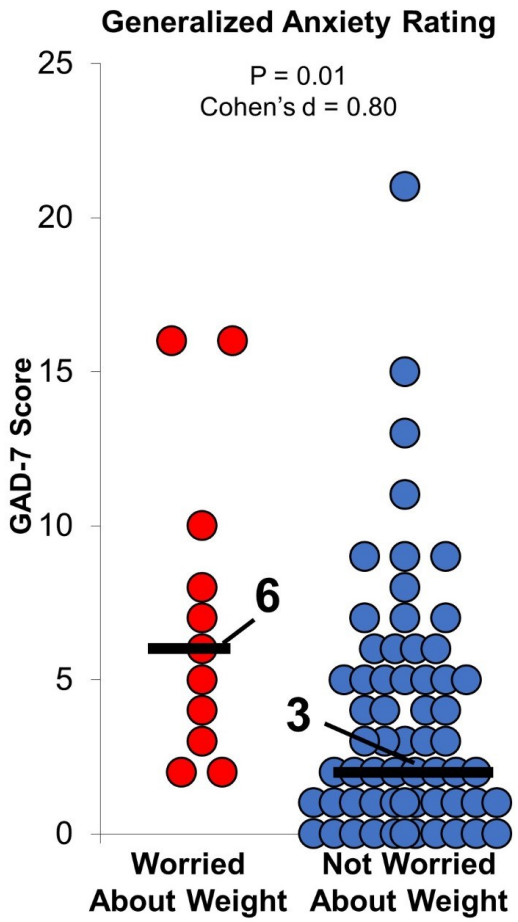

Figure 1 Self-reported anxiety ratings on the Generalized Anxiety (GAD-7) among gymnasts who did and did not report being currently worried about their weight.

DISCUSSION

We found that gymnasts who answered "yes" to the statement "Do you worry about your weight?" were older, more likely to report having a menstrual period previously, and more likely to think they are fat even through others say they are thin than gymnasts who do not worry about their weight.

These observations may not be specific to gymnasts, as puberty, which typically occurs between the ages of 9 and 13, is commonly regarded as a period in which adolescents not only go through a series of drastic physical changes, but also become increasingly concerned about their appearance, social relationships, and self-image.(Parent et al., 2003) While this is true of many adolescents, the observed association between age and concern about weight may be particularly evident among gymnasts given the unique emphasis placed on physical appearance and body composition within this sport.

We also found that gymnasts who worry about their weight report significantly higher ratings of generalized anxiety than those not worried about their weight, though this association was no longer statistically significant after adjusting for age. This finding suggests that age may mediate the relationship between worrying about weight and self-reported generalized anxiety. Our data aligns with evidence that suggests anxiety symptoms, similar to concerns about body weight, are significantly associated with age (particularly during adolescence), with many symptoms beginning around the age of 11 years. (Jones, 2013) There is also evidence that shows there are higher rates of anxiety disorders among those who have eating disorders compared to those who do not. (Pallister & Waller, 2008) More prospective research is needed to better understand the relationship between age, anxiety, worrying about weight, and eating disorder risk.

It is prudent that health care professionals, coaches, and other stakeholders consider these results within the context of the work of other research groups when working with gymnasts. Researchers have demonstrated that individuals who worry about their weight and experience anxiety are more likely to develop an eating disorder.(Davison et al., 2003; Killen et al., 1996; Ohring et al., 2002) Given that gymnasts are already at a higher risk of developing clinical eating

disorders and subclinical disordered eating patterns, it is possible that as gymnasts grow older this worry about weight and generalized anxiety may be more likely to develop into a more serious, life-threatening eating disorder, especially if there is pressure to lose weight. (Leonkiewicz & Wawrzyniak, 2022; J. Tan et al., 2014; J. O. A. Tan et al., 2016) Eating disorders are difficult to treat given their extensive physical and mental health effects, therefore early detection and treatment are paramount.(Bonci et al., 2008; *IOC Consensus Statement on the Female Athlete Triad*, 2005) Our study was limited by the single geographic region in which we enrolled participants, and both the self-reported nature of the questionnaires and the weight concerns in question are susceptible to bias, thus, extrapolation of our findings to other types of athletes should be approached with caution. We collected data on a wide pediatric age range (8 to18-year old) which may have affected our results, and younger athletes may not have fully understood the terms used in the questions. Further, the questions used to assess weight concerns may require additional investigation using reliable and valid measures of this outcome.

CONCLUSIONS

The results of our study suggest an association between a gymnast's age, generalized anxiety and concern about weight. Healthcare providers and coaches should be aware of this association and monitor gymnasts as they get older for weight concerns and/or increased anxiety. This may help gymnasts at risk to receive support they need to prevent the development of an eating disorder.

REFERENCES

Bonci, C. M., Bonci, L. J., Granger, L. R., Johnson, C. L., Malina, R. M., Milne, L. W., Ryan, R. R., & Vanderbunt, E. M. (2008). National athletic trainers' association position statement: Preventing, detecting, and managing disordered eating in athletes. *Journal of Athletic Training*, *43*(1), 80–108. PubMed. https://doi.org/10.4085/1062-6050-43.1.80

Davison, K. K., Markey, C. N., & Birch, L. L. (2003). A longitudinal examination of patterns in girls' weight concerns and body dissatisfaction from ages 5 to 9 years. *The International Journal of Eating Disorders*, *33*(3), 320–332. PubMed. https://doi.org/10.1002/eat.10142

De Souza, M. J., Nattiv, A., Joy, E., Misra, M., Williams, N. I., Mallinson, R. J., Gibbs, J. C., Olmsted, M., Goolsby, M., Matheson, G., & Expert Panel. (2014). 2014 Female Athlete Triad Coalition Consensus Statement on Treatment and Return to Play of the Female Athlete Triad: 1st International Conference held in San Francisco, California, May 2012 and 2nd International Conference held in Indianapolis, Indiana, May 2013. *British Journal of Sports Medicine*, *48*(4), 289. https://doi.org/10.1136/bjsports-2013-093218

IOC Consensus Statement on the Female Athlete Triad. (2005). International Olympic Committee. https://olympics.com/ioc/news/ioc-consensus-statement-on-the-female-athlete-triad

Jones, P. B. (2013). Adult mental health disorders and their age at onset. *British Journal of Psychiatry*, *202*(s54), s5–s10. Cambridge Core. https://doi.org/10.1192/bjp.bp.112.119164

Killen, J. D., Taylor, C. B., Hayward, C., Haydel, K. F., Wilson, D. M., Hammer, L., Kraemer, H., Blair-Greiner, A., & Strachowski, D. (1996). Weight concerns influence the development of eating disorders: A 4-year prospective study. *Journal of Consulting and Clinical Psychology*, *64*(5), 936–940. https://doi.org/10.1037/0022-006X.64.5.936

Kong, P., & Harris, L. M. (2015). The Sporting Body: Body Image and Eating Disorder Symptomatology Among Female Athletes from Leanness Focused and Nonleanness Focused Sports. *The Journal of Psychology*, *149*(2), 141–160. https://doi.org/10.1080/00223980.2013.846291

Kontele, I., Vassilakou, T., & Donti, O. (2022). Weight Pressures and Eating Disorder Symptoms among Adolescent Female Gymnasts of Different Performance Levels in Greece. *Children*, *9*(2), 254. https://doi.org/10.3390/children9020254

Leonkiewicz, M., & Wawrzyniak, A. (2022). The relationship between rigorous perception of one's own body and self, unhealthy eating behavior and a high risk of anorexic readiness: A predictor of eating disorders in the group of female ballet dancers and artistic gymnasts at the beginning of their career. *Journal of Eating Disorders*, *10*(1), 48. https://doi.org/10.1186/s40337-022-00574-1

Löwe, B., Decker, O., Müller, S., Brähler, E., Schellberg, D., Herzog, W., & Herzberg, P. Y. (2008). Validation and Standardization of the Generalized Anxiety Disorder Screener (GAD-7) in the General Population. *Medical Care*, *46*(3), 266–274. JSTOR.

Meroño, A. V., Frideres, J., & Palao, J. M. (2019). Nutrition, weight control, and weight control risk knowledge, and dietary and weight regulation practice in elite gymnast of different levels of competition. *European Journal of Human Movement*, *43*, 131–144.

Nicholls, D., & Viner, R. (2005). Eating disorders and weight problems. *BMJ (Clinical Research Ed.)*, *330*(7497), 950–953. PubMed. https://doi.org/10.1136/bmj.330.7497.950

Ohring, R., Graber, J. A., & Brooks-Gunn, J. (2002). Girls' recurrent and concurrent body dissatisfaction: Correlates and consequences over 8 years. *International Journal of Eating Disorders*, *31*(4), 404–415. https://doi.org/10.1002/eat.10049

Pallister, E., & Waller, G. (2008). Anxiety in the eating disorders: Understanding the overlap. *Clinical Psychology Review*, *28*(3), 366–386. https://doi.org/10.1016/j.cpr.2007.07.001

Parent, A.-S., Teilmann, G., Juul, A., Skakkebaek, N. E., Toppari, J., & Bourguignon, J.-P. (2003). The Timing of Normal Puberty and the Age Limits of Sexual Precocity: Variations around the World, Secular Trends, and Changes after Migration. *Endocrine Reviews*, *24*(5), 668–693. https://doi.org/10.1210/er.2002-0019

Tan, J., Bloodworth, A., McNamee, M., & Hewitt, J. (2014). Investigating eating disorders in elite gymnasts: Conceptual, ethical and methodological issues. *European Journal of Sport Science*, *14*(1), 60–68. https://doi.org/10.1080/17461391.2012.728632

Tan, J. O. A., Calitri, R., Bloodworth, A., & McNamee, M. J. (2016). Understanding Eating Disorders in Elite Gymnastics: Ethical and Conceptual Challenges. *Clinics in Sports Medicine*,

35(2), 275–292.
https://doi.org/10.1016/j.csm.2015.10.002

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ATHLETE-COACH RELATIONSHIP IN BRAZILIAN MEN'S ARTISTIC GYMNASTICS

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Abstract

Coaches' behavior has been shown to be one of the determining factors for a positive and successful sport experience. Therefore, this research aimed to point out characteristics of the gymnast-coach relationship from the standpoint of the Brazilian men's artistic gymnastics (MAG) national team athletes (2013-2021). The qualitative-exploratory methodology was used to accomplish the research objective. The data were gleaned from semi-structured interviews with five gymnasts of the Brazilian MAG national team. Interview transcripts were analyzed and organized into three thematic units: abusive coach practices in the past; changes in coach's behavior; and positive coach-athlete relationships. It was identified that the coaches' current behavior is ethical, although athletes did not deny a history of abusive patterns. Athletes observed changes in coaches' behavior after national and international governing bodies established committees to control and fight abuse in sports. The athletes also reported a mutually respectful relationship with their coaches nowadays, and they were sorry for the under-appreciation of the coach profession in Brazil.

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Keywords: *Olympic games, male gymnast, coaching, elite sports.*

INTRODUCTION

This paper aims to provide an overview of the athlete-coach relationship in the Brazilian men's artistic gymnastics (MAG) national team. It is a part of a greater project with the objective to understand the path of such athletes in this sport. Preparing elite athletes is known to be a complex phenomenon that can be analyzed from different perspectives, including the coach-athlete interpersonal relationship (Côté & Gilbert, 2009).

Subijana, Martin, Tejón, and Côté (2021) point out that coaches' professional knowledge and behavior are determining factors for a positive sports experience. Hence, they suggest that studies focus on

understanding this relationship and its possible consequences for success. This is due to the important influence coaches have on athletes' path in sport, as this relationship impacts their self-confidence, emotions, anxiety, and performance.

Moreover, the atmosphere in the training gym is determined by this relationship, which is traditionally seen as hierarchical (coach-athlete) – especially in artistic gymnastics (AG) – and sometimes abusive (Bortoleto & Schiavon, 2016; Cervin, Kerr, Barker-Ruchti, Schubring & Nunomura, 2017; Pinheiro, Pimenta, Resende & Malcolm, 2014). Oliveira, Bortoleto, and Nunomura (2017) identified coach-athlete relationships as paradoxical in women's AG (WAG). On the one hand, coaches are close to the athletes for at least four hours a day, either helping them safely perform acrobatic movements or instructing them in training; on the other hand, they hold most power in the hierarchical relationship, conducting unilaterally their work method and curbing gymnasts' critical senses (Oliveira et al., 2017). Costa, Marques, Oliveira, and Nunomura (2020) addressed this manipulation, questioning and criticizing coaches' mental violence against gymnasts, referring to the hierarchical and unilateral coach-athlete relationship in which athletes are treated as "puppets". Although their studies focus on women, coach autocracy in hierarchical relationships is present also in men's sports categories (Bortoleto & Schiavon, 2016).

Brazilian WAG has historically been visible, particularly since Daiane dos Santos became the world champion in 2003 and Rebeca Andrade won two Olympic medals at the Tokyo 2020 (2021) Summer Olympic Games. However, it was the Brazilian MAG who won the first Olympic medal at London Olympic in 2012 Games. Up to now, Brazilian male gymnasts have won four medals, that is, gold and silver, by Arthur Zanetti (2012-2016); silver, by Diego Hypólito (2016); and bronze, by Arthur Nory (2016).

Since the quality of the coach-athlete relationship is a determining factor in achieving sports results (Oliveira et al., 2017; Subijana et al., 2021) and there are fewer academic papers exclusively on the issue of men's gymnastics (Vargas, Reis, Leite & Capraro, 2021), the objective of this article is to point out characteristics of the gymnast-coache relationship from the standpoint of athletes of the Brazilian MAG national team (2013-2021).

METHODS

The issues that occur in the gym training context may be better described by athletes themselves due to their peculiarities (Oliveira, 2016). Hence, the qualitative-exploratory methodology (Sparkes & Smith, 2014) was used to reach the said objective by interviewing five gymnasts of the Brazilian MAG national team. The criteria adopted for the selection of participants were as follows: a) having been a member of the Brazilian MAG national team; b) having participated in World Championships and/or Olympic Games between 2013 and 2021, and c) currently an active gymnast (not retired). Athletes who declined to participate in the survey were excluded from the study. Therefore, five gymnasts from the Brazilian national team who were active during the same period participated in the survey, as shown in Table 1.

Table 1
Information about interviewed gymnasts.

Athlete	Start sporting career	Debut in World Championships
Gymnast 1	2004	2013
Gymnast 2	1997	2009
Gymnast 3	1996	2014
Gymnast 4	1997	2010
Gymnast 5	2002	2014

Legend: MAG: men's artistic gymnastics.
Source: The authors, based on the International Gymnastics Federation.

The athletes were contacted through the Brazilian Gymnastics Federation (CBG, in Portuguese), and they were informed about the research objectives, including ethical issues. It's important to mention that this research was approved by the Human Research Ethics Committee of the Federal University of Brasilia, protocol number: 3.896.312.

Data collection occurred at two different moments. Gymnast 1, Gymnast 2, and Gymnast 4 were interviewed at the Olympic Training Centre, in Rio de Janeiro, in July 2019. The other two athletes were individually interviewed via videoconferencing in May 2020, during the COVID-19 pandemic.

As expected in the semi-structured interviews process, a script was developed with central themes focusing on the gymnasts' history as athletes. Social aspects that had an impact on their careers in gymnastics (including the coach-athlete relationship) were addressed. The questions were guided to allow athletes to narrate their experiences from the beginning to the high level. When necessary, the funnel technique (Sparkes & Smith, 2014) was used – i.e., asking additional questions to find further information on the topic.

The interviews were transcribed and minor adjustments were made to correct the language without changing the meaning and the speech content. The transcripts were assessed by a research group who helped to interpret the data and define thematic units (Braun & Clarke, 2006). The analysis produced the following three units: abusive coaching practices in the past; changes in coaches' behavior; positive coach-athlete relationships. These thematic units are presented and discussed in the next section

RESULTS AND DISCUSSION

Abusive coach practices in the past

Oliveira et al. (2017) highlight that, in the AG microculture (Oliveira, 2014), gymnasts are aware of the importance of a positive relationship with the coach. It is a partnership that while close, given the constant physical contact and the long training hours, is also distant due to the hierarchy in the gym context (Oliveira, 2016).

Despite social stratification in the gym, Weiss (2000) mentions that sports mentors and gymnasts have an interdependent relationship, an unspoken pact, as athletes depend on the coaches' instructions while the coaches' reputation/career depends on the athletes. Oliveira (2014) points out that AG athletes are not always aware of this

interdependent relationship, especially since many coaches prefer the idea of dependence. Thus, gymnasts are taught from their earliest years in this discipline to fully respect their coaches and trust their knowledge and prospective capacity without questioning.

Renowned Russian coach Leonid Arkaev reflects that success depends on the relationship characterized by mutual dedication and loyalty (Arkaev, 2000). Coakley (2001) points out that in these relationships coaches are usually allowed to exceed the limits of socially acceptable behavior to encourage and train athletes in the effort to surpass their opponents. According to the author, "athletes are expected to obey coaches and show that they are willing to make sacrifices in their quest for success" (p. 490).

AG is a sport known for its exhaustive training and strict coaches (Kerr, Barker-Ruchti, Schubring, Cervin & Nunomura., 2019). Ryan (1995) analyzed the women's category and considered that gymnasts get used to doing their part without questioning, as coaches demand subservience. Hence, when a coach yells or makes aggressive comments beyond constructive corrections, gymnasts only listen and obey (Oliveira et al., 2017).

Tofler, Stryer, Micheli and Herman (1996) found authoritarian behaviors and demands in gymnasts' reports, culminating in outbreaks of crying strikingly present in training sessions. Likewise, Duarte, Carbinatto, and Nunomura (2015) suggest that coaches' reactions are one of the causes of emotional disturbances in Brazilian WAG athletes.

Reports are not different in MAG. Olympic medalist and first Brazilian world champion Diego Hypólito states in his autobiographical book that he had been a victim of psychological harassment during his sports career. In his book, Diego Hypolito also mentions physical punishments that took place backstage at competitions. According to him, it was conducted by older gymnasts, but the coaches knew and condoned such behavior.

The report by two-time world champion Diego Hypolito provides a glimmer of behavioral microculture in gymnastics, also pointed out by Oliveira (2016). Regarding values, Oliveira (2014) highlights gymnasts' perseverance, discipline, dedication, and submission to their coaches. As to behaviors, he confirms that athletes feel obliged to accept and withstand the pain and sacrifice. Even though Oliveira (2016) discovered that coaches were technically effective in conducting AG training sessions, they often have poor interpersonal skills which lead to a poor-quality coach-athlete relationship, as pain and fear seem to be a part of the training environment. This situation can be identified in the statement by Gymnast 2's coach on his official webpage: "*I made him* (i.e., Gymnast 2) *cry every day*". When Gymnast 2 was asked about this, he only said: "*Well... it has changed a lot.*"

Athletes often describe the training environment as intimidating, and they end up considering their coaches' abusive attitudes normal (Barker-Ruchti & Schubring, 2016; Diehl et al., 2014; Oliveira, 2016; Pinheiro et al., 2014). Many times, athletes do not realize they are in abusive situations due to an acculturation process, which begins at an early age and extends throughout their careers (Oliveira, 2016). Thus, according to Oliveira (2016), people in the gym where coach autocracy rules, see attitudes, such as denying attention, yelling, and being ironic and aggressive, as normal and even necessary.

Diehl et al. (2014) established that young German Olympic athletes often feel under pressure from their coaches – something like "this is the only way to get there", which somehow legitimizes abusive behavior. In other words, athletes seem to accept that if the coach does not have an extreme attitude, training will produce no results. Gymnast 4 said he had such experiences and explained: "*Things have changed, gradually changed; the knowledge… coaches nowadays have a different knowledge from what they used to have before. Now [this type of abusive training] does not work anymore. But in the beginning, coaches were violent, ... they (gymnasts) would suffer, cry… But as the years passed, they (coaches) realized that those attitudes were not the only way to motivate athletes for hard work in gymnastics. So, things began to change, the laws changed, some things changed, the mindset, the knowledge."* (Gymnast 4).

The gymnast's statements point to an important discussion about the different factors that can contribute, or not, to athlete's motivation. In this regard, previous studies indicate that the most important factor in sports motivation is achieving sporting success (Tusak et al., 2022). Athletes are aware that they need to strive and work hard to progress in their chosen sport. Furthermore, external factors, such as the training environment and interpersonal relationships, including the relationship with the coach, can also affect motivation (Tusak et al., 2022). Therefore, education on coping strategies and resources may aid coaches' abilities to motivate their athletes in a positive way while pursing sporting success, particularly by better managing their frustration and anxiety in stressful situations.

Changes in the coaches' behavior

The changes in the coaches´ behavior mentioned by the athletes who participated in this research were motivated by complaints of abuse in the gymnastics team of the United States, which triggered worldwide complaints. Fisher and Anders (2020) emphasize that the case of physician Larry Nassar made a big impact in societies around the world, especially since it was a serious complaint of sexual abuse. However, the authors also highlight the importance of identifying emotional abuse, which they say is very common in sports and oftentimes overlooked. According to Oliveira (2016), "there is a consensus that even overwhelming situations that would be seen as physical or psychological abuse outside the gym are necessary to excel" (p. 154). This occurs because gymnasts and coaches are immersed in a context with specific cultural norms, which are ingrained but not perceived or talked about (Weiss, 2000). We agree with Coakley (2001) that sport context encourages people to overcome the limits of their bodies, as success can only be achieved by hard work, but this can get out of control. Oliveira (2016) adds that cultural issues in AG and the difficulty to identify the fine line between abusive and positive coaching behavior inside the gym are the key. This microculture is anchored in military heritage, out of which this gymnastic discipline was borne, with its hierarchical order, discipline, methods, mentality, and civil utility. Gymnasts are submitted to a sports training process that is guided by these military characteristics, permeated by the sense of duty and honor and the need to persevere and withstand the necessary hard work – all of this backed by coach-centered power and usually empirical, orally transmitted knowledge (Barker-Ruchti,

2011; Oliveira, 2014; Bortoleto & Schiavon, 2016).

After the Larry Nassar scandal in the United States of America, the highest sport governing bodies, FIG in particular, developed strategies 22 2002. To this end, the entity considers good practices in different disciplines and provides a review and analysis of the world literature on the science of sport. Hence, the specific MAG document reinforces the need for coaches to observe the nuances of each developmental phase and provide the necessary care to prevent physical, emotional, and psychological damage (Fink & Hofmann, 2015). In other words, the impact of regulating entities to bring about significant changes in sport was once again demonstrated, as pointed out by Bortoleto and Schiavon (2016).

Almost as a counterpoint, the athletes who participated in this research showed some concern with what they called excessive preventive measures. One of the athletes ponders about the new generation of gymnasts: "*Nowadays, everything causes trouble! You can't speak a little louder, call their attention [...] to educate, to set rules*". (Gymnast 2). In this regard, another athlete comments on present-day training: "*It is still heavy. But not as it used to be, not as before. We even play so that these new kids do not suffer like we did.*" (Gymnast 4). He sees it as a potential problem for the future of the MAG national team because many athletes do not persevere: "*Now if we are a little tougher and push it further, the kid says, 'I don't want it anymore'; and now we have gyms, money, structure."* (Gymnast 4).

To a certain extent, the words of the Brazilian MAG national team gymnasts indicate that coaches have significantly changed the way they treat athletes. However, it is still believed that being tough and strict is necessary to achieve good results. These changes have occurred mostly because of the coping measures, as reinforced in this statement: "*Some coaches, when they need to be tougher, they go 'like' [hand gesture] to hold back, because it could mean trouble, you know"* (Gymnast 1). In this respect, Denison, Jones, and Mills (2019) question the current excessive regulation that coaches have to apply worldwide. In the authors' opinion, over-regulated and controlled training may have a negative effect on long-term preparation for the sport.

Preventive measures, adopted both by national and international organizations, are linked to some changes in various sectors of Western society. These changes can be justified by an increased dissemination of social discourses that constitute political correctness, as well as their implementation through laws that protect children and adolescents from abuse in various spheres. In addition, the current accessibility of audio and video capturing tools, as well as the speed of dissemination, facilitate the detection and reporting of these situations (Souza & Capraro, 2022).

Positive coach-athlete relationships

Positive coach-athlete relationships should also be pointed out. Gymnast 3 got emotional when talking about his coach: "*Well, I have been on the road with my coach for a while. It has been a long time, and I believe it is essential because now he knows me very well. He knows the days when I am bad, when I am well, when I will be able to make it, when I will not; I am very stubborn in some aspects. When I am making too many mistakes, I repeat it over and over and over again, even if I keep failing; and he knows when to say: 'Look,*

take it easy. That is enough for now; let us try another apparatus...'. Or: 'Let us finish for today'. Because he knows I may get injured because I am focused on my mistakes, and he knows when to encourage me, and when to slow me down. I believe this synchrony between the coach and the athlete is essential." (Gymnast 3).

A positive coach-athlete relationship is crucial to developing gymnasts and keeping them in the elite (Costa et al., 2020; Kerr et al., 2019; Nunomura et al., 2012). In this sense, Barker-Ruchti and Schubrig (2016) reiterate that coaches should have a trusting relationship with their athletes. Therefore, they claim that good communication with both the athletes and their families, flexibility regarding training workload, and constant motivation assessments are essential. They can be effective even in athlete's physical rehabilitation following an injury (Maurice, Voelker, Kuklick & Byrd, 2021).

Although some athletes changed clubs and coaches along their path, they have been careful to maintain a good relationship with previous coaches, as pointed out by Gymnast 5: "*I was in the same club for ten years, but I realized I really needed to change, my mind needed it, you know? You need to change! So, I looked for another club […]. I had already known the coach of my current club for a long time from competitions. I always saw him, talked to him, and liked his work. So, I got in touch with him, and it was really my decision to change clubs. I talked to him, then I had to talk with my coach at that time, right? Explain things well, what happened*." (Gymnast 5).

Further, in a positive relationship with coaches, the athletes were concerned with showing appreciation to them, as observed in these words: "*There is a need for more investment, especially in coaches*" (Gymnast 2). Other interviewed gymnasts confirm the need for specific preparation to work as a coach in MAG and the coaches' low wages. The 2016 Olympic finalist explained: "*The problem is: there is no one to teach the kids [young gymnasts], because physical education teachers finish college with very basic knowledge about gymnastics. They are not ready to get here [elite] straight from college... you know? Bu, we can't blame the university structure and such, because physical education teachers will not build their careers there [in AG]. And, about the low income: They will not get enough money to feed their family. They will spend the whole day in the gym and will not get enough money to support their family. So, I believe investing in teachers would help the discipline*." (Gymnast 4).

This financial issue had already been reported by Vargas and Capraro (2020) who established that Brazilian gymnasts share part of the resources they are granted from the Athlete Allowance Program (Programa Bolsa-Atleta, in Portuguese) with their coaches. According to the interviewees, the coaches´ income is often insufficient to pay for their regular expenses. Gymnast 1 considers the coaches' low income as one of the reasons why MAG has not spread out in other Brazilian cities beyond the axis of Rio de Janeiro and São Paulo. He explains: "*There are many professionals here [in Rio de Janeiro], but everything is in São Paulo and Rio de Janeiro. They do not go to Aracaju [a city in north-eastern Brazil] to offer gymnastics training, they do not go to Fortaleza [a city in north-eastern Brazil], where the sports structure is huge but abandoned! How can you take someone from here to there for nothing?*" (Gymnast 1).

Also concerning the financial compensation for the coaches' work, Gymnast 3 stated: "*I did not get here on my own, you know. I am only the last part. I am just the icing on the cake when we get to the competition, because before that there is my coach and the multidisciplinary team*.". Nunomura and Oliveira (2014) highlight that gymnasts depend greatly on their coaches, who play a determining role by bring their experiences, knowledge, and effort to the table. Arkaev (2000) reflects, based on the thoughts of Russian coach Boris Pilkin, that coaches are the roots, who are not seen in competitions, because only gymnasts (the flowers) appear. In other words, "gymnasts grow, develop, and flourish to show to the world their qualities, while coaches nourish their athletes' talent and provide them with stability" (Nunomura & Oliveira, 2014, p. 67).

Regarding multidisciplinary teams, Bortoleto and Schiavon (2016) explain that only recently, Brazilian athletes have obtained the support of physicians, physiotherapists, nutritionists, psychologists, and fitness coach. And only few clubs have this multidisciplinary approach, specifically those working in better financial conditions. Nonetheless, it has proved to be essential to improve results in competitions.

Lastly, the analysis of the MAG coach-athlete relationship corroborates the study by Denison et al. (2019). Moreover, interpersonal relationships are permeated with specific issues, which belong to the culture and memory of each one of those involved. Thus, it is still very common to hear sports people emphasize the need for suffering in training and rough and strict coaches. This was likewise pointed out by Olympic champion Nadia Comaneci, trained by Romanian Béla Károlyi, who was known for achieving excellent sports results at the cost of cruel training that made emotional abuse natural in AG (Vargas et al., 2021).

CONCLUSIONS

The investigation of coach-athlete relationships, based on the narrative of Brazilian MAG national team gymnasts, found that athletes do not deny their coaches' psychological abuse in the past. However, they emphasise that the coaches' behavior changed and currently is ethical. Moreover, they are concerned about the new generation's performance, due to the new standards imposed by various authorities. The exchange of knowledge with foreign coaches proved to be positive and contributed to the changes in coaches' behavior, which is different from what the literature claims regarding WAG. Also, the athletes in our study reported a respectful relationship with their coaches and are sorry for the low appreciation of the coach's profession in the country.

The literature on interpersonal coach-gymnast relationships constantly points to situations of sexual and emotional abuse. And, specifically in Brazilian MAG, the scandal involving one of the 2016 national team coaches and the complaints made by Diego Hypólito put this gymnastic discipline in the spotlight. Nevertheless, the interviewees in this research did not report such issues.

Concerning psychological abuse, changes in the coaches' behavior were verified after committees were established to control and fight abuse in various sports governing bodies. However, it is important to remember that such changes are taking place in all sectors of Western society

which to some extent indicates a change in global culture.

Lastly, athletes must be empowered so that they can identify abusive behaviors and take initiatives leading to changes. Also, continuous education measures for coaches must be taken, thus supporting good practices and curbing inadequate behavior.

Successful paths in sports, such as the ones presented here, are interesting sources for identifying factors that help comprehensively develop elite athletes. Nevertheless, this study was limited to observing the coach-athlete relationship from the gymnasts' standpoint. Hence, future studies should also address the views of coaches, judges, and families from different countries and generations of athletes.

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REFERENCES

Arkaev L. (2000). My coaching philosophy. In: Langsley E, editor. *Gymnastics in perspective.* (pp. 64-73). Moutier: Fèdération Internationale de Gymnastique.

Barker-Ruchti, N (2011). *Women's artistic gymnastics: an (auto-)ethnographic journey*. Basel: Gesowip.

Barker-Ruchti, N., & Schubring, A. (2016). Moving into and out of high-performance sport: The cultural learning of an artistic gymnast. *Physical Education and Sport Pedagogy*, 21(1), 69-80. https://doi.org/10.1080/17408989.2014.990371.

Bortoleto, M. A.C., & Schiavon, L.M. (2016). Artistic gymnastics-why do coaches resist change? *Sports Coaching Review*, 5(2), 198-201. https://doi.org/10.1080/21640629.2016.1201360.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2), 77-101. https://doi.org/10.1191/1478088706qp063oa.

Cervin, G., Kerr, R., Barker-Ruchti, N., Schubring, A., & Nunomura, M. (2017). Growing up and speaking out: female gymnasts' rights in an ageing sport. *Annals of Leisure Research*, 20(3), 317-330. https://doi.org/10.1080/11745398.2017.1310625.

Coakley, J. (2001). *Sport in society*: issues & controversies. (7. Ed). St. Louis: CV Mosby Company.

CBG. (2018). *Canal de ética e integridade [ethics and integrity channel]* https://canaldeetica.cbginastica.com.br/.

Costa, V. R., Marques, R. F.R., Oliveira, M.S., & Nunomura, M. (2020). "Puppets" in women's artistic gymnastics: the coach-gymnast relationship from Pierre Bourdieu's lens. *Science of Gymnastics Journal*, 12(3).

Côté, J., & Gilbert, W. (2009). An integrative definition of coaching effectiveness and expertise. *International Journal of Sports Science & Coaching*, 4(3), 307-323. https://doi.org/10.1260/174795409789623892.

De Bosscher, V., De Knop, P., Van Bottenburg, M., Shibli, S., & Bingham, J. (2009). Explaining international sporting success: An international comparison of elite sport systems and policies in six countries. *Sport Management Review*, 12(3), 113-136. https://doi.org/10.1016/j.smr.2009.01.001.

Denison, J., Jones, L., & Mills, J. P. (2019). Becoming a good enough coach. *Sports Coaching Review*, 8(1), 1-6. https://doi.org/10.1080/21640629.2018.1435361.

Diehl, K., Thielmann, I., Thiel, A., Mayer, J., Zipfel, S., & Schneider, S. (2014). Possibilities to support elite adolescent athletes in improving performance: Results from a qualitative content analysis. *Science & Sports*, 29(6), e115-e125. https://doi.org/10.1016/j.scispo.2014.03.004.

Duarte, L. H., Carbinatto, M. V., & Nunomura, M. (2015). Artistic gymnastics and fear: reflections on its causes. *Science of Gymnastics Journal,* 7(3).

Fink, H., & Hofmann, D. (2015). Age group development and competition program for Men's Artistic Gymnastics. *Fédération Internationale de Gymnastique*. http://www.fgp-ginastica.pt/_usr/downloads/age_group_program_por_atual.pdf.

Fisher, L. A., & Anders, A. D. (2020). Engaging with cultural sport psychology to explore systemic sexual exploitation in USA gymnastics: a call to commitments. *Journal of Applied Sport Psychology*, 32(2), 129-145. https://doi.org/10.1080/10413200.2018.1564944.

International Gymnastics Federation (2021). Biographies. https://www.gymnastics.sport/site/athletes/bio_view.php

Hypolito, D. (2019). *Não existe vitória sem sacrifício [There is no victory without sacrifice]*. São Paulo: Benvirá.

Kerr, R., Barker-Ruchti, N., Schubring, A., Cervin, G., & Nunomura, M. (2019). Coming of age: coaches transforming the pixie-style model of coaching in women's artistic gymnastics. *Sports Coaching Review*, 8(1), 7-24. https://doi.org/10.1080/21640629.2017.1391488.

Marques, R. F.R., Nunomura, M., & Menezes, R.P. (2016). Sports coaching science in Brazil. *Sports Coaching Review*, 5(2), 132-137. https://doi.org/10.1080/21640629.2016.1198453

Maurice, S., Voelker, D. K., Kuklick, C., & Byrd, M. (2021). "We don't always get it right": Coaches' perspectives on supporting injured athletes. *Sports Coaching Review*, 10(3), 295-324. https://doi.org/10.1080/21640629.2021.1897244

Milistetd, M., Ciampolini, V., Salles, W. D. N., Ramos, V., Galatti, L. R., & Nascimento, J. V. D. (2016). Coaches' development in Brazil: Structure of sports organizational programmes. *Sports Coaching Review*, 5(2), 138-152. http://dx.doi.org/10.1080/21640629.2016.1201356

Nassib, S. H., Mkaouer, B., Riahi, S. H., Wali, S. M., & Nassib, S. (2020). Prediction of gymnastics physical profile through an international program evaluation in women artistic gymnastics. *The Journal of Strength & Conditioning Research*, 34(2), 577-586. http://dx.doi.org/10.1519/JSC.0000000000001902

Nunomura, M., Okade, Y., & Carrara, P. (2012). How much artistic gymnastics coaches know about their gymnasts'motivation. *Science of Gymnastics Journal*, 4(2).

Nunomura, M., Carbinatto, M. V., & Carrara, P. D. (2013). Reflection on coaching education in Artistic Gymnastics. *Pensar a Prática*, 16(2). https://doi.org/10.5216/rpp.v16i2.17345

Nunomura, M., & Oliveira, M. S. (2014). O perfil, as motivações e os desafios dos técnicos de ginástica artística no Brasil [The profile, motivations and challenges of artistic gymnastics coaches in Brazil]. In: Schiavon, LM, Bortoleto, MAC, Nunomura, M, Toledo, E. *Ginástica de alto rendimento [High performance gymnastics]*. (pp. 65-87). São Paulo: Fontoura.

Oliveira, M. S. (2010). O panorama da ginástica artística masculina brasileira: um estudo histórico-crítico do período 2005-2008 [The panorama of Brazilian men's artistic gymnastics: a historical-critical study of the period 2005-2008]. Universidade Estadual de Campinas: Campinas.

Oliveira, M. S., Bortoleto, M. A. C., & Nunomura, M. (2017). The coach-athlete relationship in women's artistic gymnastics. *Revista Brasileira de Educação Física e Esporte*, 31(3), 639-650. https://doi.org/10.11606/1807-5509201700030639

Oliveira, M.S. (2016). Unveiling the microculture of a high performance women's artistic gymnastics gymnasium. *Sports Coaching Review*, 5(2), 205-207. https://doi.org/10.1080/21640629.2016.1201362

Pinheiro, M. C., Pimenta, N., Resende, R., & Malcolm, D. (2014). Gymnastics and child abuse: An analysis of former international Portuguese female artistic gymnasts. *Sport, Education and Society*, 19(4), 435-450. https://doi.org/10.1080/13573322.2012.679730

Reverdito, R. S., Galatti, L. R., Strachan, L., Scaglia, A. J., & Paes, R. R. (2020). Coaching and continuity make a difference: competence effects in a youth sport program. *Journal of Physical Education and Sport*, 20(4), 1964-1971. https://doi.org/10.7752/jpes.2020.04266

Ryan, J. (1995). *Little girls in pretty boxes: the making and breaking of elite gymnasts and figure skaters*. New York: Doubleday.

Sparkes, A., & Smith, B. (2014). *Qualitative research methods in sport, exercise and health*. London: Routledge.

Souza, M.T.O., & Capraro, A.M. (2022). Classical ballet training in Brazil: perceptions on the new ways of education and the unstable market for dancers from a specific context. *Motrivivência*, 34(65), 01-19. https://doi.org/10.5007/2175-8042.2022.e86362

Subijana, C. L. D., Martin, L. J., Tejón, O., & Côté, J. (2021). Adolescent athletes' perceptions of both their coachs' leadership and their personal motivation. *Perceptual and Motor Skills*, 128(2), 813-830. https://doi.org/10.1177/0031512520985760

Tofler, I. R., Stryer, B. K., Micheli, L. J., & Herman, L. R. (1996). Physical and emotional problems of elite female gymnasts. *New England Journal of Medicine*, 335(4), 281-283.

Tušak, M., Corrado, D. D., Coco, M., Tušak, M., Žilavec, I., & Masten, R. (2022). Dynamic Interactive Model of Sport Motivation. *International journal of environmental research and public health*,

19(7), 4202. https://doi.org/10.3390/ijerph19074202

Vargas, P. I., dos Reis, F. D. G., Leite, N., & Capraro, A. M. (2021). The sporting trajectory of elite athletes in artistic gymnastics: a systematic review. *Science of Gymnastics Journal*, 13(3), 337-441.

Vargas, P. I., & Capraro, A. M. (2020). Financial support in the sports trajectory of athletes of the brazilian selection of artistic gymnastics. *Research, Society and Development*, 9(10), e6969109089-e6969109089. http://dx.doi.org/10.33448/rsd-v9i10.9089

Weiss, M. S. (2000). Culture, context and content analysis: an exploration of elite women gymnasts in the high school world. In *Dyck,N. Games, sports and cultures*. Oxford: Berg.

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JUMP ABILITY AND FORCE-VELOCITY PROFILE IN RHYTHMIC GYMNASTICS

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Abstract

The jump is one of the main body elements in Rhythmic Gymnastics (RG). To perform it correctly, gymnasts must develop appropriate force and velocity levels to reach enough jump height to show the body shape during flight, as defined by the RG Code of Points. Jumping performance is influenced by the mechanical force-velocity (F-V) profile and the maximum power generated by the lower limbs. The F-V profile identification can provide a more accurate and complete mechanical representation of its capabilities and needs. This study aimed to analyse the F-V profile during the countermovement jump of RG athletes, identify the magnitude and direction of the imbalance between the two variables (force and velocity), and compare the jumping ability and mechanical variables of different age groups. Eighteen Portuguese gymnasts (average age 12.2±1.8 years) were evaluated, according to age group: beginner and youth gymnasts (G1- ages 10 to 12) and junior and senior gymnasts (G2 - ages 13 to 16), and according to the F-V profile imbalance detected. The data collection was performed after a covid-19 lockdown period. Results showed anthropometric differences between age groups but no differences in the F-V profile related variables. When gymnasts were compared according to the deficit, differences were found in variables force and velocity. Furthermore, 72.3% of the gymnasts presented force deficit, 11% presented velocity deficit and 16.6% were balanced. Considering the deficits found, the demands of the sport and of each athlete, it is essential to include strength training in the regular training routines of rhythmic gymnasts.

Keywords: *rhythmic gymnastics; profile; jump; force; velocity.*

INTRODUCTION

Rhythmic gymnastics (RG) is a sport characterized by a high level of technical difficulty and extreme physical demand, aiming to obtain a perfect execution of body movements with different types of apparatus: rope, hoop, ball, clubs and ribbon (Batista, Garganta, & Avila-Carvalho, 2019a; Monteiro, 2000). The body elements in rhythmic gymnastics are subdivided into jumps, balances and

rotations. Each group has different elements organized according to their difficulty degree and elements type. In balances case, in addition to those performed on flat foot and half pointe (*relevê*), this group of elements also includes balances on different body parts, body waves and dynamic elements that require different execution techniques. The rotations group include rotations on flat foot and on *relevê*, as well as rotations connected with heel support and on different body parts that also require different execution techniques. In jumps case, all elements belonging to this group are executed with the same technique, that is, preparation, take-off, flight phase and landing.

To achieve high levels of performance, physical training must be carefully organized and planned, focusing on the development of physical skills and repetition of specific technical movements (Laffranchi, 2001; Lebre, 1993; Román, del Campo, Sabido, & Morenas, 2012). Studies have showed that some physical skills are key for achieving success in RG, such as 1) flexibility as the main motor capacity in RG (Moraru, 2016); 2) strength is highlighted for competitive success and identification of potential talent (Bobo & Sierra, 1998), (Douda, Toubekis, Avloniti, & Tokmakidis, 2008) and Laffranchi (2001); 3) explosive strength as a precondition for proper performance of all basic body elements (Miletić, Katić, & Males, 2004), and 4) motor coordination, also linked with RG success, due to the physical demand coordinated with the apparatus handling (Bozanic & Miletic, 2011). Although flexibility is considered the main motor capacity, it does not guarantee the amplitude and intensity levels required in technical elements execution, especially in the jumps body element group. When performing different types of jumps, gymnasts' jump height should be enough to show the shape of the jump and should not be followed by a heavy landing (FIG, 2022).

The action of jumping, or ballistic performance, is defined as the ability to accelerate a mass as fast as possible and in the shortest possible time, and is considered fundamental to achieve a high sports performance (Pierre Samozino, Morin, Hintzy, & Belli, 2008). The countermovement jump (CMJ) is generally used to evaluate the power of the lower limbs, since this type of movement is similar to several jumping actions performed in different sports (Ávila-Carvalho et al., 2022). The ability to jump is also influenced by the athlete's force-velocity (F-V) profile (Samozino et al. 2008).

The analysis of jumping ability, through the vertical jump, according to the F-V profile evaluation, emerges in the literature following the studies by Samozino et al. (2013), Jiménez-Reyes et al. (2014) and Jiménez-Reyes, Samozino, Brughelli, & Morin (2017). The F-V profile, when related to body mass, represents the ratio between the external force developed and the maximum velocity capacity which is determined by the slope of the F-V profile curve (Jiménez-Reyes et al., 2017, 2014; Samozino, Rejc, di Prampero, Belli, & Morin, 2012). However, there is no real consensus among researchers about the best tests and instruments for the evaluation of vertical jump capacity in RG (Batista, Garganta, & Avila-Carvalho, 2019b). The International Federation of Gymnastics presented test protocols with assessments of flexibility, strength, balance and motor coordination. For the assessment of explosive strength,

there are only the Standing Long Jump (horizontal) and the Sargent Jump Tests (vertical), only providing information regarding the jump height (cm). The other motor capacities have several and different tests. Therefore, new possibilities of assessment of explosive strength with complementary information can help coaches to plan the training individually, according to the needs and characteristics of each gymnast.

In this sense, the aim of this study was to analyse the F-V profile during the CMJ of rhythmic gymnasts, identify the magnitude and direction of the imbalance between the two variables, and compare the jumping ability and mechanical variables of gymnasts of different age groups. We hypothesized that the majority of the rhythmic gymnasts would present a force deficit, even though we were not able to quantify its magnitude, and we also expected differences between younger and older gymnasts in F-V profile related variables.

METHODS

The sample was composed by 18 Portuguese female rhythmic gymnasts affiliated to the Portuguese Gymnastics Federation, from clubs in the north of the country, that participated in regional and/or national competitions during the 2020/2021 sports season, in two distinct performance levels: Base (lower level) and 1st division (higher level).

The following inclusion criteria were established for the sample: I. registered in the educational institution participating in the study, and II. absence of injury in the last 6 months and during the evaluation period. After a full explanation of the data collection procedures, gymnasts' legal guardians signed a consent form agreeing with the procedures of this research, since all the gymnasts were under 18 years of age. The study was conducted in accordance with the ethical standards of the Declaration of Helsinki.

Gymnasts were divided in two groups according to their age: G1 included beginner and youth gymnasts, with average age of 10.7 ± 0.7 years (ages between 10 and 12), 5.6 ± 1.7 years of practice and training volume of 13.3 ± 1.6h/week. G2 comprised junior and senior gymnasts with average age of 13.7 ± 1.1 years (ages between 13 and 16), 7.8 ± 2.0 years of practice and training volume of 13.7 ± 1.6h/week. Both groups had 9 gymnasts each.

The data collection was performed in May and June 2021, 8 months after the start of the sports season. Although the evaluation was carried out after a 4-month covid-19 lock down period (January to April 2021), the gymnasts had physical training in home environment during this period, essentially to improve the flexibility and strength levels.

A questionnaire was used to collect information about the gymnasts: chronological age, years of practice and training volume. Then, the following anthropometric measurements were taken: body mass (kg), height (cm), lower limb length (LLL) (cm) and distance from the greater trochanter to the ground in squatting position with knee flexion at 90° (cm). For the measurement of the LLL, gymnasts remained lying down and with their lower limbs fully extended. The LLL consisted of the length between the greater trochanter and the tip of the toes, with the ankle flexed. Gymnasts then squatted down with 90º of knee flexion to measure the distance from the greater trochanter to the ground (Height

90°) (Álvarez, García, da Conceição, & Jiménez-Reyes, 2020; Jiménez-Reyes et al., 2014).

The measurements required to determine the optimal F-V profile during the performance of a vertical jump were the athlete's body mass, jump height, and HPO, which is defined as the difference between the extended LLL (from the greater trochanter to the metatarsal) and the vertical distance between the greater trochanter and the ground in squat position (Álvarez, Reyes, Sousa, Conceição, & García, 2020; Jiménez-Reyes et al., 2014). Body mass was measured with a scale (Diagnostic Scale, Hoffen), and height and lower limbs measures were collected using a measuring tape and a goniometer.

At the beginning of the testing session, gymnasts performed their usual warm-up exercises. Then, they were instructed to stand with their hands on their hips to perform the CMJ. The position of the hands, described previously, was maintained throughout the movement. According to Jiménez-Reyes et al. (2014, p. 4) from this position, "participants will start a downward movement until they reach the squat position with an angle of approximately 90° at the knees followed by a jump with maximum height (immediately to the CMJ)".

Each gymnast performed four maximal CMJs with two to three overload conditions, using weighted vests. Loads were applied progressively, the first load corresponding to five kilograms and each increment was approximately five kilograms. From the moment the participants demonstrated fatigue, and consequently, difficulty in maintaining the correct technique of movement, load was not increased any further. One repetition without load with a 2-minute interval was performed, and three repetitions with additional loads with a 4–5-minute interval between them (Samozino et al., 2013).

For the measurement of jump height and subsequent calculation of the F-V profile, a scientifically validated smartphone app was used: *Myjump2* (Balsalobre-Fernández, Glaister, & Lockey, 2015).This instrument is easy to apply in the field since it immediately provides the desired variables: F0 (theoretical maximal force), V0 (theoretical maximal velocity) e Pmax (theoretical maximal power developed by the lower limbs); as well as the F-Vimb (difference between the current and the ideal F-V profile) of each gymnast (Jiménez-Reyes, Samozino, Pareja-Blanco, et al., 2017; Morin & Samozino, 2016; Samozino et al., 2012).The method used by *Myjump2* is based on the fundamental laws of mechanics, and proposes an accurate and reproducible field method to assess lower limb power with a precision similar to that obtained with specific ergometers (such as the force platform) (Samozino et al., 2008). This instrument can be used to measure the athletes' performance without expensive laboratory equipment or moving the athletes from their usual practice zone. It allows assessing the external force developed and the maximum speed capacity related to body mass (Jiménez-Reyes, Samozino, Brughelli, et al., 2017; Jiménez-Reyes et al., 2014; P. Samozino et al., 2013), thus personalizing the results to the characteristics of individual athletes (Ávila-Carvalho et al., 2022).

All data obtained were analysed using the statistical program *Statistical Package for the Social Sciences* (SPSS) 27.0, and the significance level was set at 5% ($p \leq 0.05$). Descriptive statistics were presented using the mean, standard deviation and minimum and maximum values. An exploratory data

analysis was performed to determine the existence of assumptions for the use of parametric statistics through the *Shapiro-Wilk* normality tests. According to the normality test applied, the variables were considered non-normal. Therefore, we used the nonparametric *Mann Whitney* test for data comparisons.

RESULTS

Table 1 shows the morphological (body mass, height, lower limb length - LLL and Height 90º) and training characteristics (years of practice and weekly training volume) of the whole sample and according to age group (G1- beginner and youth gymnasts with ages between 10 and 12; and G2 - junior and senior gymnasts with ages between 13 and 16).

No significant differences were found between groups in the training characteristics (years of practice and training volume), while in morphological characteristics, the groups differ in all analysed variables (Table 1).

Myjump2 was used to plot the gymnasts' F-V profile, and provided variables related to jumping ability (CMJ, Pmax, V0, F0), as well as the direction and magnitude of the imbalance between force and velocity capabilities (F-Vimb). Table 2 shows the performance and mechanical variables of the vertical jump of the entire sample and by age groups (G1 and G2).

According to Table 2, no significant differences were found in CMJ height, as well as in the variables related to the F-V profile between the two groups (G1 versus G2), except for the HPO measure.

Table 1
Morphological and training characteristics of whole sample and by age group

Age Group	Whole Sample (n=18)		Beginners/Youth G1 (n=9)		Juniors e Seniors G2 (n=9)		Mann-Whitney
Variables	x̄±sd	Min-Max	x̄±sd	Min-Max	x̄±sd	Min-Max	test
Age (years)	12.2±1.8	10-15	10.7±0.7	10-12	13.7±1.1	12-16	**0.000***
Years of practice (years)	6.7±2.1	2.5-11.0	5.6±1.7	2.5-7.0	7.8±2.0	5.0-11.0	0.083
Training volume (h/week)	13.5±1.5	12.0-15.0	13.3±1.6	12.0-15.0	13.7±1.6	12.0-15.0	0.460
Body mass (kg)	42.9±9.3	23.7-56.6	36.7±7.9	23.7-48.3	49.0±6.2	39.3-56.6	**0.001***
Height (cm)	151.3±11.8	127-170	142.3±9.0	127-156	160.2±6.0	151-170	**0.003***
LLL (cm)	99.2±9.3	81.9-116.0	92.6±7.1	81.9-104.0	105.7±6.1	98.4-116.0	**0.001***
Height 90º (cm)	63.4±6.4	54.0-77.3	58.6±4.4	54.0-66.7	68.1±4.3	62.0-77.3	**0.001***

Legend – LLL: lower limb length; Height 90º: in squatting position with knees bent at 90º; G1: Group 1; G2: Group 2; Min-Max: minimum and maximum value; x̄: average; sd: standard deviation; * p≤0.05: significant differences between groups.

Table 2

Performance and mechanical variables of whole sample and according to age group

Age Group	Whole sample (n=18)		Beginners/Youths G1 (n=9)		Juniors e Seniors G2 (n=9)		Mann-Whitney
Variables	x̄±sd	Mín-Máx	x̄±sd	Mín-Máx	x̄±sd	Mín-Máx	test
HPO (m)	36.0±4.9	26.3-47.1	33.9±5.0	26.3-40.0	38.1±4.0	33.0-47.1	**0.034***
CMJ (cm)	28.3±4.7	22.9-40.7	26.6±3.2	22.9-32.1	29.9±5.6	23.0-40.7	0.083
Pmax (W/kg)	24.5±5.9	18.2-38.2	22.5±4.8	18.2-32.8	26.5±6.6	18.5-38.2	0.408
V0 (m/s)	3.5±1.6	2.0-7.2	3.1±1.2	2.0-6.0	4.0±1.8	2.2-7.2	0.315
F0 (N/kg)	29.9±6.2	21.2-44.8	31.0±6.7	22.0-44.8	28.8±5.9	21.3-38.2	0.633
% F-Vimb	39.2±24.6	1.3-79.5	37.2±23.2	3.5-73.8	43.2±26.6	1.3-79.5	0.897

Legend – HPO: distance travelled by the center of mass during push-off; CMJ: Countermovement jump; Pmax: maximum power developed by the lower limbs; V0: maximum velocity; F0: maximum force; F-Vimb: difference between the current and the ideal profile of each gymnast; Min-Max: minimum and maximum value; x̄: average; sd: standard deviation; * $p \leq 0.05$: significant differences between groups; G1: Group 1; G2: Group 2.

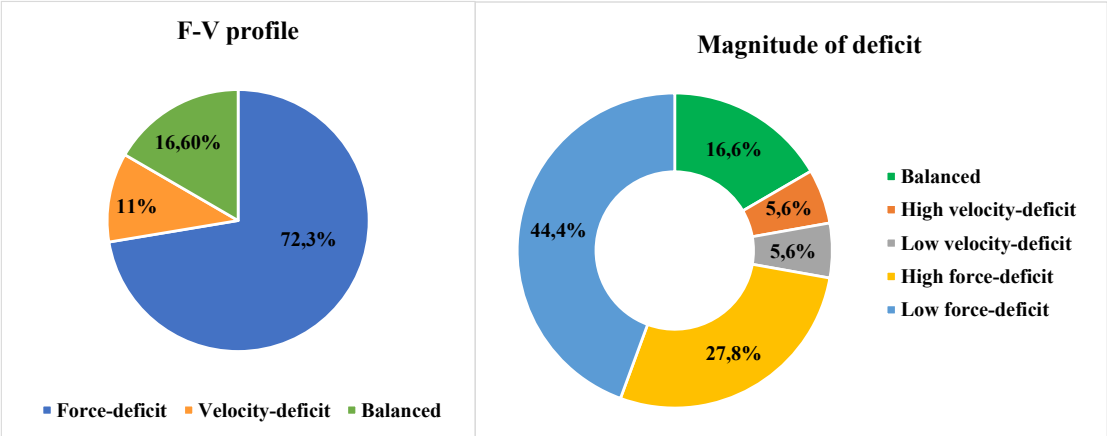

Figure 1: Percentage value of force-velocity (F-V) profile deficit and magnitude in all gymnasts.

Figure 1 shows the percentage of gymnasts that presented each classification. Gymnasts were classified according to the magnitude of F-Vimb, as follows: >40%, high velocity or force deficit; between 40% and 10%, reduced force or velocity deficit; and <10% balanced (Jiménez-Reyes et al, 2017). We highlight that 72.3% of the gymnasts' present force deficit and 11% have velocity deficit. Regarding the deficit magnitude, it is important to detail that 44,4% presented low force deficit and 27.8% high force deficit. We also analysed the classification according to the magnitude of the deficit of the gymnasts according to age group (G1 - Beginners/Youths and G2 - Juniors/Seniors) and there were no differences between groups.

Finally, we analysed the gymnasts according to the type of deficit presented. Thus, Table 3 shows the morphological, training, jumping performance and mechanical characteristics of each group, organized by type of deficit verified.

When we compare the two groups, significant differences were found in variables F0 and V0 (Table 3).

Table 3

Morphological, training and jump variables according to the type of deficit (force or velocity) verified in the force-velocity profile.

F-V profile	Force deficit (n=16)		Velocity deficit (n=2)		Mann-Whitney
Variables	$\bar{x}$±sd	Min-Max	$\bar{x}$±sd	Min-Max	test
Age (years)	12.1±1.7	10-15	13.0±2.8	11-15	0.549
Years of practice (years)	6.8±2.2	2.5-11.0	6.0±1.4	5.0-7.0	0.641
Training volume (h/week)	13.3±1.5	12.0-15.0	15.0±0.0	15.0-15.0	0.261
Body mass (kg)	42.7±8.9	23.7-56.2	44.5±17.2	32.3-56.6	0.837
Height (cm)	151.3±10.6	127-164	151.5±16.3	133-170	0.941
HPO (m)	36.0-5.1	26.3-47.1	36.0±4.2	33.0-39.0	0.941
CMJ (cm)	28.3±5.0	22.9-40.7	27.7±0.3	27.6-27.9	0.941
Pmax (W/kg)	24.9±6.2	18.2-38.2	21.2±1.0	20.5-21.9	0.641
V0 (m/s)	3.7±1.6	2.3-7.2	2.1±0.1	2.0-2.2	**0.013***
F0 (N/kg)	28.4±4.7	21.2-35.2	41.5±4.7	38.2-44.8	**0.013***
% F-Vimb	39.6±25.8	1.3-79.5	36.4±17.1	24.3-48.5	0.941

Legend – HPO: distance travelled by the center of mass during push-off; CMJ: Countermovement jump; Pmax: maximum power developed by the lower limbs; V0: maximum velocity; F0: maximum force; F-Vimb: difference between the current and the ideal profile of each gymnast; Min-Max: minimum and maximum value; $\bar{x}$: average; sd: standard deviation; * $p \leq 0.05$: statistically significant differences between groups.

DISCUSSION

The aim of this study was to analyse the F-V profile during the CMJ of rhythmic gymnasts, identify the magnitude and direction of the imbalance between the two variables, and compare the jumping ability and mechanical variables of gymnasts of different age groups. Our first hypothesis was confirmed since 72.3% of gymnasts presented force deficit. This work allowed us to quantify the magnitude of this deficit (44.4% - low force deficit and 27.8% - high force deficit). We also expected differences between younger and older gymnasts in F-V profile related variables, which was not verified in this work.

The age groups have different ages and morphological characteristics. However, their years of practice and training volume did not differ. The studied groups included gymnasts of different age groups: beginner and youth gymnasts (G1 - ages 10-12) and junior and senior gymnasts (G2 - ages 13-16). As a result, morphological differences were expected since older individuals are usually taller and heavier, similar to previous studies (Pinto et al., 2018). Regarding the training characteristics, the lack of differences may highlight a continuous work in terms of training volume across ages, regardless of the level of competition. The study by Dallas, Pappas, Ntallas, Paradisis, & Exell, 2020 evaluated gymnasts of ages lower than the gymnasts in G1, but with years of practice close to that presented by the gymnasts in our study, which highlights a clear early specialization, similar to other gymnastics disciplines. In fact, both groups included base and 1st division gymnasts and the groups selection was based only on age.

Another study found differences in years of practice and training volume in Portuguese gymnasts of different performance levels, and with ages similar to our sample (Batista et al., 2019b). However, these authors used a much larger sample (n=164), which allowed for higher generalization, and three competitive levels (Base, 1st division and Elite), which supports the differences found.

Among the variables of jump performance, only the HPO diverged between groups. This difference was expected since HPO is directly related to the anthropometric variables, specially the LLL. The remaining F-V profile variables showed no significant differences between age groups. Previous studies also found no differences in explosive force of lower limbs between distinct maturational levels (Pinto et al., 2018), but the sample included sedentary school girls. The jump height of 10 to 19-year-old gymnasts indicated a gradual increase in jump height with age, but also without significant differences (Gateva, 2013). Nevertheless, all the mean values reached by G2 were higher than in G1, except in the F0 variable, perhaps due to the lack of strength training in their usual training routine. This indicates that our sample developed the jump height, V0 and Pmax capacities across age groups, except for F0. Usually, younger rhythmic gymnasts spend more training time learning new skills and body movements than the older ones. The limited level of physical preparation is one of the main problems in the RG practice, and is often related to the greater emphasis placed by coaches on technical preparation (Gateva, 2013). Coaches plan gymnasts' training that covers all RG components, that is, artistic body technique, apparatus technique and physical preparation. In addition, training should be organized with respect to the gymnasts' age. This investigation highlights the lack of specific physical preparation for improving jumping performance in RG, which may be a result of repeated training adaptations where physical preparation is one of the components most frequently neglected.

Despite no statistically significant differences between jump height and F-V profile related variables between age groups, our results show a tendency for rhythmic gymnasts' jumping performance to increase with age. Younger gymnasts (8.0 ± 0.8 years old) in another study presented lower CMJ values than ours (Dobrijević, Moskovljević, Marković, & Dabović, 2018). Eleven-year-old gymnasts achieved higher values than our G1 (Gateva, 2013) and Portuguese 1st division gymnasts with ages corresponding to the G2 also jumped higher than this group (Batista et al., 2019b). Nevertheless, these two studies performed vertical jumps with free arms, allowing an execution with indirect forces. Spanish senior gymnasts obtained a lower CMJ value (24.6 ± 3.6cm) (Rodríguez, Sampedro, Rivilla-García, & Bofill 2010) than the G2. Older dancers (18.9 ± 1.3 years old) presented a lower CMJ height than G2 gymnasts in our sample (Álvarez et al. 2020). These data are meant to compare both groups of our sample with other published results from gymnasts and dancers, trying to understand their level. This suggests that further studies are required that will lead to more concrete conclusions that can be applied to RG reality. For instance, it would be interesting to investigate the influence of jump height improvements in specific RG technical elements, namely the jumps, evaluated according to the RG Code of Points.

Regarding the Pmax variable, experienced ballet dancers (average age of 18.9 years) and senior gymnasts, respectively (Rodríguez et al., 2010, Álvarez et al. 2020) achieved lower Pmax values than the values obtained by G2. The relativization of body mass could be a factor that explains the values reached.

Finally, F0 and V0 differ significantly when the morphological, training and jump variables were compared according to the type of deficit presented. These findings clearly show that knowledge of the F-V profile facilitates the detection of force and/or velocity deficits (Samozino et al. 2014), and it should be analysed regularly to achieve better accuracy and balance between force and velocity capabilities (Jiménez-Reyes et al., 2017a). A larger sample would be required to better understand the magnitude of the deficit according to age group (G1 - Beginners/Youths and G2 - Juniors/Seniors). Nevertheless, this highlights that there are deficits across all ages, perhaps due to the lack of strength training since early ages.

Most gymnasts presented a force deficit (72.3%), while 11% had a velocity deficit. In fact, two studies found that entire samples of 46 ballet dancers (Álvarez, Fuentes García, et al., 2020) and 87 dancers (Álvarez, Reyes, et al., 2020) presented force deficit. This information could be used for planning a more specific training program to improve jump performance (Álvarez et al., 2020; Jiménez-Reyes et al., 2017a; Jiménez-Reyes et al., 2019). In fact, jumping ability was improved through a training program based on F-Vimb as it is more efficient than training programs guided by increasing Pmax (Jiménez-Reyes, Samozino, Brughelli, et al., 2017). No studies were found in the literature about F-V profile or training programs directed to the F-Vimb of RG athletes. However, there are studies that have proven effectiveness of the training programs that improve jumping performance of GR athletes (Dallas et al., 2020; Dobrijević et al., 2018; Piazza et al., 2014; Rodríguez et al., 2010). A 16-week training program showed improvements in CMJ performance, maximum speed and power of ballet dancers (Ávila-Carvalho et al., 2022). The present evaluation moment was performed after a Covid-19 lockdown period (January to April/2021). However, gymnasts had physical training in home environment during this period, essentially to improve the flexibility and strength levels, and have not been in a period of recovery, rest or physical inactivity. Nevertheless, it would be interesting to apply a training program based on the F-V profile of rhythmic gymnasts in upcoming investigations.

In this sense, based on our results and the studies presented, the imbalance of the F-V profile is an important parameter to be considered when we evaluate the jump ability and plan the gymnasts' training. It is known that the action of jumping is highly required in both training and competition routines of RG athletes. According to deficits found in our study, where most gymnasts presented a force deficit, and considering the demands of the sport and each athlete, it becomes essential to include strength training in the usual training routines of rhythmic gymnasts.

LIMITATIONS

We must acknowledge some limitations found in this work. The small sample size is related to the fact that this study was conducted in a pandemic year

(covid-19), reflecting the difficulty of integrating gymnasts from other regions and other clubs in Portugal. Another limiting factor is related to the data collection period, which took place in May and June 2021, right after the lockdown period that lasted from January to April 2021. We must highlight that this is not an investigation intended to assess the consequences of the lockdown period for jumping performance of rhythmic gymnasts since only one evaluation moment was performed. The fact that we were not able to implement a specific training protocol that would allow us to understand the changes promoted in the jump height, in the mechanical variables and in the F-V profile is a limitation that would be interesting to see solved in future studies.

Thus, we suggest that further studies can be conducted using a higher number of gymnasts, different ages and performance levels. Furthermore, individualized training plans, oriented to the individual F-V profile, can be tested for the improvement of deficits between these two abilities and consequent improvement of rhythmic gymnasts' jump performance.

Finally, we also suggest the use of specific RG jumps to understand the influence of jump height on specific RG technical elements.

CONCLUSIONS

The rhythmic gymnasts from clubs in the north of Portugal, of different age groups (G1-Beginner/Youth and G2-Junior/Senior), presented similar years of practice and training volume. However, the groups differ in all morphological variables analysed (body mass and height).

Furthermore, regarding the vertical jump performance and the magnitude of the imbalance between force and velocity capabilities, the groups also did not show statistically significant differences in jump height (CMJ) and in the variables related to F-V profile. When gymnasts were divided by the type of deficit, differences were found in F0 and V0 variables, suggesting that future investigations should evaluate each deficit separately.

Based on the analysis of the F-V profile of all gymnasts, we verified that 73.2% presented force deficit, while 11% had velocity deficit. In addition, different magnitudes of deficits were observed. For these reasons, coaches should plan gymnasts' training in such a way that it covers all RG components and is organized with respect to the gymnasts' age. This investigation highlights the lack of specific physical preparation for improving jumping performance in RG, which may be a result of repeated training adaptations where physical preparation is one of the components most frequently neglected.

We found a small number of research studies evaluating jump performance using the F-V profile, and specifically, using the *MyJump2* app as an analysis tool. Our study provided information on the effectiveness of this methodology and encourages the use of F-Vimb variable to identify the force or velocity deficit of jumps in gymnasts' performance.

Considering the results found, this study may be useful for gymnastics coaches who wish to assess the lower limb force of their team's gymnasts in a practical way in the training environment. Furthermore, we suggest that fitness (and/or a supplementary training program) should be implemented in addition to the usual training routine, and that it should be planned, whenever possible, on an individual basis and be

guided by the deficit presented by each gymnast.

REFERENCES

Álvarez, J. A. E., Fuentes García, J. P. F., da Conceição, F. A., & Jiménez-Reyes, P. (2020). Individualized Training Based on Force–Velocity Profiling During Jumping in Ballet Dancers. *International Journal of Sports Physiology and Performance*, *15*(6), 788–794. https://doi.org/10.1123/ijspp.2019-0492

Álvarez, J. A. E., Reyes, P. J., Pérez Sousa, M. Á. P., da Conceição, F., & García, J. P. F. (2020). Analysis of the Force-Velocity Profile in Female Ballet Dancers. *Journal of Dance Medicine & Science*, *24*(2), 59–65. https://doi.org/10.12678/1089-313X.24.2.59

Ávila-Carvalho, L., Conceição, F., Escobar-Álvarez, J. A., Gondra, B., Leite, I., & Rama, L. (2022). The Effect of 16 Weeks of Lower-Limb Strength Training in Jumping Performance of Ballet Dancers. *Frontiers in Physiology*, *12*. https://doi.org/10.3389/fphys.2021.774327

Balsalobre-Fernández, C., Glaister, M., & Lockey, R. A. (2015). The validity and reliability of an iPhone app for measuring vertical jump performance. *Journal of Sports Sciences*, *33*(15), 1574–1579. https://doi.org/10.1080/02640414.2014.996184

Batista, A., Garganta, R., & Avila-Carvalho, L. (2019a). Body difficulties in rhythmic gymnastics routines. *Science of Gymnastics Journal*, *11*(1), 37–55.

Batista, A., Garganta, R., & Avila-Carvalho, L. (2019b). Strength in Portuguese rhythmic gymnasts of different competition levels. *Journal of Physical Education and Sport*, *19*(2), 1213–1221.

Bobo, M., & Sierra, E. (1998). *Ximnasia Rítmica Deportiva - Adestramento e competición*. Santiago de Compostela: Editora Lea.

Bozanic, A., & Miletic, D. (2011). Differences between the sexes in technical mastery of rhythmic gymnastics. *Journal of Sports Sciences*, *29*(4), 337–343. https://doi.org/10.1080/02640414.2010.529453

Dallas, G. C., Pappas, P., Ntallas, C. G., Paradisis, G. P., & Exell, T. A. (2020). The effect of four weeks of plyometric training on reactive strength index and leg stiffness is sport dependent. *The Journal of Sports Medicine and Physical Fitness*, *60*(7). https://doi.org/10.23736/S0022-4707.20.10384-0

Dobrijević, S., Moskovljević, L., Marković, M., & Dabović, M. (2018). Effects of proprioceptive training on explosive strenght, aglility and coordination of young rhythmic gymnasts. *Fizicka Kultura*, *72*(1), 71–79. https://doi.org/10.5937/fizkul1801071D

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

FIG. (2022). Code of Points Rhythmic Gymnastics - 2022-2024. Retrieved January 24, 2023, from Federation International de Gymnastique website: https://www.gymnastics.sport/publicdir/rules/files/en_2022-2024%20RG%20Code%20of%20Points.pdf

Gateva, M. (2013). Investigation of strength abilities of rhythmic gymnasts. *Research in Kinesiology*, *41*(2), 245–248.

Jiménez-Reyes, P., Samozino, P., Brughelli, M., & Morin, J.-B. (2017). Effectiveness of an Individualized Training Based on Force-Velocity Profiling during Jumping. *Frontiers in Physiology*, *7*. https://doi.org/10.3389/fphys.2016.00677

Jiménez-Reyes, P., Samozino, P., Cuadrado-Peñafiel, V., Conceição, F., González-Badillo, J. J., & Morin, J.-B. (2014). Effect of countermovement on power–force–velocity profile. *European Journal of Applied Physiology*, *114*(11), 2281–2288. https://doi.org/10.1007/s00421-014-2947-1

Jiménez-Reyes, P., Samozino, P., Pareja-Blanco, F., Conceição, F., Cuadrado-Peñafiel, V., González-Badillo, J. J., & Morin, J.-B. (2017). Validity of a Simple Method for Measuring Force-Velocity-Power Profile in Countermovement Jump. *International Journal of Sports Physiology and Performance*, *12*(1), 36–43. https://doi.org/10.1123/IJSPP.2015-0484

Laffranchi, B. (2001). *Treinamento desportivo aplicado à Ginástica Rítmica* (1st ed.). Londrina: UNOPAR Editora.

Lebre, E. M. X. G. (1993). *Estudo comparativo das exigências técnicas e morfofuncionais em Ginástica Rítmica Desportiva* (Doutoramento em Ciências do Desporto: Treino Desportivo). Universidade do Porto, Porto.

Miletić, D., Katić, R., & Males, B. (2004). Some anthropologic factors of performance in rhythmic gymnastics novices. *Collegium Antropologicum*, *28*(2), 727–737.

Monteiro, S. G. P. (2000). *Quantificação e classificação das cargas de treino em ginástica rítmica : Estudo de caso : Preparação para o Campeonato do Mundo de Osaka 1999 da Selecção Nacional de Conjuntos Sénior* (Mestrado em Ciência do Desporto: Treino de Alto Rendimento Desportivo). Universidade do Porto, Porto.

Moraru, C. E. (2016). *Physical Training in Rhythmic Gymnastics Theory and Practice*. LAP LAMBERT Academic Publishing.

Morin, J.-B., & Samozino, P. (2016). Interpreting Power-Force-Velocity Profiles for Individualized and Specific Training. *International Journal of Sports Physiology and Performance*, *11*(2), 267–272. https://doi.org/10.1123/ijspp.2015-0638

Piazza, M., Battaglia, C., Fiorilli, G., Innocenti, G., Iuliano, E., Aquino, G., … di Cagno, A. (2014). Effects of resistance training on jumping performance in pre-adolescent rhythmic gymnasts: A randomized controlled study. *Italian Journal of Anatomy and Embryology*, *119*(1), 10–19.

Pinto, V. C. M., Santos, P. G. M. D. dos, Medeiros, R. C. D. S. C. de, Souza, F. E. S., Simões, T. B. dos S., Dantas, R. P. N. de C., & Cabral, B. G. D. A. T. (2018). Maturational stages: comparison of growth and physical capacity indicators in adolescents. *Journal of Human Growth and Development*, *28*(1), 42. https://doi.org/10.7322/jhgd.127411

Rodríguez, I. G., Sampedro, J., Rivilla-García, J., & Bofill, A. M. (2010). Evolución y relación de la capacidad de salto y amortiguación en gimnastas de rítmica de alto nivel. *Cuadernos de Psicología Del Deporte*, *10*, 43–50.

Román, M. L., del Campo, V. L., Sabido, R., & Morenas, J. (2012). Perfil y diferencias antropométricas y físicas de gimnastas de tecnificación de las modalidades de artística y rítmica. *Retos.*

Nuevas Tendencias En Educación Física, Deporte y Recreación., *21*, 58–62.

Samozino, P., Edouard, P., Sangnier, S., Brughelli, M., Gimenez, P., & Morin, J.-B. (2013). Force-Velocity Profile: Imbalance Determination and Effect on Lower Limb Ballistic Performance. *International Journal of Sports Medicine*, *35*(06), 505–510. https://doi.org/10.1055/s-0033-1354382

Samozino, Pierre, Morin, J.-B., Hintzy, F., & Belli, A. (2008). A simple method for measuring force, velocity and power output during squat jump. *Journal of Biomechanics*, *41*(14), 2940–2945. https://doi.org/10.1016/j.jbiomech.2008.07.028

Samozino, Pierre, Rejc, E., di Prampero, P. E., Belli, A., & Morin, J.-B. (2012). Optimal Force–Velocity Profile in Ballistic Movements—Altius. *Medicine & Science in Sports & Exercise*, *44*(2), 313–322. https://doi.org/10.1249/MSS.0b013e31822d757a

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THE EFFECTS OF 12-WEEK ISOKINETIC TRAINING ON KNEE STABILIZERS STRENGTH AND THE EFFICIENCY OF THE PERFORMANCE OF GYMNASTICS VAULTS

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Abstract

The aim of the research was to examine the effects of isokinetic training on knee stabilizer muscles strength, and whether this increases the efficiency of performing basic gymnastic vaults. A total of 60 respondents, students of the Faculty of Sports and Physical Education (average age 19.7±1.5 years, weight 75.3±2.9 kg, height 179.8±6.7 cm) were included. The subjects were divided into two groups, experimental (EG) (n=30) and control (CG) (n=30). As part of the 12-week program, the experimental group (EG) in addition to exercises within the regular classes at the university had an additional concentric isokinetic training 3 times a week on the Biodex System 3 dynamometer, while the control group (CG) only had exercises within the regular classes at the university. The results indicated statistically significant differences ($p < 0.05$) between EG and CG, both in increasing the knee stabilizer muscles strength and in the performance of gymnastic vaults in favor of EG. It can be concluded that the additional isokinetic training resulted in a greater increase in strength, but also a better performance of gymnastic vaults. The results of the research can be used as guidelines for planning and programming isokinetic strength training of knee stabilizer muscles, which will contribute to a better performance of gymnastic vaults. Since there is a small amount of research on the topic of this work, this study represents a good foundation and basis for some future research on the effects of isokinetic training in sports gymnastics.

Keywords: *artistic gymnastics, isokinetic, vaulting, muscular strength.*

INTRODUCTION

Artistic gymnastics is a closed-skill, multi-discipline sport performed on six and four apparatus by men and women, respectively (Gröpel & Beckmann, 2017). Gröpel and Beckmann (2017) stated that, according to the authors Cogan and Vidmar (2000), sports gymnastics consists of high demands, flexibility, courage, precision, balance, and artistic creativity. One of the most important ways in which a gymnast

can distinguish his performance from others is the height of the flight, such as the height achieved on the vault, as this can indirectly affect the scoring by the judges (Prassas et al., 2006).

Vaulting is a gymnastics discipline characterized by a run towards the springboard, where competitors perform various acrobatic elements after take-off in the air, before landing on their feet (Bradshaw et al., 2010). Vaults are based on a complex movement structure and intense physical effort that is achieved in a short period and require highly developed speed, agility, and muscle strength from gymnasts (Kochanowicz et al., 2016). Of all the ways of performing vaults (handspring vaults, Tsukahara vaults, Yurchenko vaults), handspring vaults generally achieve the highest speed during the run-up phase (Schärer et al., 2021).

Vaulting is a dynamic activity performed in both men's and women's artistic gymnastics. Success in vaulting depends on a multitude of variables, some independent and some within the gymnast's control. Each vault and group of vaults has a different time structure. Vault can be divided into 7 phases. Some vaults require a faster run, some slower, some vaults have a long first flight phase, some have a short one, etc. In the competition, gymnasts perform the most difficult vault in their knowledge, which can be safely performed. As is shown in Figures 1 and 2, each vault in the Code of Points (CoP) can be divided into seven phases: (1) running, (2) jump on springboard, (3) springboard support and push phase, (4) first flight phase (1stfp), (5) support and push on the table, (6) second flight phase (2ndfp), and (7) landing (Atiković & Smajlović, 2011; Čuk & Karacsony, 2004; Ferkolj, 2010; Prassas & Gianikellis, 2002; Prassas et al., 2006; Takei, 2007).

There is no significant number of studies that investigated the effects of isokinetic training on the knee stabilizer muscles strength and the efficiency of performing gymnastic vaults; hence, in this research, other studies were used that had similar problems.

A high level of gymnast's entire body strength is required for successful performance of the demanding technical gymnastic elements. Numerous authors agree that a prerequisite for proper learning of technical movements is a high level of strength, while a low level of strength negatively affects the development of technical skills (Brown et al., 2007). Strength adaptation is sport-specific and an athlete's specialization and training determine the muscle groups where the adaptations occur (Seger & Thorstensson, 2000).

Training on isokinetic machines has proven to be the best solution, due to the optimal training load potential and continuous resistance (Cools et al., 2007; Teng et al., 2008). It has been shown that isokinetic strength training is relatively safe since once the movement is stopped the resistance is removed (De Ste Croix et al., 2009). To quantify a muscle group's ability to generate torque or force, isokinetic training may be used, and it is also useful as an exercise modality in the restoration of a muscle group's pre-injury level of strength (Rochcongar, 2004).

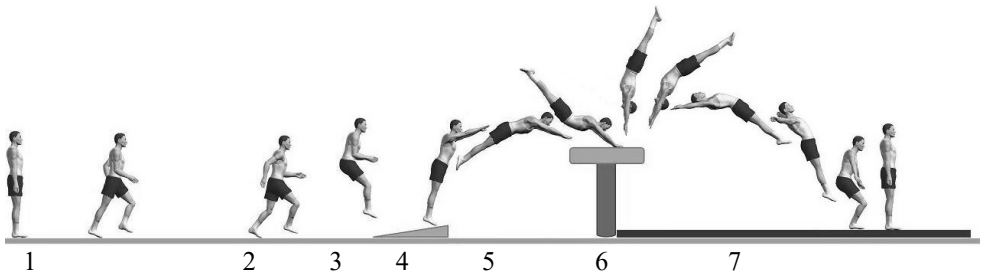

Figure 1. Vault seven phases (Atiković, 2012).

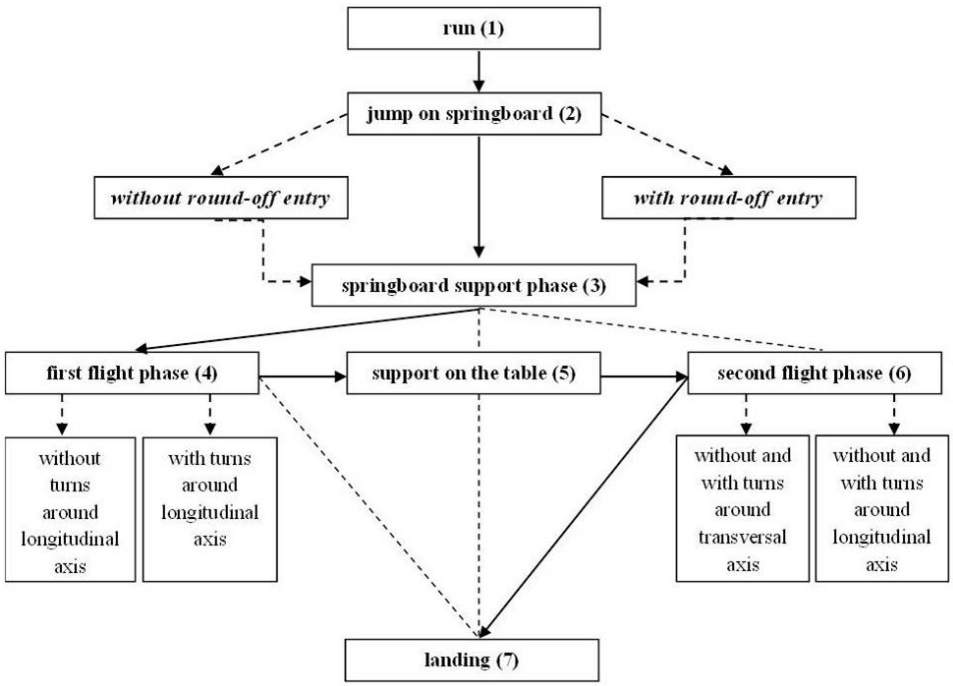

Figure 2. Schematic presentation of a possible jump to the vault (Atiković, 2012).

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

There are limited intervention studies on artistic gymnasts. Previous findings suggested that a gymnastic intervention program improved lower limbs strength in pre-adolescent athletes (Douda et al., 1997; Pienaar & Van der Walt, 1988). Bassa et al. (2002) described the isometric and isokinetic knee torque in prepubescent male gymnasts six months after the beginning of the annual training period and concluded that long-term gymnastic training is associated with increased torque in knee extensor but not knee flexor muscles.

The handspring vault is a technical gymnastic skill that demands considerable force and power output and is of paramount importance for a gymnast's vaulting development. A study by Hall et al. (2016) examined the plyometric training effects, when added to habitual gymnastic training, on handspring vault performance variables in twenty youth female competitive gymnasts and found significant improvements for run-up-velocity, take-off velocity, a hurdle-to-board distance, board contact time, table contact time, and post-flight time.

Tabaković et al. (2016) research findings showed that isokinetic training of knee extensor and flexor muscles increases functional correlation between speed and strength, leading to improved performance of acrobatic elements in floor exercises.

Authors' Dallas et al. (2021) study investigated the effect of an isokinetic training program on muscle strength and gymnastic performance in preadolescent female gymnasts. However, the handspring vault requires both technical skill and power production to achieve success. The 10-week isokinetic training that was added to the traditional training improved the knee strength, which consequently improved aspects of the vault, but did not affect other technical aspects of the handspring performance.

To the best of our knowledge, there are no other studies that have examined the effects of isokinetic training on the knee stabilizer muscles strength and the performance of gymnastic vaults in college students. Therefore, the main purpose of this research was to examine the effects of a 12-week isokinetic training program on the knee extensor and flexor muscles strength, and whether it increases the efficiency of performing basic gymnastic vaults in students. It is hoped that this study will focus attention upon this important performance aspect of gymnastic vaults and stimulate interest in future scientific investigations in this area.

Our research hypothesized that an additional 12-week program of isokinetic training would increase the knee extensor and flexor muscles strength, facilitating better gymnastic vaults performance in students.

METHODS

This study included sixty students (n=60) of the Faculty of Sports and Physical Education at the University of Sarajevo, (mean age 19.7±1.5 years, weight 75.3±2.9 kg, height 179.8±6.7 cm). Using the random sample method, the subjects were divided into two groups, experimental (EG) (n=30) and control (CG) (n=30). All procedures were conducted in accordance with the Declaration of Helsinki, as well as according to the ethics committee standards of the Faculty of Sports and Physical Education at the University of Sarajevo. The study was conducted within one academic year semester (3 months). All subjects who had an injury to the lower extremities in the last six months were excluded from the procedure.

All subjects of the experimental (EG) and control group (CG) performed a regular practical lessons program in sports gymnastics. In addition to the regular gymnastics classes program, the experimental group subjects had additional isokinetic training of the knee stabilizer muscles on the Biodex 3 system dynamometer. The knee stabilizer muscles strength assessment was performed in the initial and final measurements in both groups, and in the final measurement, an

assessment of gymnastic vaults performance was also conducted. The research participants were thoroughly acquainted with the research program before the start.

In this research, body height and weight were measured for each participant in the experimental group (EG) and control group (CG), in the initial and final measurements. Body height and weight were measured using an InBody BSM370 stadiometer (InBody Co.).

The strength test on knee joint extensor and flexor muscles was conducted using Biodex System 3 (Biodex Corporation, Shirley, New York, USA) isokinetic dynamometer. All knee joint extensor and flexor muscles strength measurements were performed from a sitting position with a 90° average angle of the body and upper leg. Bands for stabilization were positioned over the body, hips, and the distal upper leg part for the tested leg. During the whole isokinetic training procedure, examinees held their hands crossed on their chests. Also, during the examination, the examinees were given instructions to give their maximum effort for each exercise.

A standardized test routine improves the operator's control of several variables which influence tests: testing of the uninvolved side first, the axis of rotation alignment, warm-ups, subject stabilization, verbal commands, visual feedback, test position, system calibration, angular velocity selection, system stabilization, skill, education of the examiner, gravity compensation, rest intervals, test repetition, data collection (print - out) for future analysis, data analysis using statistical software (Biodex Medical Systems).

Most used isokinetic angular velocities are $60°\cdot s^{-1}$, $180°\cdot s^{-1}$, and $300°\cdot s^{-1}$; often referred to as slow, medium, and high speed. Selecting low strength ($60°\cdot s^{-1}$), medium ($180°\cdot s^{-1}$), and high endurance ($300°\cdot s^{-1}$) isokinetic testing speed is essential for optimal strength evaluation, given that in slow muscle action the vast majority of motor units are recruited, while faster testing velocities enrich the force-velocity spectrum of the acting muscles (Baltzopoulos & Brodie, 1989).

In this study, an isokinetic angular velocity of 60°·s–1 was used to determine the knee joint extensor and flexor muscles strength. That angular velocity was chosen because 12 weeks of additional training was realized at that angular velocity. Another reason that this angular velocity was chosen was because the student participants encountered gymnastic vaults for the first time, and it turned out that this angular velocity was the most optimal for them to be able to apply force in conditions similar to those encountered during the take-off phase from the springboard. In support of the chosen angular velocity is the studies of Tabaković et al. (2016) and Dallas et al. (2021), which found that knee strength at 60°·s–1 improved significantly in the EG after the isokinetic training program in contrast to the CG which indicated no significant improvement.

In this research, the following variables were used to assess the maximum muscle strength of dynamic knee stabilizers (Table 1).

Each of the listed variables for assessing the maximum muscle strength of dynamic knee stabilizers can be influenced. Peak torque (PT) - highest muscular force output at any moment during a repetition expressed in (Nm). Peak Torque indicates the muscle's maximum strength capability. Variables indicate results separately for extension and flexion of the left and right leg. Total work (TW) - the amount of work

accomplished for the entire set. This represents the muscle's capability to maintain torque throughout the test bout. If the ROM is smaller on one side, the total work will be affected even if the peak torque is the same. Average power (AVG power) equals the amount of total work divided by the time to complete that total work. This value is used to provide a true measure of work rate intensity defined as total work divided by time. Power represents how quickly a muscle can produce force. It expresses the ability of the muscle to do the work for a specified period, and the intermuscular ratio (AGONIST TO ANTAGONIST RATIO) is expressed in percentages for both legs (Biodex Medical Systems).

As shown in Figures 3 and 4, to evaluate the success of performing elements of gymnastic vaults, the following were used:

- ST – squat through
- FHS – front handspring vault

Table 1
Variables for estimating maximum muscle strength of the dynamic knee stabilizers.

Maximum muscle strength of knee extensor	EXTLEF60 (Nm) – peak torque of the knee extensors of the left leg EXTRIG60 (Nm) – peak torque of the knee extensors of the right leg EXLFTW60 (J) – total work of the knee extensors of the left leg EXRGTW60 (J) – total work of the knee extensors of the right leg AVGEXLF60 (W) – average power of the knee extensors of the left leg AVGEXRG60 (W) – average power of the knee extensors of the right leg
Maximum muscle strength of knee flexors	FLXLEF60 (Nm) – peak torque of the knee flexors of the left leg FLXRIG60 (Nm) – peak torque of the knee flexors of the right leg FXLFTW60 (J) – total work of the knee flexors of the left leg FXRGTW60 (J) – total work of the knee flexors of the right leg AVGFLLF60 (W) – average power of the knee flexors of the left leg AVGFLRG60 (W) – average power of the knee flexors of the right leg
The ratio between knee flexor and extensor muscles	AGANLF60 – intermuscular ratio (Flexors/Extensors) of the left leg AGANRG60 – intermuscular ratio (Flexors/Extensors) of the right leg

Figure 3. ST – squat through (Atiković et al., 2009)

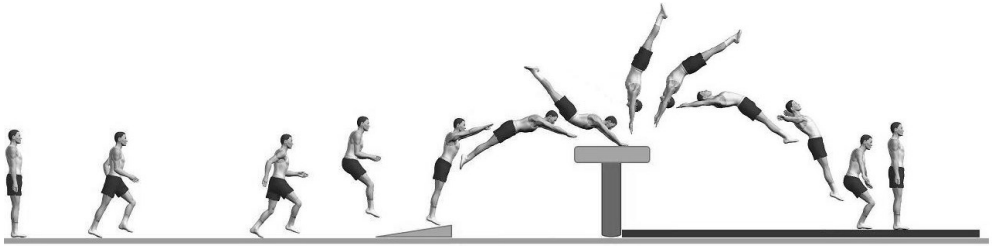

Figure 4. FHS – front handspring vault (Atiković, 2012).

The participants did not have prior knowledge of gymnastic vaults. Therefore, the initial performance assessment of gymnastic vaults (ST – squat through and FHS – front handspring), was not conducted. However, after the basic 12-week program of regular practical training, a final evaluation of the experimental and control groups was conducted by university lecturers (N=4) with more than 20 years of work experience in various sports clubs and at the Faculty of Physical Education and Sports. Evaluation of gymnastic vaults motor knowledge was conducted at the gym hall on a gymnastic apparatus for the vaulting of 135 cm height, with a maximal run-up of 25 m, using "Elan" springboard for take-off. Before the assessment, the examiners carefully read the description of the assignment and the criteria (Table 2). Each examiner evaluated the participants in silence and not making their evaluations public. Once the assessment was completed, the three evaluations (N=3) that were the closest to the mean values were taken, while the evaluations that had the largest deviations from the mean value were excluded from the final evaluation.

The subjects performed both gymnastic vaults (ST – squat through and FHS – front handspring) twice, and only the better performance was used in the analysis. After evaluation of better performances, the final grade for each examinee in each task was calculated as the arithmetic means of the grade assigned by each examiner. The final evaluation was made using a scale from 6 to 10 points, according to the criteria, where 10 points was the highest/best score. The same procedure was followed by seven teachers, experts in the field of gymnastics, to set the criteria for optimum performance of a "handspring" vault (Milosis et al., 2018).

Table 2
Criteria for Gymnastic vaults knowledge evaluation.

Measuring scale (points)	Description of standards - Gymnastics Vault
Points 10	The exercise (vault) is performed optimally in such a way that there are no mistakes in the initial position, body position, leg, and/or hand positions. There are no mistakes in the aesthetic part of the exercise, in the coordination of performance, technical performance, range of motion, speed, and pace, and finally, there are no mistakes in the final position.
Points 9	The exercise (vault) is performed optimally with minor errors found in certain technical requirements of the initial position, body position, and position of the legs and/or hands. Possible minor errors may be found in the aesthetic part of the exercise, range of motion, speed and pace, and final position. The total maximum number of minor faults is 1 to 2.
Points 8	The exercise (vault) is still well-performed with a small number of errors noticed in certain technical requirements of the initial position, body position, and position of the legs and/or hands. Possible errors may be found in the exercise's aesthetic part, performance coordination, range of motion, speed, pace, and final position. However, these errors do not impair the whole structure of the movement. The total maximum number of minor errors is 3 to 4.
Points 7	The performance of the exercise (vault) is flawed. There are errors in almost all the above-mentioned technical requirements. There is also a noticeable distortion in the structure of the movement.
Points 6	The exercise (vault) is poorly performed with a large number of errors. There are major deficiencies in all of the abovementioned technical requirements. The structure of the movement is significantly impaired.

All subjects of the experimental (EG) and control group (CG) performed a regular program of practical lessons in sports gymnastics. The regular practical lessons program in sports gymnastics, as shown in Table 3, consisted of three hours a week lasting 45 minutes each, a total of 135 minutes per week, for 12 weeks. The regular classes protocol included the following: warming up the body for 10 min, stretching the body for 25 min, and practical sports gymnastics exercise for 100 min. In the program performed by subjects from the control group, there was no additional stimulus, such as training on the dynamometer of the Biodex 3 system.

Table 3
A regular program of practical lessons in sports gymnastics (EG) and (CG).

Exercise	Regular sports gymnastics classes
3 classes x 45 min	Body warmup for 10 min
	Body stretching for 25 min
Σ 135 min	Practical exercise of sports gymnastics (100 min)

The experimental group (EG) of examinees followed an isokinetic program of exercise (Table 4) three times a week x 40 min for 12 weeks. All subjects had knee range of motion (ROM) by 90 degrees. Knee testing angular velocity was set at $60°\cdot s^{-1}$ for concentric and eccentric muscle action. Participants were encouraged to exert maximum effort. Standard instructions were given to each subject. The testing protocol included the following: warm-up and overall body stretching – 20 min; positioning the examinee in optimal stabilization; alignment of joints and dynamometric axis of rotation; positioning the resistance pad; verbal introduction into the isokinetic concept of exercises; gravitation correction; warm-up (3 submaximal, 1 maximal repetition); maximum test speed of $60°\cdot s^{-1}$ (5 repetitions); rest (30 seconds); contralateral extremity testing, and recording test details to ensure test repeatability.

Table 4
Resistance training program (EG).

Exercise	Sets/Repetitions/Rest	Speed
	Warming up on bicycle ergometer for 10 min (75 RPM, 50 WATT)	
	Static stretching muscles of lower extremities (10 min)	
3 sets	4 - 6 repetitions	with the left leg on the angular speed of $60°\cdot s^{-1}$
	pauses of 30s between the series	
3 sets	4 - 6 repetitions	with the right leg on the angular speed of $60°\cdot s^{-1}$
	pauses of 30s between the series	
	Pause between exercises of 3 min	

The Statistical Package for the Social Sciences (SPSS), version 21.0 (SPSS Inc., Chicago, Illinois) was used for data processing. Descriptive statistics (mean value and standard deviation) were calculated for all variables and each group. ANCOVA was used to determine the effects of the experimental program. As a preliminary analysis (assumption) for ANCOVA, the Levene's test was used to evaluate the equality of variances between the compared groups. The Mann-Whitney U test was used to determine the differences between the experimental and control

groups in the vault performance scores. The Kolmogorov-Smirnov test was used to check the normality of the distribution.

RESULTS

The results of the arithmetic means and standard deviation for variables of average age, body height, and body weight for experimental (EG) and control (CG) groups in initial measurement are presented in Table 5. Going through the results, we can conclude that there are no differences in arithmetic means in the results of the applied variables. Average values of average age for the experimental and control group were calculated, and they were within the following range: EG: 19.9±1.6; CG: 19.8±1.4; the values for body height EG: 179.63± 6.19; CG: 180.81± 7.40, and values for body weight were the following: EG: 75.11± 3.35; CG: 75.90± 3.13. *p*-values are based on comparisons of the experimental group and control group of average age (p =.42), body height (p=.51), and body weight (p =.35). From the statistical point of view, there were no differences between the control and the experimental group.

Table 5
Comparison of three variables after the initial measurements (M ±SD) and (p).

Variable	(EG) $M \pm SD$ (n=30)	(CG) $M \pm SD$ (n=30)	p
	Initial measurement		
Average age (years)	19.9±1.6	19.8±1.4	.42
Height (cm)	179.63± 6.19	180.81± 7.40	.51
Weight (kg)	75.11± 3.35	75.90± 3.13	.35

Data are presented as the $M \pm SD$. *p*-Values are based on comparisons of the experimental group (EG) and control group (CG) using ANOVA

The first analysis was conducted on the experimental (EG) and control groups (CG) before the program's implementation. The results presented in Table 6 show that from the statistical point of view, examinees are not substantially different in all strength variables for knee extensor and flexor muscles. Preliminary testing tested the assumption of variance homogeneity; no perceived contingency was noted in the applied variables. The statistical significance of Levene's test in all variables is p>.05, indicating that the observed variances for the two groups of respondents are similar in these variables, which means that there are no significant differences between the variables. The null hypothesis is accepted, and we conclude that the condition of homogeneity is met. Therefore, the differences in the final measurement between the groups can be attributed to the effects arising from the experimental program. ANCOVA showed that a significant difference was found for all variables in the maximum knee extensor and maximum knee flexor muscles strength, between unspecific and specific training program on Biodex 3 (p<.05).

The calculated effect size (Partial eta-squared) for all variables assessing the knee extensor and flexor muscles strength ranges from (η_p^2 = .09) to (η_p^2 = .18), which indicates a medium and high effect size value. In the variables for assessing the knee

extensor and flexor muscles ratio, Leven's test obtained statistical significance (p<.05), which means that the null hypothesis is rejected, and there are statistically significant differences in the initial measurements between the groups. By analyzing the arithmetic means in the initial and final measurements, it can be concluded that the arithmetic means in the final measurement are almost equal, which means that the differences in the ratios between the knee extensor and flexor muscles have decreased.

Table 6

ANCOVA of dynamic knee stabilizer muscles between experimental and control groups in the initial and final measurements (speed 60°·s^{-1}).

Variable	Group	Initial measurement $M \pm SD$	Final measurement $M \pm SD$	Levene's statistic	ANCOVA			
				p	df	F	p	η_p^2
Maximum muscle strength of knee extensors								
EXTLEF60 (Nm)	EG	210.27±37.93	264.57±44.96	.76	1.00	10.07	.02*	.15
	CG	217.04±37.40	229.04±40.14					
EXTRIG60 (Nm)	EG	204.93±32.40	257.35±44.38	.74	1.00	11.05	.02*	.16
	CG	218.39±35.16	220.32±37.56					
EXLFTW60 (J)	EG	856.00±173.54	1123.98±217.19	.06	1.00	10.89	.00*	.16
	CG	946.47±187.28	964.47±149.11					
EXRGTW60 (J)	EG	859.79±123.32	1118.53±223.23	.27	1.00	12.26	.00*	.18
	CG	905.92±117.88	932.80±169.15					
AVGEXLF60 (W)	EG	132.92±21.59	172.42±39.95	.09	1.00	9.70	.00*	.15
	CG	136.58±16.96	145.62±27.82					
AVGEXRG60 (W)	EG	125.21±12.55	167.05±39.91	.21	1.00	7.37	.01*	.12
	CG	127.30±10.31	141.86±28.92					
Maximum muscle strength of knee flexors								
FLXLEF60 (Nm)	EG	119.60±14.21	151.20±26.73	.83	1.00	7.01	.01*	.11
	CG	124.58±11.91	132.69±25.90					
FLXRIG60 (Nm)	EG	130.25±20.46	149.60±27.99	.90	1.00	5.68	.02*	.09
	CG	135.70±24.71	132.03±26.40					
FXLFTW60 (J)	EG	501.15±54.58	789.84±159.86	.33	1.00	8.50	.01*	.13
	CG	489.26±66.54	673.58±142.32					
FXRGTW60 (J)	EG	547.40±72.50	799.98±152.98	.82	1.00	11.95	.00*	.17
	CG	525.18±71.79	663.90±157.03					
AVGFLLF60 (W)	EG	90.14±6.30	113.37±22.78	.93	1.00	9.20	.00*	.14
	CG	92.02±7.24	96.46±22.03					
AVGFLRG60 (W)	EG	93.12±18.18	115.73±24.66	.67	1.00	11.48	.00*	.17
	CG	90.83±13.86	94.83±22.34					
The ratio between knee flexors and extensors (F/E ratio)								
AGANLF60 (%)	EG	54.31±3.44	58.88±3.66	.00	1.00	.15	.70	.00
	CG	56.59±5.50	58.26±7.52					
AGANRG60 (%)	EG	58.67±5.82	60.74±3.93	.00	1.00	.00	.98	.00
	CG	62.12±8.71	60.13±7.49					

Data are presented as the $M \pm SD$. Levene's test p-level of statistical significance. df-Degree of freedom. F-F ratio. p-Values are based on comparisons of the experimental group (EG) and control group (CG) using ANCOVA. η_p^2-Partial-eta squared. *. The mean difference is significant at the .05 level

The Mann-Whitney U test, represented in Table 7, was used to evaluate the differences in performance ratings of gymnastics vaults between the experimental and control groups. The test showed statistically significant differences (p<.05) between the experimental and control groups in both vaults. Based on the formula for calculating the size of the effects, statistically significant values were obtained for both vaults (r=.59), which means that there are large differences in the scores between the groups.

Table 7
Mann-Whitney U test for the gymnastics vaults performance evaluation.

Variable	Group	*M rank*	*U*	*z*	*p*	*r*
ST – squat through	EG (n=30)	40.10	162.00	-4.56	.00*	.59
	CG (n=30)	20.90				
FHS – front handspring	EG (n=30)	40.32	155.50	-4.60	.00*	.59
	CG (n=30)	20.68				

Data are presented as the *M rank*-Mean rank. *U*-Mann-Whitney test value. *z*-z-score. *p*-Values are based on comparisons of the experimental group (EG) and control group (CG). *r*-Pearson's correlation. *. The mean difference is significant at the .05 level

DISCUSSION

This study examined the effects of a 12-week isokinetic training program on the knee stabilizer muscles strength and the performance of gymnastic vaults in college students. The aim of this study was to examine whether the additional protocol of 12-week isokinetic training results in increased biomechanical values of certain parameters, but also to determine whether isokinetic training or resistance training increases the functional correlation between speed and strength, leading to improved performance of gymnastic vaults. The main finding is that the EG achieved better results than the CG in the strength of the knee stabilizers and the efficiency of performing gymnastic vaults after the program in the final measurement. Another finding was that knee stabilizer muscles strength at an angular velocity of 60°·s–1 was significantly improved in EG after a 12-week program intervention, in contrast to CG, where there was no significant improvement. This finding is confirmed by the results of the research by Tabaković et al., (2016) and Dallas et al. (2021).

The control group had a different work protocol during 12 weeks than the experimental one, because between the two measurements for the control group, only a regular practical lessons program in sports gymnastics was conducted, without an additional exercise program. In the program, to which the examinees from the control group were subjected, there were no additional stimuli, such as training on the Biodex System 3 dynamometer; therefore, the whole process was focused on the regular practical classes at the faculty. Therefore, structural changes in the

maximum dynamic knee stabilizer muscles strength occurred with lower intensity for the control group.

The experimental group indicated obvious structural changes, which could be dominantly registered through variables for the assessment of the maximum dynamic knee stabilizer muscles strength (the maximum moment of force, overall work, and average strength).

In the initial measurement, before the implementation of the program, the groups indicated practically no differences, which is an excellent indicator of a balanced position for the possible application of a specific additional training program of the dynamic knee stabilizer muscles, with two applied transformation procedures. However, in the second measurement (at the end of the program), the groups indicated significant differences in the assessment of the maximum dynamic knee stabilizer muscles strength, as well as in the assessments of vault performance, and the obtained changes are in favor of the experimental group compared to the control group.

In variables assessing the maximum dynamic knee stabilizer muscles strength and variables assessing the gymnastic vaults' performance, we obtained statistically significant differences in almost all applied variables.

It was determined, when it comes to the gymnastics vault elements, that the changes obtained for both gymnastic vaults, which required the change of the maximum dynamic knee stabilizers strength, were statistically more significant.

The results of our research partially agree with the data obtained in the research studies mentioned below. Explosive strength, which is defined as the ability to activate the maximum number of muscle units in a unit of time, has significant correlations with success in performing artistic gymnastics elements and elements of other sports in the majority of research (Lešnik et al., 2015; Mujanović et al., 2014).

One of the factors affecting the performance results is the take-off speed on the springboard (Bradshaw et al., 2010). The fact that no significant improvement was shown in knee strength at 300°/sec is one of the reasons why both groups failed to affect the take-off phase from springboard due to the fast duration of this phase. It explains why we took a smaller angular speed of 60°/sec in our research.

The results of our study are consistent with data confirming the effectiveness of isokinetic training to improve muscle strength in trained athletes (Zebrowska et al., 2005), and they verify the findings of Pienaar and Van der Walt (1988) and Douda et al. (1997) who stated that young gymnasts improved vertical jumping performance and explosive strength of lower limbs after a specialized training program. These facts lead to the conclusion that for a successful performance of applied vaults, more significant engagement of musculature is necessary on the principle of transitory activation of the maximum muscle units' number in the unit of time (explosive strength of lower extremities).

The correct performance of the handspring vault requires the correct body position during various phases of the vault and sufficient explosive power and speed in the lower limb musculature in order to perform body rotation while maintaining body control (Marina & Jemni, 2014).

The results of Rochcongar's study (2004) suggest that both training modalities (isokinetic and traditional training) are equally effective in artistic gymnastics in

relation to the lower limb strength. The author also suggests that isokinetic exercises have several advantages over other exercise modalities, such as (i) that a muscle group may be exercised to its maximum potential throughout a joint's entire range of motion; (ii) it provides a safer alternative to other exercise modalities.

Preparing additional training for the dynamic knee stabilizer muscles (and probably on many other types of muscles) by using training protocols on isokinetic equipment would prove to be the best solution, first of all, because of the optimum training load possibility for a performer, and continuous resistance which is allowed by this equipment (Cools et al., 2007; Teng et al., 2008).

Certainly, precise defining of sorts and types of protocol, number of repetitions depending on transformation stages and the objectives of the work, overall volume, and specific content, should all be developed in accordance with the characteristics of muscle groups, which is a topic for future research. It is completely certain that the applied training in this study eventually proved to be an important method for improving dynamic knee stabilizer muscles strength, as well as a significant influence on the improvement of effectiveness in performing elements of gymnastic vaults.

In a study conducted by Calmels et al. (1995), the effects of intensive training on concentric and eccentric isokinetic flexor and extensor muscles strength of 9 young national competitors in gymnastics were tested using an isokinetic dynamometer at angular speeds of $60°\cdot s^{-1}$ and $120°\cdot s^{-1}$. Authors present in their results that eccentric strength is greater than concentric strength, there is no significant difference between the dominant and non-dominant limb, and a significant increase of the flexor/extensor peak torque ratio was observed with increasing speed, due to the concentric ratios. The same increase in flexor/extensor peak torque ratio values was observed by Siatras et al. (2004) in young male gymnasts, between angular velocities of 60-120°/s ($p<0.01$) as well as 60-180°/s ($p<0.01$). These results provide information about the relationship between angular velocity and eccentric muscle strength, already reported in previous studies, and, in particular, the fact that the knee flexor and extensor muscles behave differently during eccentric and concentric work as the angular velocity increases.

The results of our study are consistent with the data of the study of Tabaković et al. (2016), which concluded that the maximum dynamic knee stabilizer muscles strength significantly affects the success of floor exercises in artistic gymnastics. This study examined whether additional training protocol of isokinetic training results in increased biomechanical values of certain parameters and whether it increases functional correlation between speed and strength, leading to improved performance of acrobatic elements in floor exercises. The experimental group indicated obvious structural changes that can be dominantly registered through variables assessing the maximum dynamic knee stabilizers strength. In variables assessing the performance of floor exercise elements in artistic gymnastics, authors obtained statistically significant differences in elements requiring maximum dynamic knee stabilizers strength changes: dive roll, back handspring, and forward and backward somersault. The above facts lead to a conclusion that for a successful performance of applied acrobatic elements on the floor for this type of performance,

more significant engagement of musculature is necessary on the principle of transitory activation of the maximum number of muscle units in the unit of time (explosive strength of lower extremities).

A study conducted by Dallas et al. (2021) investigated the effect of an isokinetic training program on muscle strength and gymnastic performance in preadolescent female gymnasts. However, the handspring vault requires both technical skill and power production to achieve success. The 10-week isokinetic training that was added to the traditional training improved the knee strength, which consequently improved aspects of the vault, but did not affect other technical aspects of the handspring performance. However, further research should aim to examine whether the incorporation of additional specific exercises, such as sprinting or jumping movements, may have a positive influence on the performance score. The results of the study confirm that optimal performance is the result of a complex interaction of several factors.

Control, management, and distribution of training load are important factors not just in terms of intensifying the teaching process, but also in bringing the process of additional training closer to the authentic problems of students. This happens mostly due to the fact that the influence of adequate kinesiology operators in the appropriate time and space (which implies the implementation of certain control, management, and load distribution) leads to positive changes in motor abilities and motor skills appear. In other words, adaptive changes partially occur in muscles. This also has a positive influence on creating favorable adaptive structures and a better overall functional state of student bodies. It is clear that such students adapt better to the load during the learning process, but also reduce the risk of injuries due to weak muscle strength. Therefore, the overall effects of solving various motor tasks would be larger.

In our research, the strength of the knee extensor and flexor muscles came to the fore in both applied vaults, especially in the front handspring. Greater activation of knee extensor and flexor muscles strength was required in certain phases of the vault, namely: running, jump on springboard, springboard support phase, and first flight phase. Our results are supported by Marinšek (2010), who stated that in artistic gymnastics all phases of vaults exercises such as running, jump on springboard, springboard support phase, first flight phase, and landing, depend on the physical preparation and motor control of the gymnasts.

This research has some limitations in theoretical and practical utility. These limitations are reflected in the fact that the results of our research can mainly be applied to the population of sports faculty students, so they cannot be generalized and may not be applicable to high-level gymnasts. Also, one of the limitations is that in addition to the strength of the extensor and flexor muscles of the knee, other muscles of the body that were not covered by this research are also important for the success in performing gymnastic vaults.

CONCLUSIONS

This study investigated the effects of an isokinetic training program on muscle strength and performance of gymnastic vaults. The 12-week isokinetic training program improved knee strength, which consequently improved aspects of the

vaults. In the initial measurement of our research, before conducting the training program, the two groups, experimental and control, showed no differences. However, in the second measurement (at the end of the program) the groups showed significant differences in the assessment of the maximum dynamic knee stabilizer muscles strength, as well as in the assessment of performance of gymnastic vaults. The changes obtained after the experimental training in the isokinetic dynamometer and regular faculty classes, lasting 12 weeks, are in favor of the experimental group compared to the control group, both in variables for assessing the knee extensor and flexor muscles strength, as well as in the variables for assessing the success in performing gymnastic vaults.

The value of this study is reflected in the fact that the applied isokinetic training can be used as training to increase the knee stabilizer muscles strength, which leads to easier learning and better performance of gymnastic vaults in a population that has no previous experience in sports gymnastics.

Future research should be conducted on a population of high-level gymnasts and should aim to examine whether the inclusion of additional specific exercises, in addition to knee stabilizer strength training, such as lunge training, jumping training, and training involving arm and shoulder girdle strength can, have a positive effect on performing gymnastic vaults.

REFERENCES

Atiković, A. (2012). New Regression Models to Evaluate the Relationship between Biomechanics of Gymnastic Vault and Initial Vault Difficulty Values. *J Hum Kinet*, *35*, 119-126. https://doi.org/10.2478/v10078-012-0085-6

Atiković, A., & Smajlović, N. (2011). Relation between vault difficulty values and biomechanical parameters in men's artistic gymnastics. *Science of Gymnastics Journal*, *3*(3), 91-105. https://www.dlib.si/details/URN:NBN:SI:DOC-BC64UZVA

Atikovic, A., Tabaković, M., Hmjelovjec, I., Kalinski, S., & Stoicescu, M. (2009). Differences between Vaults during the Qualification C.1 Aarhus 2006-39th Men's & 30th Women's Artistic Gymnastics World Championships. *Revista Discobolul*. https://www.researchgate.net/publication/315714655_DIFFERENCES_BETWEEN_VAULTS_DURING_THE_QUALIFICATION_C1_AARHUS_2006-39_TH_MEN'S_30_TH_WOMEN'S_ARTISTIC_GYMNASTICS_WORLD_CHAMPIONSHIPS

Baltzopoulos, V., & Brodie, D. A. (1989). Isokinetic Dynamometry. *Sports Medicine*, *8*(2), 101-116. https://doi.org/10.2165/00007256-198908020-00003

Bassa, E., Michailidis, H., Kotzamanidis, C., Siatras, T., & Chatzikotoulas, K. (2002). Concentric and eccentric isokinetic knee torque in pre-pubescent male gymnasts. *Journal of Human Movement Studies*, *42*, 213-227. https://go.gale.com/ps/i.do?p=AONE&u=googlescholar&id=GALE|A190052937&v=2.1&it=r&sid=AONE&asid=832d94a2

Biodex Medical Systems, Inc. *Biodex System 3 Pro - Application/Operation manual*. Retrieved 24.08. from https://www.biodex.com/sites/default/files/835000man_06159.pdf

Bradshaw, E., Hume, P., Calton, M., & Aisbett, B. (2010). Reliability and

variability of day-to-day vault training measures in artistic gymnastics. *Sports Biomech*, *9*(2), 79-97. https://doi.org/10.1080/14763141.2010.488298

Brown, A. C., Wells, T. J., Schade, M. L., Smith, D. L., & Fehling, P. C. (2007). Effects of plyometric training versus traditional weight training on strength, power, and aesthetic jumping ability in female collegiate dancers [Article]. *Journal of Dance Medicine & Science*, *11*, 38. https://link.gale.com/apps/doc/A190052937/AONE?u=googlescholar&sid=bookmark-AONE&xid=46a7d6b7

Calmels, P., Van Den Borne, I., Nellen, M., Domenach, M., Minaire, P., & Drost, M. (1995). A pilot study of knee isokinetic strength in young, highly trained, female gymnasts. *Isokinetics and Exercise Science*, *5*, 69-74. https://doi.org/10.3233/IES-1995-5202

Cogan, K. D., & Vidmar, P. (2000). *Gymnastics*. Fitness Information Technology, Incorporated. https://books.google.ba/books?id=Pq2iHEOYoNoC

Cools, A. M., Geerooms, E., Van den Berghe, D. F., Cambier, D. C., & Witvrouw, E. E. (2007). Isokinetic scapular muscle performance in young elite gymnasts. *J Athl Train*, *42*(4), 458-463. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2140070/

Čuk, I., & Karacsony, I. (2004). *Vault: methods, ideas, curiosities, history*. ŠTD Sangvinčki. https://books.google.ba/books?id=uXVaAAAACAAJ

Dallas, G., Dallas, G., & Maridaki, M. (2021). The Effect of 10-week Isokinetic Training on Muscle Strength and Gymnastic Performance in Preadolescent Female Gymnast. *Science of Gymnastics Journal*, *13*, 399-409. https://doi.org/10.52165/sgj.13.3.399-409

Douda, H., Tokmakidis, S., & N., T. (1997). *The effect of training during growth of rhythmic sports gymnastics development* The Third Annual Congress of the European College of Sport Science, Manchester, England.

Ferkolj, S. M. (2010). A kinematic analysis of the handspring double salto forward tucked on a new vaulting table. *Science of Gymnastics Journal*, *2*(1), 35-46. http://www.dlib.si/details/URN:NBN:SI:doc-TDL7WOH8

Gioftsidou, A., Ispirlidis, I., Pafis, G., Malliou, P., Bikos, C., & Godolias, G. (2008). Isokinetic strength training program for muscular imbalances in professional soccer players. *Sport Sci Health*, *2*, 101-105. https://doi.org/10.1007/s11332-008-0047-5

Gröpel, P., & Beckmann, J. (2017). A Pre-Performance Routine to Optimize Competition Performance in Artistic Gymnastics. *The Sport Psychologist*, *31*(2), 199-207. https://doi.org/10.1123/tsp.2016-0054

Hall, E., Bishop, D. C., & Gee, T. I. (2016). Effect of Plyometric Training on Handspring Vault Performance and Functional Power in Youth Female Gymnasts. *PLoS One*, *11*(2), e0148790. https://doi.org/10.1371/journal.pone.0148790

InBody Co., Ltd. . *BSM 370*. Retrieved 24.08. from https://www.inbody.in/product-page.php

Kochanowicz, A., Kochanowicz, K., Niespodziński, B., Mieszkowski, J., Aschenbrenner, P., Bielec, G., & Szark-Eckardt, M. (2016). Maximal Power of the Lower Limbs of Youth Gymnasts and Biomechanical Indicators of the Forward Handspring Vault Versus the Sports Result.

Journal of Human Kinetics, *53*(1), 33-40. https://doi.org/doi:10.1515/hukin-2016-0008

Lešnik, B., Glinšek, V., & Zvan, M. (2015). Correlation between gymnastics elements knowledge and performance success in younger categories of alpine skiing. *Science of Gymnastics Journal*, *7*, 67-79. https://www.dlib.si/details/URN:NBN:SI:DOC-BDOO9DX1

Marina, M., & Jemni, M. (2014). Plyometric Training Performance in Elite-Oriented Prepubertal Female Gymnasts. *The Journal of Strength & Conditioning Research*, *28*(4), 1015-1025. https://doi.org/10.1519/jsc.0000000000000247

Marinšek, M. (2010). Basic landing characteristics and their application in artistic gymnastics. *Science of Gymnastics Journal*, *2*. https://www.researchgate.net/publication/265995608_Basic_landing_characteristics_and_their_application_in_artistic_gymnastics

Milosis, D., Siatras, T., Proios, M., Proios, M., Christoulas, K., & Papaioannou, A. (2018). Accuracy of University Students' Skill-Specific Self-efficacy and Self-efficacy-Performance in Gymnastics Relationship. *International journal of sport psychology*, *49*. https://doi.org/10.7352/IJSP2018.49.429

Mujanović, E., Atiković, A., & Mujanović, A. (2014). Relation between acrobatic elements knowledge and alpine skiing parallel turns among physical education students. *Science of Gymnastics Journal*, *6*. https://www.dlib.si/details/URN:NBN:SI:DOC-8LHZS49P

Pienaar, A., & Van der Walt, C. (1988). The influence of participation in a gymnastics program on selected anthropometrical variables of six to nine-year old girls. . *Journal of Research in Sport Physical Education and Recreation*, *11*, 39-47.

Prassas, S., & Gianikellis, K. (2002). Vaulting mechanics. XX International Symposium of biomechanics in sports,

Prassas, S., Kwon, Y. H., & Sands, W. A. (2006). Biomechanical research in artistic gymnastics: a review. *Sports Biomechanics*, *5*(2), 261-291. https://doi.org/10.1080/14763140608522878

Rochcongar, P. (2004). [Isokinetic thigh muscle strength in sports: a review]. *Annales de réadaptation et de médecine physique : revue scientifique de la Société française de rééducation fonctionnelle de réadaptation et de médecine physique*, *47*(6), 274-281. https://doi.org/10.1016/j.annrmp.2004.05.013

Schärer, C., Gross, M., Lorenzetti, S., & Hübner, K. (2021). Energy Transformation on Vault in Elite Artistic Gymnastics: Comparisons between Simple and Difficult Tsukahara and Yurchenko Vaults. *Applied Sciences*, *11*(20), 9484. https://www.mdpi.com/2076-3417/11/20/9484

Seger, J. Y., & Thorstensson, A. (2000). Muscle strength and electromyogram in boys and girls followed through puberty. *Eur J Appl Physiol*, *81*(1-2), 54-61. https://doi.org/10.1007/pl00013797

Siatras, T., Mameletzi, D., & Kellis, S. (2004). Knee Flexor:Extensor Isokinetic Ratios in Young Male Gymnasts and Swimmers. *Pediatric Exercise Science*, *16*, 37-43. https://doi.org/10.1123/pes.16.1.37

Tabaković, M., Atikovic, A., Kazazović, E., & Turković, S. (2016).

Effects of isokinetic resistance training on strength knee stabilizers and performance efficiency of acrobatic elements in artistic gymnastics. *Science of Gymnastics Journal*, *8*, 135-148. https://www.dlib.si/details/URN:NBN:SI:DOC-EIRJN1BL

Takei, Y. (2007). The roche vault performed by elite gymnasts: somersaulting technique, deterministic model, and judges' scores. *J Appl Biomech*, *23*(1), 1-11. https://doi.org/10.1123/jab.23.1.1

Teng, W. M., Keong, C. C., Ghosh, A. K., & Thimurayan, V. (2008). Effects of a resistance training programme on isokinetic peak torque and anaerobic power of 13-16 years old taekwondo athletes. *International Journal of Sports Science and Engineering*, *2*(2), 111-121. http://www.worldacademicunion.com/journal/SSCI/SSCIvol02no02paper08.pdf

Zebrowska, A., Zajac, A., Poprzecki, S., & Waligóra, G. (2005). The Influence of Eccentric and Concentric Muscle Contractions on Concentration of Growth Factors in Strength Trained Athletes. http://www.johk.pl/files/02zebrowska_in.pdf

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THE ARTISTIC-EXPRESSIVE DIMENSION OF GYMNASTICS FOR ALL

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Abstract

The expressive and poetic dimension of Gymnastics for All (GfA) is often recognized in choreographies performed at gymnastics festivals, emphasising its communicative and referential function. The aim of this study was to discuss the artistic-expressive dimension of GfA based on Pierre Parlebas' theory and in the sociological notion of sportivisation. The particular and unfinished sportivisation of the GfA process includes the absence of institutionalised gesture codes, characterising the artistic-expressive dimension as a "potency", which therefore may or may not be part of GfA's activities, according to the decision of each group. This analysis allows us to distinguish GfA from other artistic sports, such as rhythmic gymnastics and figure skating, and from other art forms, such as dance and circus.

Keywords: *gymnastics, motor praxeology, artistic sports, sportivisation process.*

INTRODUCTION

The relationship between sport and art constitutes an interesting concept, combining contributions from history, sociology, and philosophy. Recent studies have revived discussions about the artistic aspects of some sports, including artistic swimming, figure skating, rhythmic gymnastics and acrobatic gymnastics (Chiat & Ying, 2012; Leandro, Avila-Carvalho, Sierra-Palmeiro & Bobo-Arce, 2016; Manos & Popescu, 2014; 2020; Toledo & Antualpa, 2016). For all these competitive sports, the artistic-expressive dimension is controlled by criteria formally detailed in its rules, in combination with coaches', choreographers', and referees' decisions.

However, different studies argue that the artistic-expressive dimension has particularities in the case of gymnastics for all (GfA). In that regard, the aim of this study was to analyse the artistic-expressive dimension of GfA based in the motor praxeology theory presented by the French sociologist Pierre Parlebas (2001) and the following discussions proposed by Mateu & Bortoleto (2011) concerning the expressive motor situation (EMS). In addition, the sociological notion of sportivisation was

used to locate the GfA in the *continuum* of expressive practices (Mateu, 2010).

GYMNASTICS FOR ALL IN THE PARLEBAS' PERSPECTIVE

According to the International Gymnastics Federation (FIG), GfA is a group gymnastics activity oriented to well-being, health, and leisure promotion (FIG, 2020). The GfA activities often result in choreographed programs (Carbinatto & Reis-Furtado, 2019) performed at gymnastics festivals (Patrício, Bortoleto, Carbinatto, 2016). Throughout its long history, GfA has consolidated an inclusive gymnastics practice with enormous technical and aesthetic diversity (Menegaldo & Bortoleto, 2020).

GfA and its purpose aimed at participation has been developed in several European countries since the 19th century, building the foundations of the FIG, as defended by one of its founders, the Belgian Nicholas Cuperus. Regarding other disciplines, i.e., artistic gymnastics and rhythmic gymnastics, also under the FIG governance, GfA has notable differences. Three of them are particularly interesting for our study:

a) the absence of a gestural codification – or a Code of Points – to guide the development of GfA. This fact results in the emergence of different group performances, changing the participants' profile (age group, gender, gymnastic skills), the number of group members and the technical level. Furthermore, the absence of regulations also allows different configurations regarding other elements that constitute its choreographies: the possibility of using apparatus, music, and even the use of themes for the development of these performances (Almeida, 2016; Carbinatto & Reis-Furtado, 2019).

b) its non-competitive development, particularly when referring to a GfA groups' participation in gymnastics festivals for demonstrative purposes (Patrício, Carbinatto & Bortoleto, 2016). What interests us is, in addition to the non-competitive trait of the events, is the fact that the absence of an objective system to compare performances allows for an important diversity of choreographies that are developed by different groups (Carbinatto & Reis Furtado, 2019). Additionally, the motivations that guide people to do GfA differ substantially from those seen in competitive disciplines (Menegaldo, 2022; Patrício, 2022; Bortoleto, Heinen, Jun, Toledo, Schiavon, Pasqua, Oliveira & Menegaldo, 2019; Wichmann & Jarvis, 2015).

c) its sportivisation process. Because of the previously mentioned absence of rules and, therefore, the absence of evaluation criteria and of a regulation of technical issues, it is evident that the sportivisation process of GfA takes place differently from those seen in competitive disciplines, such as artistic gymnastics and rhythmic gymnastics (Silva, Menegaldo, Almeida & Bortoleto, 2021). Despite the institutional recognition by FIG and by several national gymnastics federations (Bento-Soares & Schiavon, 2020), the GfA sportivisation process is distinct, and may be considered unfinished (Menegaldo, 2022). Nevertheless, it is worth mentioning that this seems intentional from an institutional perspective, since the resistance to certain trends of a sportivisation process seems to be convenient to maintain diversity and inclusion in the GfA context.

In order to analyse those characteristics, a systemic perspective was

adopted to study the GfA "internal logic". According to Parlebas (2001), every "motor situation" (sports, games) has a unique internal logic (Parlebas, 2021), made up of systemic relationships among four structural elements: space, participants, time and implements. Each of those elements are determined by rules or the social contracts established by the participants. This theory proposes a taxonomy system named CAI following three main criteria: a) presence (C) or absence (C) of teammates, b) presence (A) or absence (A) of opponents, and c) presence (I) or absence (I) of uncertainty regarding the space (practice performed in a stable or unstable facilities) (Figure 1). Combining these criteria, we have eight categories:

The GfA internal logic places it in the Sociomotor Situation (performed in group), without opponents, in a stable space (CAI). However, since the GfA practice has no rules (Code of Points), the number of participants in each group, the space used for performances and the use of implements are not pre-determined and all these aspects can be defined by each GfA group, according to their goals and possibilities. Theoretically, GfA may give rise to multiple internal logics (Figure 2) (Menegaldo & Bortoleto, 2020), based on different ways to set the systemic elements (participants, space, time and implement). Despite that, one major aspect never changes: GfA is a sociomotor situation with cooperation as its most relevant aspect

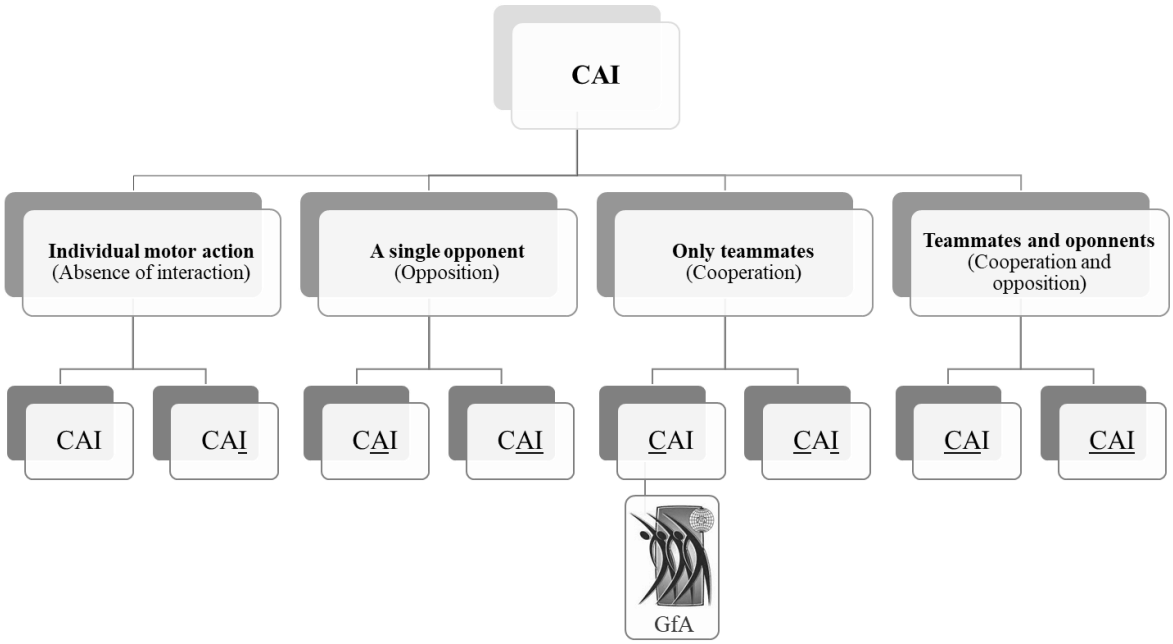

Figure 1. CAI Taxonomy.
Source: adapted from Parlebas (2001).

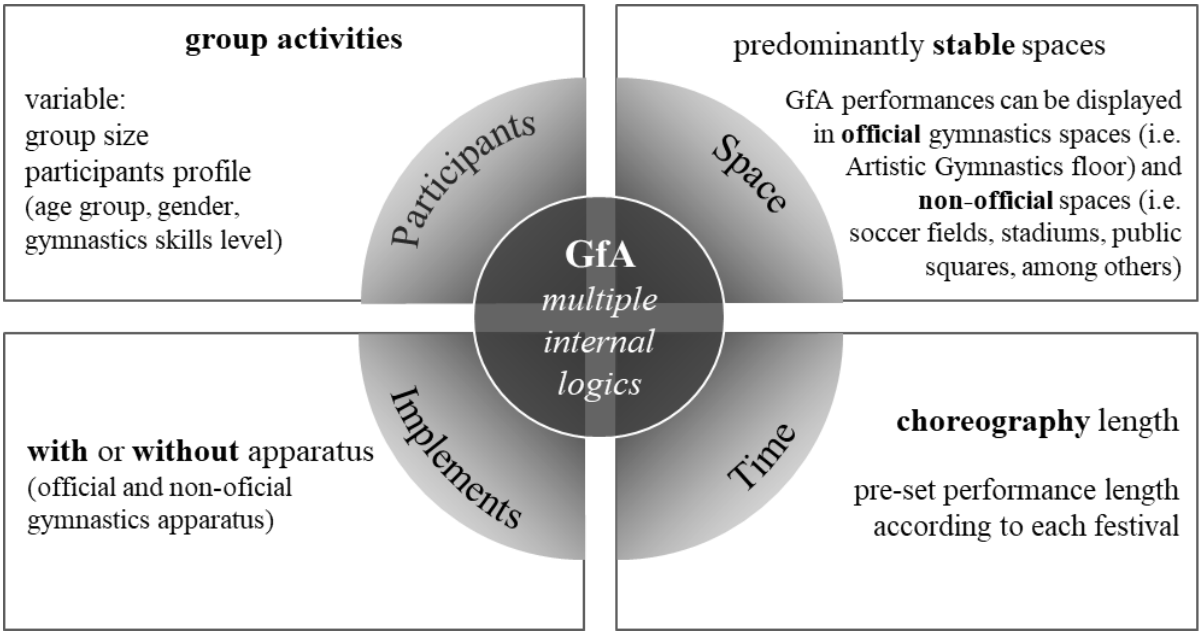

Figure 2. GfA multiple internal logics.
Source: created by the authors.

GYMNASTICS FOR ALL AS AN EXPRESSIVE SITUATION

Considering all this, we are particularly interested in the fact that, regardless of the way each group structures its internal logic, in most cases, GfA has the motor objective of showing its choreographic compositions, similar to some other artistic-expressive practices. Nevertheless, different from other sports identified as "artistic", such as acrobatic gymnastics and artistic swimming, which all have expressive objectives orchestrated and conditioned to regulations and gestural patterns, GfA shows more similarities with artistic practices such as dance and circus (Mateu & Bortoleto, 2017), since it does not measure its artistic-expressive dimension on the basis of a set of regulations.

The GfA artistic-expressive dimension has been mentioned in recent studies and is always linked to its choreographic compositions analysis (Lopes, 2020; Carbinatto & Reis-Furtado, 2019; Scarabelim & Toledo, 2016). Based on Mateu & Bortoleto (2011) proposal, GfA is an expressive motor situation (EMS), combining the motor (physical) and the expressive dimension, that is, a gymnastics activity that incorporates intentionally a poetic, communicative and referential function to its internal logic (Mateu, Garcías, Spadafora, Andrés, & Febrer, 2021; Mateu & Bortoleto, 2017). Therefore, when we attend a GfA festival, most of the performances that we see emerge as an aesthetic experience with deliberate poetic-communicative content.

The EMS includes situations in which motor skills become gestures, communicating messages (poetic function) and may even relate to a theme or any external reference (referential function). Thus, EMS covers a huge number of practices from spontaneous expression (play with toys alone in a room, i.e.) to a maximum codification (rhythmic gymnastics, i.e.) and are characterised by an expressive-communicative intention of

alterity (Mateu & Lavega, 2017). Nevertheless, not all motor situations have this artistic-expressive dimension. According to motor praxeology, this dimension needs to be intentional and constitute a central element in the operativity of internal logic. In Figure 3 below, it is possible to see the classification of motor situations (CAI) along with the artistic-expressive criteria (E).

As highlighted by Mateu & Bortoleto (2011), a determining characteristic of EMS is the absence of opponents, which makes four out of eight categories of CAI lack this expressive-communicative subdomain. The four remaining categories are those that may have an artistic-expressive motor objective: a) CAIE: corresponds to psychomotor situations characterised by the absence of a teammate (C) and/or an opponent (A) (there is no motor interaction), as well as the absence of space uncertainty (for example, a mimicker, a dancer or a solo equilibrist); b) CAIE: psychomotor situations in which protagonists intervene individually, with no teammate (C) and/or opponent (A), but with uncertainty (I) of space to practice the activity (for example, solo dance performances in nature); c) CAIE: sociomotor situations (group practices) that only have teammates (C), without the presence of opponents (A) and that take place in a stable environment, with no uncertainty of space (I) (gymnastics for all); d) CAIE: sociomotor situations (group practices) that have only teammates (C), without the presence of opponents (A) and that take place at an unstable environment, with uncertainty of space (I) (for example, outdoor group dance or dance/climbing).

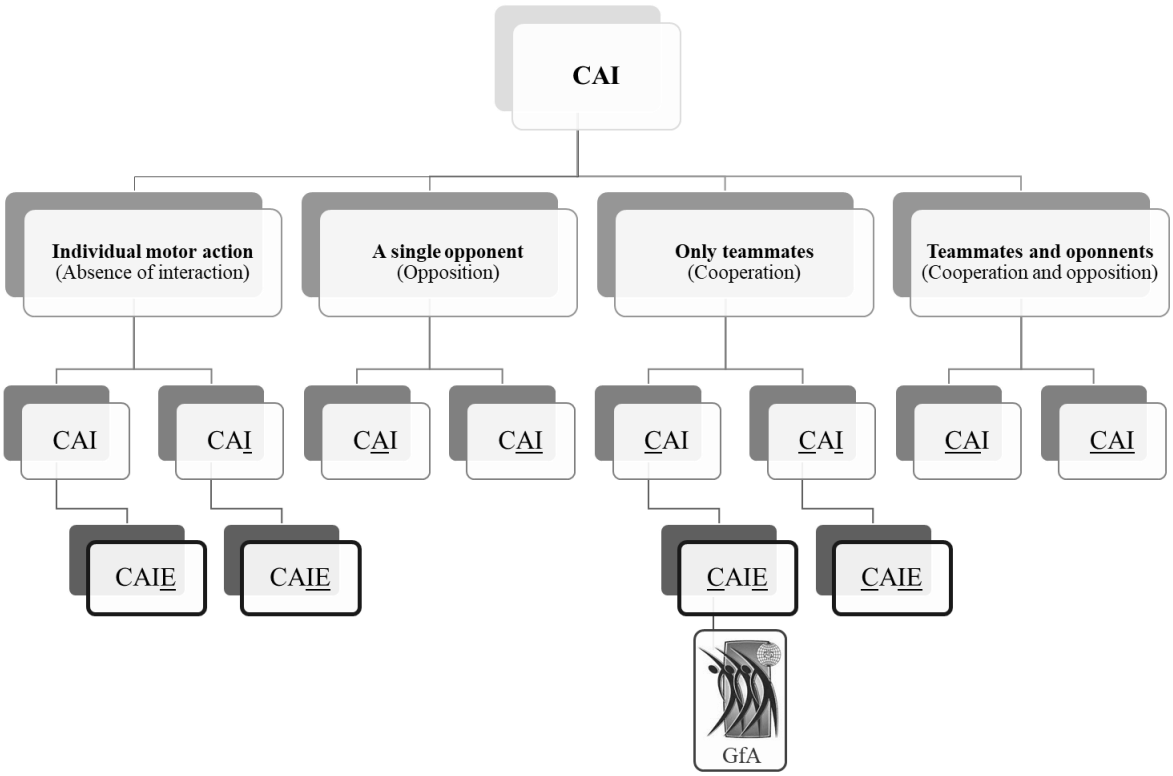

Figure 3. CAI Classification and subdomains of Expressive Motor Situations (EMS). Source: adapted from Parlebas (2001) and Mateu & Bortoleto (2011).

For all EMS it is the referential function that attributes sense to the systems. Thereby, this referential semiotic function models the objectives of these activities to beyond the concrete dimension ("matter") of motor actions, incorporating a subjective layer to all systemic relations and providing them with singularity and expressive specificity. A single walk that can be seen in the return of a football player after taking a shot at goal has only a motor function (move the player from one place to another). Nevertheless, during a theatre performance, while observing an actor walking from one side to the other of the stage in a display of pain over the loss of a close relative, the same motor action is identified (movement in walking), but with a distinct intentionality on the part of the actor. The actor's walk is intentionally expressive; it requires a complex interpretation for its execution, which must be perceived and interpreted by the audience.

Motor actions that comprise these two different ways of walking are deeply distinct and modelled by motor objectives that are also different. The first one has no referential function. The walk represents only a way of going from one place to another and, sometimes, resting while this happens. In the second one, an expressive load is intentionally added to this motor action thus transferring to the observer (the audience) the deep pain of losing a loved one. To enable the expression-communication of this walk, body language needs to build the sense of pain (the feeling of loss), even if, when observed, there are no guarantees of how it will be interpreted by the spectator. The subjectivity that follows the actor's walk requires a subjective interpretation by the audience.

Indeed, EMS is based on semiotricity[1], in this case of referential, poetic and expressive function (Mateu & Bortoleto, 2011, p. 138), not only instrumental function. This expressive dimension linked to semiotricity (Parlebas, 2001) occurs not only through the interaction among individuals during performance (in case of sociomotor situations), but also regarding the relationship with implements and space. Consequently, we may say that in EMS all the systemic organisation/internal logic (Parlebas, 2001) will be established based on the artistic-expressive dimension. Thus, GfA choreographies often intentionally attempt to "build" a scene, showing a story that moves it. Hence, GfA choreographies are commonly themed, combining music and other elements (such as, costumes, makeup and sometimes even scenery), in order to amplify the expression-communication of the theme/message through choreography (Almeida, 2016). GfA performances usually intend to convey a message or a meaning using bodies and movements, and this "communicative project" is designed for each choreography and affects all elements of internal logic.

In this sense, semiotricity is strongly related to the choreographies performed in different gymnastics festivals (Patrício, Bortoleto & Carbinatto, 2016; Wichmann, 2014; Meckbach & Lundquist Waneberg, 2011) and it represents an overlapping of instrumental, poetic, and referential semiotic functions (Mateu, 2010). This set

1 Semiotricity considers the nature of motor situations from the point of view of the application of systems of signs associated with the motor behaviour of participants. Referential semiotricity (approaching and external theme to the practice itself) that is directly related to those artistic-expressive practices (Parlebas, 2001).

of semiotic functions[2] is directly linked to intentionality and, therefore, to the goals of GfA groups and, more specifically, their choreographies. Thus, EMS ends up being driven by a) purpose of the motor action, by b) communication, by c) predominance of the poetic function in communication, by d) referential semiotricity and by d) aesthetic intentionality of the motor action (Mateu, 2010).

THE GYMNASTICS FOR ALL SPORTIVISATION PROCESS AND ITS RELATIONS WITH THE ARTISTIC-EXPRESSIVE DIMENSION

The unfinished sportivisation process previously mentioned is a determining factor not only to characterise GfA as an EMS, but mainly to understand why this artistic-expressive dimension may be developed differently among groups. Thus, there is a significant distinction between the expressive potential of GfA and other kinds of gymnastics, such as rhythmic gymnastics and aerobic gymnastics. Although all of them have been characterised as EMS, in the case of sportivised disciplines, the artistic-expressive subdomain is submitted to Code of Points for each discipline.

The presence of these codes is strongly related to the competitive and, consequently, sportivised character of sports disciplines. Regarding the development of the artistic-expressive aspects, the criteria established in these documents to measure performance directly influence composition of routines and subsequently guide the artistic components of the performances (Mateu & Bortoleto, 2011; Toledo & Antualpa, 2016). For instance, when observing the Code of Points for rhythmic gymnastics, the section dedicated to the artistic components, where the guidelines to evaluate the "composition and artistic performance from the standard of aesthetic perfection" are (FIG, 2022, p. 112), each component of the artistic-expressive dimension is detailed in order to regulate how it should be developed within a routine – the music, the rhythm, the body expression, the character/interpretation, the use of space, the dance steps, the harmony, the connections, among other elements.

This means that, even if gymnastics sports and even figure skating and artistic swimming are recognized, including socially, by its artistic-expressive dimension and, moreover, are characterised as EMS from the theory assumed here, the imposition and enforcement of these codes make it impossible for the primary objective of these sports to have referential functions. The artistic-expressive dimension is an important part of the internal logic of these sports, but it is limited by their rules, which also limit their aesthetic categories.

Due to its unfinished sportivisation process (Silva, Menegaldo, Almeida & Bortoleto, 2021), GfA does not have a regulation to develop its artistic-expressive potential and, thus, it does not have an objective evaluation of these elements. The music, the costumes (which, different from gymnastics sports, do not need to be leotards), the body expression, the use of space (directions, levels and movements), the use of dance and theatre elements, and also elements of other cultural manifestations may be explored and included in GfA choreographies in multiple

2 Semiotic function refers to the general ability to signify and consists of the production (coding) and reception (decoding) of signs. When this ability is applied to motor actions, it is called semiotic function (Parlebas, 2001).

ways (Carbinatto, Soares & Bortoleto, 2016; Pasqua, Hess & Toledo, 2020; Paoliello, Ayoub, Toledo, Bortoleto & Graner, 2014), as long as they are aligned with the expressive project developed by the group, i.e., with the idea/message that the group expects to achieve during a performance. In this sense, while observing the EMS categories proposed by Mateu & Bortoleto (2011), GfA seems to move between different categories, for example, a *quasi-expressive sport* (predominantly expressive-communicative objective) and *expressive sport* (predominantly instrumental objective).

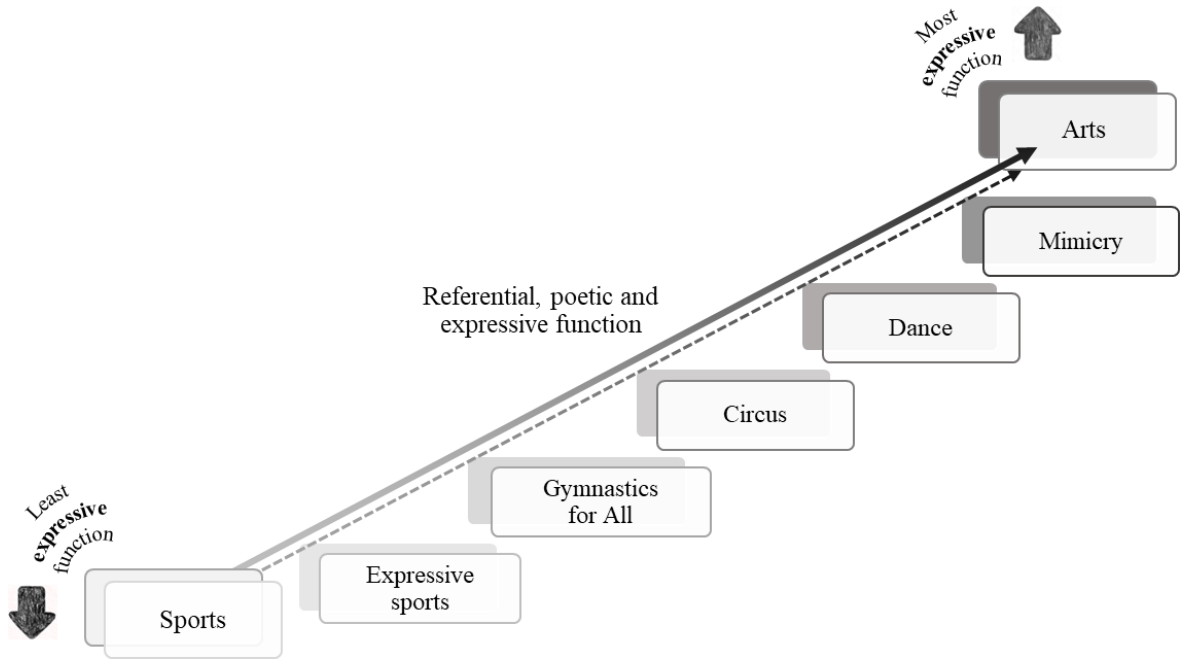

Figure 4. Continuum of Expressive Motor Situations (Mateu, 2010).

These categories are proposed from semiotic functions of each motor situation building a notion of *continuum* (Mateu, 2010). In this *continuum*, which has Sports at one side and Arts at the other (see Figure 4), it is possible to identify the increased poetic, expressive and referential functions as we approach the end related to artistic practices. GfA comes right after *expressive sports*, bringing it closer to different art forms (circus and dance). Nevertheless, this likely approximation of GfA to other artistic forms comes from the development of its expressive potentiality. However, as we mentioned before, this development may vary among GfA groups.

The prevalence of expressive, poetic, and referential functions is, as other elements of the GfA internal logics, conditioned by choices, goals and strategies established by each group (Menegaldo & Bortoleto, 2020), since the emergence of the symbolic function related to metacommunication is not imposed. This dimension may, and, to our understanding, should make up the choreographies. However, this will depend on the goal of each group not only regarding choreographic composition, but also on the

investment in dynamics and teaching proposals on expressive functions during training and daily group activities.

In that sense, although the expressive function becomes visible in choreographic compositions, it can also compose the group's processes (Almeida, 2016; Lopes, 2020; Paoliello, Ayoub, Toledo, Bortoleto & Graner, 2014). The development of expressive skills can be worked on during collective proposals of choreographic compositions, exploration of traditional and no-traditional apparatus, creative processes of choreographic thematization. In addition, theatrical games and body expression dynamics are also examples of strategies that drive the expressive project and the development of the artistic-expressive dimension within the groups.

This is why it is not possible to place GfA at a single point on the EMS *continuum* (Figure 4). When we watch different performances in a gymnastics festival, it would be possible to state that this expressive subdomain has different "weights" in different choreographies. In some groups, semiotic, referential, expressive, and even poetic functions prevail, without reducing praxic or instrumental functions. Nevertheless, in some groups, due to their technical and composition choices, praxic and instrumental functions are emphasised, minimising the expressive potential from a semiotic perspective (Parlebas, 2001; Mateu & Bortoleto, 2011). Thus, within the same festival, distinct GfA choreographies may be located in different points on this *continuum*. This is not a problem; it just corroborates the GfA sportivisation particularities and confirms the fact that the artistic-expressive dimension is recognised and developed differently in different GfA groups and choreographies.

FINAL CONSIDERATIONS

Similar to figure skating, artistic swimming and several other gymnastics sports, GfA is recognized as an expressive motor situation (EMS). Nonetheless, according to all concepts previously discussed, GfA combines features of gymnastics sports and those of artistic practices, which would explain the particular dialogue this gymnastics has with the sportivisation process (Silva, Menegaldo, Almeida & Bortoleto, 2021), as well as with its movement at different points of the *continuum* of expressive practices (Mateu, 2010).

Given the flexible aspect of the social contract that guides the GfA activities, multiple internal logics are allowed for its development (Menegaldo & Bortoleto, 2020). In this sense, GfA has a distinct internal logic that differs from other sportivised gymnastics disciplines, once it enables multiple expressive forms that depend on choices and approaches adopted by each group. Still, in all cases, a cooperative sociomotor gymnastics activity is observed, driven by a constant search for optimising the communication among participants, in order to favour the communication with the audience to convey what is planned for each choreographed composition – regarding emotions, a message, a theme or a story.

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REFERENCES

Adams, M. (2018). *Artistic Impressions*: Figure Skating, Masculinity, and the limits of Sport. Toronto: University of Toronto Press.

Almeida, T. L. (2016). *Composição coreográfica coletiva e tematização como estratégias pedagógicas para o ensino/aprendizagem da acrobacia coletiva* [Collective choreografic composition and thematization as pedagogical estrategies for Teaching/learning of collective acrobatics]. (Master thesis). Faculty of Physical Education of University of Campinas, Campinas. DOI: https://doi.org/10.47749/T/UNICAMP.2016.971045.

Bento-Soares, D., & Schiavon, L. M. (2020). Gymnastics for All: different cultures, different perspectives. *Science of Gymnastics Journal*, *12*(1), 5-18. DOI: https://doi.org/10.52165/sgj.12.1.5-18.

Bortoleto, M. A. C., Heinen, T., Menegaldo, F. R., Schiavon, L. M., Toledo, E., Oliveira, M. S., & Pascua, L P M. (2019). What motivates people to participate in a Non-Competitive Gymnastics Festival? A case study of World Gymnaestrada. *Science of Gymnastics Journal*, *11*(1), 15-22.

Carbinatto, M. V., & Reis-Furtado, L. N. (2019). Choreographic process in Gymnastics for all. *Science of Gymnastics Journal*, *11*(3), 343-354. DOI: https://doi.org/10.52165/sgj.11.3.343-353.

Carbinatto, M. V., Soares, D. B., & Bortoleto, M. A. C. (2016). Gym Brasil: festival nacional de Ginástica para Todos. *Motrivivência*, *28*(49), 128-145. DOI: https://doi.org/10.5007/2175-8042.2016v28n49p128.

Chiat, L. F., & Ying, L. F. (2012). Importance of music learning and musicality in rhythmic. Gymnastics. *Procedia: Social and Behavioral Sciences*, *46*. DOI: https://doi.org/10.1016/j.sbspro.2012.06.037.

Domingues, L. S., & Tsukamoto, M. H. C. (2021). Ginástica para todos e lazer: onde seus caminhos se cruzam? *Corpoconsciência*, 171-186. DOI: https://doi.org/10.51283/rc.v25i1.11921.

Fédération Internationale de Gymnastique (FIG). (2020). *Manual of Gymnastics for All*.

Fédération Internationale de Gymnastique (FIG). (2022). *Rhythmic Gymnastics*: Code of Points 2022-2024.

Leandro, C., Avila-Carvalho, L., Sierra-Palmeiro, E., & Bobo-Arce, M. (2016). The evaluation rules in the view of the Rhythmic Gymnastics judges. *Journal of Sports Sciences*, *4*, 232-240. DOI: https://doi.org/10.17265/2332-7839/2016.04.007.

Lopes, P. R. (2020). "*A gente abre a mente de uma forma extraordinária*": potencialidades da pedagogia freiriana no desenvolvimento da Ginástica para todos ["A gente abre a mente de uma forma extraordinária": potencialidades da pedagogia freiriana no desenvolvimento da Ginástica para todos]. (Doctoral dissertation). Faculty of Physical Education and Sport of University of São Paulo, São Paulo. DOI: https://doi.org/10.11606/T.39.2020.tde-13052021-142814.

Manos, M., Popescu, L. (2014). The Impact Induced by the 2009-2012 FIG Code of Points on Artistic Compositions in Rhythmic Gymnastics Group Events. *Procedia: Social and Behavioral Sciences*, *117*, 300-306. DOI: https://doi.org/10.1016/j.sbspro.2014.02.217.

Manos, M., Popescu, L. (2020). Impact of FIG Code of Points on exercise composition in group Rhythmic Gymnastics. *Physical Education, Sport and Kinetotherapy Journal*, *59*, 507-521.

Mateu, M. (2010). *Observación y análisis de la expresión motriz escénica*. Lógica interna de los espectáculos artísticos profesionales: Cirque du Soleil (1986-2005) [Observation and analysis of scenic motor expression. Internal logic of professional artistic shows: Cirque du Soleil (1986-2005)]. (Doctoral dissertation). University of Barcelona, Barcelona.

Mateu, M., & Bortoleto, M. A. C. (2011). La lógica interna y los dominios de acción motriz de las situaciones motrices de expresión (SME). *Emancipação*, *11*, 129-142. DOI: https://doi.org/10.5212/Emancipacao.v.11i1.0010.

Mateu, M., & Bortoleto, M. A. C. (2017). Lá lógica interna del Circo: rasgos fundamentales. In Ribas, J. F. M. (Eds.). *Praxiologia Motriz na América Latina*: aportes para a didática na Educação Física. Ijuí: Unijuí.

Mateu, M., Garcías, S., Spadafora, L., Andrés, A., & Febrer, E. (2021). Student moods before and after body expression and dance assessments: gender perspective. *Frontiers in Psychology*, *11*. DOI: https://doi.org/10.3389/fpsyg.2020.612811.

Mateu, M., & Lavega, P. (2017). Lógica interna de los lenguajes artísticos motores: panorama actual. *Tándem Didáctica Educación Física*, *55*, 7-13.

Mechbach, J., Lundquist Waneberg, P. (2011). The World Gymnaestrada: a non-competitive event. *Scandinavian Sport Studies Forum*, *2*, 99-118.

Menegaldo, F. R., & Bortoleto, M. A. C. (2020). Ginástica para todos: o que a Praxiologia Motriz diz sobre isso? *Conexões*, *18*. DOI: https://doi.org/10.20396/conex.v18i0.8659110.

Menegaldo, F. R. (2022). *A dimensão social da Ginástica para Todos: o que move as relações sociais no interior dos grupos de prática?* [The social aspects of Gymnastics for All: what drives the relations build into the groups?] (Doctoral dissertation). Faculty of Physical Education of University of Campinas, Campinas.

Paoliello, E., Toledo, E., Ayoub, E., Bortoleto, M. A. C., & Graner, L. (2014). *Grupo Ginástico Unicamp*: 25 anos. Campinas: Unicamp.

Parlebas, P. (2001). *Juegos, deporte y sociedad*: léxico de praxiología motriz. Barcelona: Paidotribo.

Parlebas, P. (2021). The Universals of Games and Sports. *Frontiers in Psychology*, *21*. DOI: https://doi.org/10.3389/fpsyg.2020.593877.

Pasqua, L. de P. M., Hess, C. M., & Toledo, E. de. (2020). Gingando com a Ginástica para Todos: aproximações e singularidades. *Corpoconsciência*, *24*(1), 153-169.

Patrício, T. L. (2021). *Ser no mundo e ser com o outro: experiências vividas em um festival de ginástica* [Being in the world and being with another: lived experiences in a gymnastics festival] (Doctoral dissertation). Faculty of Physical Education and Sport of University of São Paulo, São Paulo. DOI: https://doi.org/10.11606/T.39.2021.tde-16032022-170822.

Patrício, T. L., Bortoleto, M. A. C., & Carbinatto, M. V. (2016). Festivais de ginástica no mundo e no Brasil: reflexões gerais. *Revista Brasileira de Educação Física e Esporte*, *30*(1), 199-216. DOI:

https://doi.org/10.1590/1807-55092016000100199.

Silva, H. M. R., Menegaldo, F. R., Almeida, T. L., & Bortoleto, M. A. C. (2021). O processo de esportivização das práticas ginásticas: particularidades da Ginástica para todos. *Acción Motriz*, *26*, 52-63.

Toledo, E. de, & Antualpa, K. (2016). A valorização dos aspectos artísticos do Código de Pontuação na ginástica rítmica: uma análise das últimas três décadas. *Revista Brasileira de Educação Física e Esporte*, *30*(1), 119-131. DOI: https://doi.org/10.1590/1807-55092016000100119.

Wichmann, A., & Jarvis, N. (2015). Commitment, expertise, and mutual recognition: oscillating sports tourism experiences of performing and watching at the World Gymnaestrada. *Journal of Sport & Tourism*, *19*. DOI: https://doi.org/10.1080/14775085.2015.1124797.

Wichmann, A. (2014). *Sports tourism participation at the World Gymnaestrada*: an expression and experience of community and identity. (Doctoral dissertation) – University of Brighton, Brighton.

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THE BALANCE BEAM AS AN ARTISTIC GYMNASTICS APPARATUS FOR WOMEN: FROM THE ORIGIN TO ITS CONSOLIDATION

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Abstract

This article seeks to increase understanding of the historical development of artistic gymnastics, particularly women's participation in the sport. Through historical research, we analyzed the genesis and inclusion of the balance beam apparatus as a core component of this gymnastics discipline. The period under study ranged from the 1896 Olympic Games to the years between 1952 and 1964, which are known for the stabilization of the competitive characteristics of women's artistic gymnastics. We observed that, in the beginning, as in sport in general, women were excluded from this cultural experience. However, throughout history, we observed that the balance beam became a protagonist of artistic gymnastics, becoming a stage for both reinforcing and confronting what women could and could not do in this gymnastics discipline.

Keywords: *Women, gymnastics, sport history.*

PRELUDE

Modern sport emerged in an exclusively male context. Eitzen (2009) mentions that, due to these historical roots, men have been encouraged to engage in the sport universe from an early age. However, women were denied access to sports during the renaissance (Vogler & Schwartz, 1993), and they still fight for gender equality today.

It's important to emphasize that when women entered sports, they were encouraged to avoid those disciplines that did not promote the image of femininity. Simões, Conceição and Nery (2004) recall that gymnastics was also part of an exclusively male domain. And, as in other sports, women were excluded from gymnastics' social, cultural and political experience under eugenic allegations. The admiration of strength, disciplined bodies, physical training, and athletic beauty was attributed to men´s universe, as if they were

naturally prone to have these characteristics (Schpun, 1998)

In this vein, the core of German Gymnastics Movement in the beginning of the 19th century, both girls and women were not granted access to gymnastics as proposed by Friedrich Ludwig Jahn at the Hasenheide in Berlin (Pfister, 2000). In this place, under large pine trees and surrounded by bushes, Jahn built a gymnastics camp in 1811, with large apparatuses that formed the basis of the modern artistic gymnastics. Publio (2005) credits Jahn with spreading gymnastics apparatuses around the world.

It is important to highlight that, in this initial period of German gymnastics, women were restricted to the role of spectators. According to Pfister (1999), the emphasis given by the "father of German gymnastics"[1] to military preparation and his patriotic goals kept women away from the open air area designed for gymnastics activities, the *turnplatz*. Besides these factors, the author alludes that Jahn's proposed activities were considered unsuitable for the "fragile sex".

Despite this stigmatized perspective of weakness and fragility, women gradually gained their place in gymnastics. But, they were restricted to a form of gymnastics that only promoted exercises aimed at the preservation of decency and femininity.

Around 1850, Huguenin (1981) cites that the number of gymnastic societies which contemplated women increased and kept growing until the end of the 19th century. The gymnastics festivals and, also, the work of gymnastics educators who promoted gymnastics for women were essential in this process of inclusion (Huguenin, 1981).

From Hagelin's work (1995), we learn that Phokion Heinrich Clias, Adolf Spiess and Johann Adolf Ludwig Werner were some of the educators who contributed to this movement. We highlight that in Spiess' work, in 1834, boys had gymnastics classes from a very young age at the Burgdorf School in Switzerland, which was led by the reformer and creator of the kindergarten Friedrich Froebel. In this environment, Hagelin (1995) suggests, it did not take long for the girls to be included due to their interests. Hence, "special classes were formed and suitable exercises devised to meet their needs" (p. 156).

During the 19th century, women gained gradual access to gymnastics. However, gymnastics for girls was guided by societal values, so gender bias influenced the exercises. Pfister (1999) alludes, for example, to the care that teachers should take with women by limiting the students' movements to protect decency.

Eitzen (2009) remarks that the society expected women to nurture characteristics, such as kindness, amiability and passivity, which explains why women were guided toward sports that emphasized femininity. Pfister (2000) adds that "women were not allowed to compete in those sports that involved visible exertion, physical strength or bodily contact" (p. 4). Also according to the author, the femininity of women athletes was something that should be protected "as far as possible" (Pfister, 2000, p. 5). Thus, women had access to sports as long as they did not lose their grace, delicacy and

[1] We opted to put the expression "father of German gymnastics" in quotes, because although this expression is present in the literature about German gymnastics, recent historical studies have questioned and avoided the use of this expression, mainly because it reinforces an individual and personalized interpretation of historical events.

beauty, which are still characteristics linked to the supposed feminine essence (Goellner, 2007).

Towards the end of the 19th century, women gradually found their space in gymnastics. However, it took a long time for female athletes to be accepted in the competitions. This happened in 1928, at Amsterdam Olympic Games, when the first international competition for women in artistic gymnastics was held (Huguenin, 1981; Pfister, 2000).

In this period, sports for women were guided by physical and psychological concerns which were perceived as natural and distinct between men and women (Pfister, 2000). Furthermore, women sports maintained the premise that the important thing was to prepare girls and women for their future roles in society as mothers, wives, and worthy citizens.

Pfister (2000) claims that "enjoyment of sport and team spirit were considered more important than personal performance and achievement" (p. 8), a stance that helps us to understand why women would not compete in artistic gymnastics individual events until 1952. Goehler (1978) suggests that including individual events in the early period of women's artistic gymnastics (WAG) competitions was too daring for the time.

When analyzing the 1950s, we observe that this decade is pivotal for the WAG, as it led to the incorporation of individual competitions, and the competitive format restricted to the four apparatuses (vault, uneven bars, balance beam and floor) came into force (Huguenin, 1981). Previously, women team competitions included athletics events (long jump, 60 meters race, javelin throw) as well as gymnastics apparatuses: vault, rings, symmetrical and asymmetrical parallel bars, balance beam, team free exercises and team exercises with hand apparatuses.

Even within this range of events in WAG team competition at that time, the balance beam was a part of it. It was also present in the genesis of the German Gymnastics Movement back at the end of the 18th century (Herholz, 2020). In 1952, this apparatus was consolidated as an individual event of artistic gymnastics for women (Huguenin, 1981). But, it is important to highlight that this apparatus was initially systematized for men.

Searching for a better understanding of the origins and consolidation of balance beam in artistic gymnastics, this study aimed to analyze the historical course of this gymnastics event over time, seeking for elements that will help us understand why this gymnastics apparatus was included in women AG competitions.

The research initially spanned from the first Olympic Games, in 1896, to the period of 1952-1964, which is characterized by the stabilization of competitive nature of WAG. According to Kerr (2003), during Helsinki Olympic Games, in 1952, the competitive program included the four apparatuses (floor, balance beam, vault, and uneven bars) in individual events, all around and team competition. Moreover, we believe that the International Gymnastics Federation (FIG) considers the period from 1952 to 1964 as the period that marked the entry of gymnastics into the modern era (Huguenin, 1981). Despite this historical delimitation, started at the emergence of the modern Olympic Games, our study used complementary sources that goe further back into the past, such as the recognized work "Gymnastik für die Jugend" of 1793 (Guts Muths, 1793).

DRAWING OUT THE HISTORICAL SOURCES APPROACH

We consider that when studying history, specifically related to sport, the objectives include the following: to provide a broader perspective about the phenomenon under study, and, also, to make us more aware of the development of the cultural element under consideration.

Luca (2021) suggests that "thanks to the traces and indications that have reached the present researchers can propose explanations about what happened" (p. 8). According to the author, any event from the past has the potential to be revisited, inspiring and resulting in new researches. We know that historical knowledge is dynamic, which allows each generation to reread, reinterpret, and rewrite the past.

In this regard, based on the potential presented in this study, we chose the methodological path of historical research that, according to Richardson (1999), can be oriented to the production of new knowledge through the elaboration of new ways of understanding certain phenomena of the past, as well as shedding light on new perspectives of how these phenomena have developed.

Additionally, Isaac and Michael (1981, p. 44) claim that the purpose of historical research is to revisit the past by “collecting, evaluating, verifying, and synthesizing evidence to establish facts and reach defensible conclusions, often in relation to particular hypotheses". We can see that this methodological approach is concerned with understanding facts that occurred in the past in an attempt to extract general principles that can guide society in the present and in the future (Gressler, 2003).

We consider that this method of research allows us to interpret with a certain degree of depth the existing social structures, which should not be restricted by and thought of according to the criteria of norms or rules in force in today's society. Gressler (2003) states that historical research "contributes to the knowledge of the present in the light of past events" (p. 50). And, it allows reflections and verifications of ruptures and permanencies that were established in the course of history.

Barros (2019) points out that, in order to understand the core of history, we must analyze elements of the past in order to properly interpret its social aspects. It is worth mentioning that "these vestiges, evidences, written texts, and material objects—capable of manifesting continuities between the two temporalities in the most diverse forms—are the so-called "historical sources" (Barros, 2019, p. 8). In other words, they are the "marks of history" (p. 15), which can be simple or complex, and can range from textual documents to archaeological remains and pictorial representations to material culture sources. However, we must not forget that in contemporary times, historical sources can also be found in virtual environments.

For the purposes of our study, we consulted gymnastics programs, guidelines and reports of each edition of Olympic Games that were available at the World Olympic Library and also at the LA84 Foundation.

Table 1
List of consulted documents that were obtained from the World Olympic Library and from LA84 Foundation.

EDITION	PROGRAM	OLYMPIC REPORT
1896	x	x
1900	x	x
1904		x
1908	x	x
1912	x	x
1920	x	x
1924	x	x
1928	x	x
1936	x	x
1948	x	x
1952	x	x
1956	x	x
1960	x	x
1964	x	x

In addition, we examined the pioneering magazines in the field of gymnastics, namely: The Modern Gymnast and Mademoiselle Gymnast. They were released in 1956 and 1963, respectively, and were combined into Gymnast magazine, which included both men's and WAG. Currently, the magazine is called International Gymnast, a change that occurred in 1972. It is worth mentioning that the magazines from the period of analysis are available in the researchers' collection and some copies can be accessed on the USA Gymnastics online library.

We corroborate Luca (2021) that "the paths that lead from an area to the theme and from this to the object presuppose the reading and the mastery of specific biography" (p. 84). Our study included extensive bibliographic research in the researchers' personal collections and on the Open Library managed by the Internet Archive. Furthermore, we consulted the Periodical Portal of Coordination for the Improvement of Higher Education Personnel (CAPES) in Brazil which provides access to the national and global scientific literature in different databases.

Many of these secondary sources were published in different historical periods, from 1793 to 1964. However, they all converge in portraying historical moments of WAG that supported the development of the research, filling in its gaps. They are not direct materials for the study's theme, such as the documents obtained from the World Olympic Library and from LA84 Foundation. Instead, they are works written by other authors who have reflected on the same theme we are studying, or that contain important data to support our study (Barros, 2015).

In addition to the primary sources, we also conducted bibliographical research, also known as secondary research (Godoy, 1995). We selected, classified, and archived topics of interest to the study that were published, such as: printed documents, scientific articles, books, master's degrees and doctoral theses. This approach allowed us to obtain information that clarified the primary documents, as well as helped us

contextualize the path of women in artistic gymnastics.

The sources obtained and mobilized in the development of this research consisted of choices that supported the text's argumentation and had traces of the past that needed to be purified. In the conception of Le Goff (2013), these traces remain mute and encapsulate a signal that can be decoded and interpreted. However, as Luca (2021) warns, they are not definitive, since they are articulated in the moment and by the individuals that manipulate them. In this a way, we went through gymnastics literature in search of vestiges of the past. We did not discard what has already been made, but we tried to join and consider what has been produced in search of generating an understanding about the phenomenon

FROM THE GERMAN FIELDS TO THE SPORTS STAGES

Herholz (2020) claims that the first balance beam appeared in the period of German gymnastic systematization in Johann Christoph Friedrich Guts-Muths' work. According to the author, Guts-Muths dedicated a chapter of his book "Gymnastics for Youth" to balance training through the use of this device. The balance beam that Guts-Muths used for exercises (Figure 1) was a pine trunk, round in shape, placed horizontally and about 20 meters long.

Figure 1.
Gymnasts exercising on the balance beam. Photo from the first edition of Guts Muths' book "Gymnastik für die Jugend" (1793).
Note. Adapted from Guts-Muths (1793, p. 400).

According to Tonry and Tonry (1980), this apparatus was later adapted by Friedrich Ludwig Jahn in 1811, who renamed it "*Schwebebaum*" (Herholz, 2020), balance tree. Kaiamakamis et al. (2009) note that in Jahn's book entitled *Die Deutsche Turnkunst*, published in 1816 with the assistance of his student and collaborator Ernst Eiselen, four pages were dedicated to the balance beam and its exercises, which can be taken as an indication of the importance assigned to balance and this apparatus by the "father of German gymnastics" (*turnvater*).

Herholz (2020) observes that the length of balance beam in Jahn's gymnastics camp was 12 meters with a diameter of approximately 25cm. Also, according to the author, the wooden log used by Jahn was made of resinous smooth pine. The log was screwed between pairs of wooden posts (Figure 2), which could be arranged at different heights

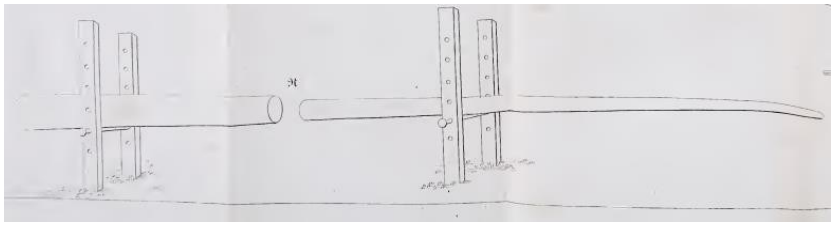

Figure 2. Balance beam, *Schwebebaum*, in *Die Deutsche Turnkunst zur Einrichtung der Turnplätze*. Source: Jahn and Eiselen (1816).

In his book, Jahn described that the apparatus should be neither stable nor unstable, as it was used to refine balance during movement (Herholz, 2020; Kaimakamis et al., 2009). According to Kaimakamis et al. (2009), Jahn suggested that the exercises performed on balance beam should first be learned on floor for safety reasons. Jahn also made suggestions about the body and head positions, the gaze direction, and the feet placement when walking on the balance beam. Similar features can be found in current works that teach how to exercise on this apparatus.

During this period, women gymnastics was of no concern, mainly due to the emphasis on military preparation and the nationalistic goals related to the unification of Germany. It was up to women to gain their space with the support of educators and followers of the German Gymnastics Movement, started by Guts Muths and Jahn, such as: Phokion Heinrich Clias, Adolf Spiess and Johann Adolf Ludwig Werner (Hagelin, 1995), who also used the balance beam in their gymnastic activities.

While the initial use of this apparatus was attributed to Guts Muths and Jahn in the middle of the 19th century, Takemoto and Hamada (1958) claim that it was Adolph Spiess who first conceived the use of balance beam for women at a public school in Basel (Figures 3 and 4). The authors refer to the Spiess' book, published in 1846, which has engravings of girls on this apparatus. But Takemoto and Hamada (1958) also mention that our ancestors used structures that challenge balance long before, either in the a form of entertainment or as children's play.

Figure 3 and 4.
Gymnastic activities with female participation in Adolf Spiess' work.
Note. Adapted from Spiess (1847).

We note that Pehr Henrik Ling, the predecessor of the Swedish Gymnastics movement, also introduced the balance

beam in his work. Hagelin (1995) mentions the Dane Franz Nachtegall's influence on Ling's career, since the Swede attended his private gymnastic institute in Denmark, the first in Europe, which was greatly influenced by Guts Muths' work that already used the balance beam in Germany.

Herholz (2020) cites that the balance beam was called "balansribba" in Sweden, and that the exercises used to promote balance were also performed on the Swedish bench, an adaptation used until nowadays. Herholz (2020) adds that exercises on the balance beam were part of the daily routine in Swedish gymnastics method, mainly due to the versatility of this apparatus that facilitated the training of other physical skills in addition to balance.

Swedish Gymnastics Movement also supported women inclusion, and the use of balance beam as an apparatus. In Pfister's words (1999), "although Ling envisioned his program as solely for men and boys, Swedish gymnastics eventually became the seedbed of women's physical education" (p. 444). Mostly, because "it was hoped that "Swedish gymnastics" would provide inexpensive rational discipline without militaristic associations. The ideal was "noncompetitive physical development without sacrificing femininity" (p. 445).

It is worth mentioning that Anton Santesson is considered the first to foster gymnastics for women in Sweden. Among his published works in the 1850s and 1860s, the book "Gymnastics for Young Women and Girls in Schools" of 1866 influenced other nations to include women in gymnastics (Westberg, 2018). In Santesson's conception, "gymnastics fostered strong women, who would give birth to strong sons. Moreover, women would, thanks to gymnastics, be able to provide their sons with correct clothing, food, and physical education" (p. 266).

In Sweden, the balance beam was instituted for women on the principle that it would promote civility and grace, as guided by Santesson in his work released in 1866 (Westberg, 2018). This was a vision that, according to Westberg (2018), contrasted with men's training that advocated the development of courage and intelligence.

The above mentioned principles guided women´s performances in the period when gymnastic festivals of the 19th century emerged and women used the balance beam in team exhibitions. However, we observe that at the time of the first German championship with women participation, in 1921, this apparatus was not in the program. It was an absence that lasted until 1934, when the first World Championship was held with women participation (Herholz, 2020).

The balance beam was introduced at the World Championship program with only 8 cm width (Herholz, 2020). As a highlight of this competition, the Hungarian gymnast Gaki Meszaros won the audience's admiration by performing a split on the beam. It surprised everyone as she was the first to perform it at an event of this nature (Huguenin, 1981; Gutman, 1996; Herholz, 2020; Porter, 2004).

Later, in the second Olympic Games with women participation in 1936 (HUGUENIN, 1981), gymnasts used the balance beam in the team competition. It was something that also occurred in London, in 1948, when the Olympic Games returned after the Second World War. The apparatus was approximately 5 meters long, 10cm wide and 1.20m high

(The Organising Committee for the Xiv Olympiad, 1948). Goodbody (1982) mentions that the artistic gymnastics competition in London was supposed to have taken place at Wembley Stadium, but due to the storm it was held indoor for the first time.

Still at the 1948 Olympic Games, the competition regulations stated that free exercises on the balance beam should include 4 or 5 difficulty elements, and any use of force in exercise was undesirable. The preference should be for dynamic movements (The Organising Committee for the Xiv Olympiad, 1948).

This quest to distance women from the strength component of exercises was not only related to biological aspects, but also to social and psychological ones. It was grounded in a stigmatized view of women. Thus, gymnasts had to comply with feminine stereotypes which, according to Simões, Conceição, and Nery (2004), have "negative connotations, such as fragility, sweetness, vanity, and shyness" (p. 64). The exhibition of strength elements would contradict this vision of woman in the society.

The routines were limited to rolls, poses, and simple dance movements. More dynamic movements were only possible with changes in the balance beam design. Porter (2004) cites that "women gymnasts wanted firmer footing and safer conditions to perform dazzling moves on the beam, and the rule-makers agreed." (p. 8). Thus, the width of the balance beam was ratified at 10cm and there were no more competitions with 8 cm width as previously observed.

In this period, due to its characteristics, Takemoto and Hamada (1958) point out that this apparatus became one of the symbols of WAG. Especially in the 1950s when the Union of Soviet Socialist Republics' entrance in this sport with an artistic style that showed influences of *ballet*. We observed previously that this apparatus was a beam for balance, with little risk and low complexity elements. This was mainly due to the idea that it should maintain and develop a style of gymnastics aligned with the "limitations" of women's bodies, in line with the societal biases back then, as well as reduce risk and restrict the use of force (Prestidge, 1979).

All these limitations indicate that women had access to competitive artistic gymnastics, but the patriarchal society resisted their presence by limiting what they could or could not do on the apparatus. There was a concern that women would be stripped of their feminine qualities if they went in the direction of men's sport that could masculinize them (Simões, Conceição, & Nery, 2004). Simões (2004, p. 30) also reflects that "the feminine tendency to gain social projection always had an uncomfortable alliance with the masculine sense within the sport context as a social reality", which leads us to wonder whether there men were afraid to share the spotlight and the apparatus with women gymnasts.

In 1952, at the Helsinki Olympic Games, the competition program started to include women's individual competitions in the four apparatuses: floor, vault, balance beam and uneven bars (Huguenin, 1981). We point out that these changes had been decided at the 28th FIG Congress held in Stockholm in 1949.

In Finland, the balance beam rules specified that exercises should last between 1 minute 30 seconds and 2 minutes, the gymnast had to use the

surface 5 meters long set at the height of 1.20 meters. And the routine should not:

'*be carried out at too slow and monotonous rhythm, but must be full of life and make use of the entire body. The exercise must include sitting and lying positions, steps and running, jumping, turning, with some confirmed positions, without in any way allowing these latter to predominate over the other movements.*' (Organising Committee for the Olympic Games Helsinki, 1952, p. 51)

Four years later, at the Melbourne Olympic Games, the artistic component of this gymnastics discipline increased as stated in the report of this Olympic edition (Organising Committee for the Olympic Games Melbourne, 1956). The olympic champion on the balance beam was Agnes Keleti from Hungary, who was 35 years old at the time: "The fact that years of practice are required to attain perfection and control in advanced gymnastics, was amply demonstrated by the beauty of movement reached in maturity by Agnes Keleti" (Organising Committee for the Olympic Games Melbourne, 1956, p. 476).

Nunomura (2008) reports that the 1956 balance beam champion, Agnes Keleti, became the first heroine of WAG, and also became an icon of longevity among gymnasts. At this same competition the first cartwheel was performed on the balance beam, a feat accomplished by Eva Bosáková from the Czech Republic, former Czechoslovakia. This element can be understood as the first example of pre-acrobatic skills in this gymnastics event. Nowadays, this element would be named after her in the Code of Points.

In the early 1960s, the balance beam underwent some modifications. This apparatus continued to be made of solid wood and, as Oliveira (2014) states, it had its sides curved. This change was introduced in the rules of 1960 Olympic Games in Rome (Organising Committee for the Olympic Games Rome, 1960). Hence, following the prescribed measures of height (1.20 meters), length (5 meters) and width of the top surface of the apparatus (10 cm), the rules also included specifications related to the balance beam body, which should be rounded and 13 cm wide at the widest point.

In Italy, the balance beam champion was Eva Bosáková, the first great icon of WAG in Czechoslovakia (Czech Republic). Goodbody (1982) cites that Eva Bosáková represented the best of Czech gymnastics in that period. Due to her success, she had an opportunity to invitd girls to participate in the sport in a television appearance. One of the young Czechoslovakian (Czech) spectators was Vera Caslavska, who later became the next Olympic balance beam champion in 1964.

Simons (1995) believes that Caslavska was a milestone in WAG that started a new era. In this period, the routines acquired a more dynamic and acrobatic structure. According to Haycock (1991), Vera Caslavska's style and personality impacted greatly the sport around the world, and she certainly was a major contributior to the popularization of the WAG. Oliveira (2014) mentions that Caslavska was a woman with adult-like features, just like Eva Bosáková, an aspect that contrasts with the childish appearance of gymnasts who dominated the sport from the 1970s onward.

The balance beam apparatus on which Vera Caslavska became an Olympic champion in 1964 by performing bridges, jumps, choreographic movements, balances, spins, and the cartwheel back layout dismount, was ruled by the same specifications as stipulated by the 1960 XVII Olympiad Games Organizing

Committee (Comite D'organisation des Jeux de la XVIII Olympiade, 1963). This demonstrates stability in the morphological aspects of balance beam through these Olympic cycles.

The Louis Perschke Company, in its advertisement (Figure 5) published in The Modern Gymnast (1963), provided some specifications of the their beam, such as: its height could be adjusted from 91 cm to 1.20 cm, an aspect that facilitated initiation and training; its length was 5 meters; with a walking surface of 10 cm wide, and its sides were rounded. The company claims that all these measurements were in accordance with the Olympic specifications.

Figure 5.
Louis Perschke advertisement.
Note. Adapted from The Modern Gymnast (1963).

Although there was a tendency for this apparatus to develop in the direction of pre-acrobatic elements, which were displayed in free exercises during the 1964 Olympics, we found that at these games, the focus of the compulsory routine remained on the body and dance elements, such as: displacements, waves, spins, rolls, balances, and jumps (Figure 6).

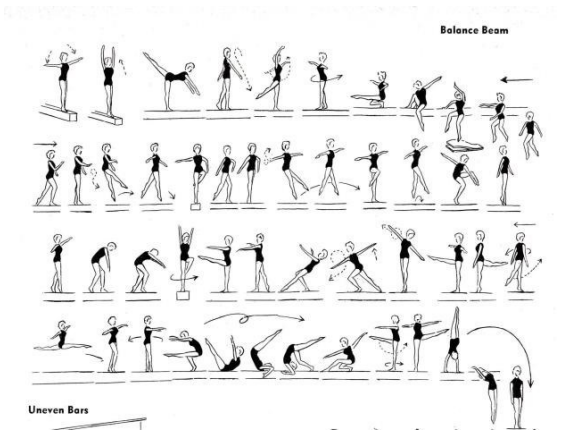

Figure 6.
1964 Olympics compulsory routine.
Note. Adapted from Modern Gymnast (1963).

Takemoto and Hamada (1958) suggest a few reasons for this decision to limit the development of this apparatus through compulsory exercises. The authors exemplify that in Germany there was thinking that flips, handsprings, and excessive flexibility could be harmful to women in physical and psychological ways. But, Takemoto and Hamada (1958) claim that there was no evidence of such harm, either from the medical profession or from the German Gymnastics Federation. It was a view that was not shared by the Union of Soviet Socialist Republics, since scientists in that country considered WAG harmless (Takemoto & Hamada, 1958).

In addition to this way of thinking about female`s athlete body and her place in society, we notice that the balance beam itself did not support the development of acrobatic performance at the time. This equipment was made of a polished laminated wood that did not provide firmness to the feet during execution of acrobatic elements, and it was at a height

of 1.20 meters, which was high enough to cause fear. It is important to mention that mats, back then, were not made with the technology that we have today. Thus, the purpose of this apparatus was restricted to demonstrating balance on a narrow structure with charm and elegance (Kerr, 2003). However, if the world saw the first cartwheel on the balance beam at the 1956 Olympic Games, in 1962 this element was already combined by Vera Caslavska with back straight layout at dismount. This dictated changes in the following years to meet the pace of development imposed by the athletes.

One of the icons of this development process in WAG was Erika Zuchold of East Germany who performed the flick on balance beam 1964. Unfortunately, due to a calcaneal tendon injury, the gymnast did not participate at the 1964 Olympic Games (Friedrich, 1970). This daring to perform an acrobatic element on beam, defying gravity, may signal that these women wanted to innovate. In Erika Zuchold's case, at certain moments, the inspiration came from the men's sector that already had a list of acrobatic elements presented in competitions. This shows that women were willing to cross the imposed limits. The impact of the athletes such as Caslavska and Zuchold compelled the International Gymnastics Federation to create space for the evolution of women in this apparatus and in artistic gymnastics as a whole.

AS A FINAL NOTE

"A horse sweats, a man perspires, but a lady only glows" (Jokl, 1981, p. XI). This Victorian period statement helps us understand the thinking that guided attitudes towards physical exercise and sports for women at that time. The author mentions that sports as a phenomenon reflects the society which, according to Simões (2003), has a social dimension that mergers cultural, moral, economic, political and ideological values. In this regard, as in other areas conducted and dominated by men, women were restricted and even excluded from participation.

Coackey (2017) says that sport was a place to establish and prove the dominance of heterosexual masculinity. And, according to Bourdieu (2001), the principle of social changes lies in the actions of individuals, represented in this context by women, who seek to subvert the order that imposes the dominant sense.

Guttmann (1978) remembers that the first place for women to practice gymnastics was built in 1832. And, in the competitive scene, the first international competition took place in 1928 in Amsterdam. At this historical landmark, female athletes were guided to perform elements that were aligned with the behavior of passivity and submission. There was a concern that dictated that the female gymnasts remain close to their functions in society, in other words, to their natural destiny: marriage and procreation.

The balance beam, an apparatus introduced by great systematizers of German Gymnastics Movement, back then a predominantly male practice, was incorporated into the women`s competitive program in 1934 at the World Championship in Hungary. It was aligned with the social expectations for female gender: posture, grace, lightness, elegance, and femininity. It is important to remark that in these first competitions, the gymnasts performed on this apparatus only in the team event, that is, there were no individual competitions. Thus, the

competitive aspect was further softened by the team work: it required unity for the sake of victory and did not expose the women individually.

The balance beam competitions included individual competitions in 1952, but kept the characteristics linked to the stereotype of women in society. However, we agree with Guttmann (1981) that the conquests of women in society and their athletic achievements opened up possibilities for women to seek their own space in sports and, in the case of this study, in artistic gymnastics.

If initially *ballet* was the *primary objective* on the balance beam with movements of low risk and low complexity elements, pre-acrobatic elements started to be executed on this apparatus in the period analyzed in this study, which culminated in cartwheels, walkovers and combinations of elements (e.g., cartwheel followed by back layout at dismount).

The balance beam became a protagonist of WAG by highlighting their potential in the development of acrobatic and dance elements, combining grace and power. It led to the need to change the rules and also the apparatus construction in the following years, which is outside the scope of this paper.

Sport is a human activity. It is not more suitable for men than for women. However, it is important to note that sport differs from culture to culture. Nowadays, there are nations which oppose women participation in sports. There are also countries that support their women to engage in sports and compete in the Olympic Games.

We do not seek to discuss equality between men and women in artistic gymnastics. As Chantal Mouffe (1999) states, the dilemma of equality versus difference is false, to the extent that we no longer have a 'homogeneous woman entity' confronted with a 'homogeneous male entity', but a multiplicity of social actions in which sexual difference is constructed in various ways. Thus, we consider that the issue of difference is one of the only paths to equality.

It is important to mention that this paper authors hope that its impact will be attractive equally to women and men interested in the scientific assessment of women and sport, as well as to many practitioners who diligently work for the public acceptance and development of sport for all women.

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REFERENCES

Andrade, M. M. (2018). *Introdução à metodologia do trabalho científico* [Introduction to scientific work methodology] **(1**0th ed). São Paulo: Atlas.

Bourdieu, P. (2001). Masculine Domination. Stanford, CA: Stanford University Press.

Coackey, J. (2017). Sports in society: issues and controversies. 12th ed. New York: McGraw-Hill.

Eitzen, S. (2009). Sport and gender. In Eitzen, S. *Sport in contemporary society: an anthology* (8th ed., pp. 313-318). Boulder: Paradig.

Friedrich, K. H. (1970). Flip-flap on the 4-inch bema: Erika Zuchold – sênior women's gymnast of the GDR. *Mademoiselle Gymnast*, 5(2), 22-23.

Godoy, A. S. (1995). Pesquisa qualitativa: tipos fundamentais [Qualitative research: fundamental type]. *Revista de Administração de Empresas*, 35(3), 20-29.

Goehler, J. (1978). Highlights of women's olympic gymnastics. In Straus, H. (ed.). *Gymnastics guide* (pp. 16-19). Mountain View: World Publications.

Goellner, S. V. (2007). Feminismos, mulheres e esportes: questões epistemológicas sobre o fazer historiográfico [Feminisms, women and sports: epistemological questions about historiographic making]. *Movimento*, 13(2), 171-196.

Goodbody, J. (1982). *The illustrated history of gymnastics***.** London: Stanley Pou & Co.

Gressler, L. A. (2003). *Introdução à pesquisa: projetos e relatórios* [Introduction to research: projects and reports]. São Paulo: Loyola.

Gutman, D. (1996). *Gymnastics***.** Penguin Books: London.

Guts Muths, J. C. F. (1793). *Gymnastik für die jugend: enthaltend eine praktische anweisung zu leibesübungen* [Gymnastics for youth: containing a practical instruction on physical exercises]. Schnepfenthal: Erziehungsanstalt.

Hagelin, O. (1995). *Kinetic jottings: rare and curious books in the library of the old Royal Central Institute of Gymnastics.* Estocolmo: Idrottshögskolan.

Haycock, K. (1991). *Gymnastics*. New York: Maxwell Macmillan International.

Herholz, E. (2020, January 22). *History of Gymnastics on Balance Beam***.** GYMmedia International. http://www.gymmedia.com/ghent2001/appa/beam/history_be.htm

Huguenin, A. (1981). *100 years of the International Gymnastics Federation 1881-1981***.** FIG: Moutier.

Isaac, S., & Michael, W. (1981). *Handbook in research and evaluation: a collection of principles, methods, and strategies useful in the planning, design, and evaluation of studies in education and the behavioral sciences* (2th ed.). San Diego: Edits.

Jahn, F. L., & Eiselen, E. (1816). *Die deutsche Turnkunst zur Einrichtung der Turnplätze* [The German gymnastics art for setting up the gymnastics arenas]. Berlin: Der Herausgeber.

Jokl, E. (1981). Preface. In Borms, J., Hebbelinck, M., & Venerando, A. (Ed.). *Women and sport: an historical, biological, physiological, and sports medical approach* (pp. XI-XIII). Basel: Karger.

Kaimakamis, B., Papadopoulos, P., Duka, S., Kaimakamis, D. (2009). Balance beam as a multiple purpose apparatus in gymanstic systems and the great gymnasts of the first half of 19th century. *Studies in physical culture and tourism*, 16(3), 309-314.

Kerr, R. (2003). *The evolution of women's artistic gymnastics since 1952***.** Master's thesis, University of Sydney, Sydney, Australia.

Minot, S. (1995). *Women's gymnastics: a history. Volume 1: 1966 to 1974*. Carmel: Welwyn Pub. Co.

Mouffe, C. (1999). Deliberative democracy or agonistic pluralism? *Social Research: An International Quarterly*, 66 (3),745-758.

Nunomura, M.(2008). *Ginástica artística* [Artistic gymnastics]. São Paulo: Odysseus.

Oliveira, M. S. (2014). *A microcultura de um ginásio de treinamento de ginástica artística feminina de alto rendimento* [The training gym microculture of women's artistic gymnastics at high level sport]. Doctoral thesis, School of Physical

Education and Sport, University of São Paulo, São Paulo, Brazil.

Organising Committee for the XVth Olympic Games Helsinki 1952. (1952). *Gymnastics*. Helsinki: Organising Committee.

Pfister, G. (1999). Women´s sports. In Levinson, D., & Christensen, K. (Ed.). *Encyclopedia of world sport: from ancient times to the present* (pp. 442-457). Oxford: Oxford Press.

Pfister, G. (2000). As mulheres e os jogos olímpicos: 1900-97 [Women and the Olympic Games]. In Drinkwater, B. L. (Ed.). *Mulheres no esporte* [Women in sport] (pp. 3-15). Rio de Janeiro: Guanabara Koogan.

Porter, D. (2004). *Winning gymnastics for girls.* Nova York: Mountain Lion.

Prestidge, J. (1979). *The love of gymnastics*. Londres: Octopus Books.

Publio, N. S. (2005). Origem da ginástica olímpica [Origin of Olympic gymnastics]. In Nunomura, M., & Nista-Piccoli, V. *Compreendendo a ginástica artística* [Understanding artistic gymnastics] (pp. 15-26). São Paulo: Phorte.

Richardson, R. J. (1999). *Pesquisa social: métodos e técnicas* [Social research: methods and techniques]. São Paulo: Atlas.

Sabo, D., & Messner, M. A. (1993). Whose body is this? Women's sports and sexual politics. In Cohen, G. (Ed.). *Women in sport: issues and controversies* (pp. 15-24). Newburry Park: Sage.

Schpun, M. R. (1998). Entre feminino e masculino: a identidade política de Carlota Pereira de Queiroz [Between feminine and masculine: the political identity of Carlota Pereira de Queiroz]. *Cadernos Pagu*, 12, 331-377.

Simões, A. C. (2004). O universo das mulheres nas práticas sociais e esportivas [The universe of women in social and sports practices]. In Simões, A. C., & Knijnik, J. (Ed.). *O mundo psicossocial da mulher no esporte: comportamento, gênero e desempenho* [The psychosocial world of women in sport: behavior, gender and performance] (pp. 23-46). São Paulo: Aleph.

Simões, A. C., Conceição, P. F. M., & Nery, M. A. C. (2004). Mulher, esporte, sexo e hipocrisia. In Simões, A. C., & Knijnik, J. (Ed.). *O mundo psicossocial da mulher no esporte: comportamento, gênero e desempenho* [The psychosocial world of women in sport: behavior, gender and performance] (pp. 61-86). São Paulo: Aleph.

Takemoto, M., & Hamada, S. (1958). *Illustrated women's gymnastics***.** Tokyo: Banyu Shuppan.

The Modern Gymnast. (1963). 1964 olympic compulsory stick figures for women. *The Modern Gymnast*, 5(3), 12 -13.

The Organising Committee for the XIV Olympiad London. (1948). *General regulations and programme: gymnastics* (Vol. 12). Londres: The organising committee for the XIV Olympiad.

The Organizing Committee of the Games Of The XVII Olympiad. (1960). *The Official Report of the Organizing Committee* (Vol. 2). Roma: The Colombo Printing Establishment / The Rotografica Romana.

The Organizing Committee of the XVI Olympiad Melbourne. (1956). *General rules and special sports regulation: gymnastics* (Vol. 9). Melbourne: The Organizing Committee of the XVI Olympiad.

Tonry, D., Tonry, B. (1980). *Sport illustrated women's Gymnastics 2: the vaulting, balance beam, and uneven parallel bars events* (vol. 2). Lippincott e Crowell: New York.

Vogler, C., & Schwartz, S. (1993). *The sociology of sport: an introduction***.** New Jersey: Prentice Hall.

Westberg, J. (2018). Ajusting Swedish gymnastics to the female nature: discrepancies in the gendering of girls' physical education in the mid-nineteenth century. *Espacio, Tiempo y Educación*, 5(1), 261-279.

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SHORT HISTORICAL NOTES XXVII

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.

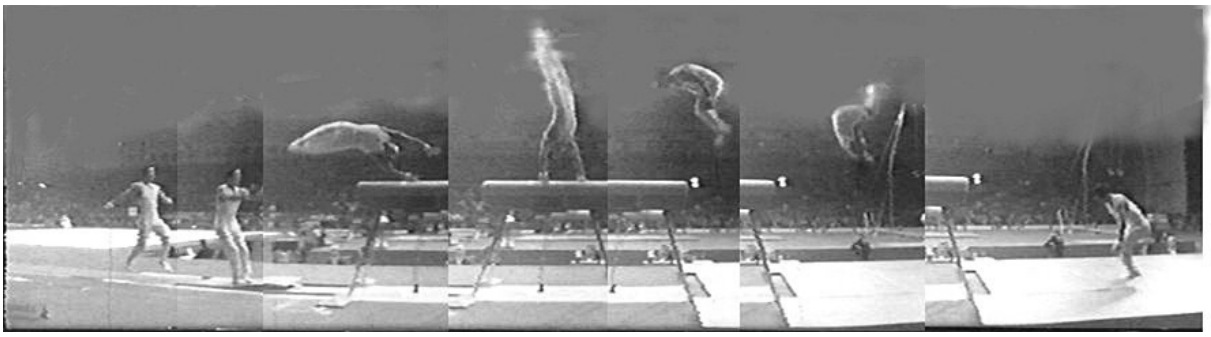
Mitsuo Tsukahara (December, 22, 1947, Tokio, Japan)

Mitsuo Tsukahara started with gymnastics at age of 13, what is from today perspective very, very late. His body constitution and extreme high quality of motor control with great motor abilities allowed him fast development of technical knowledge.

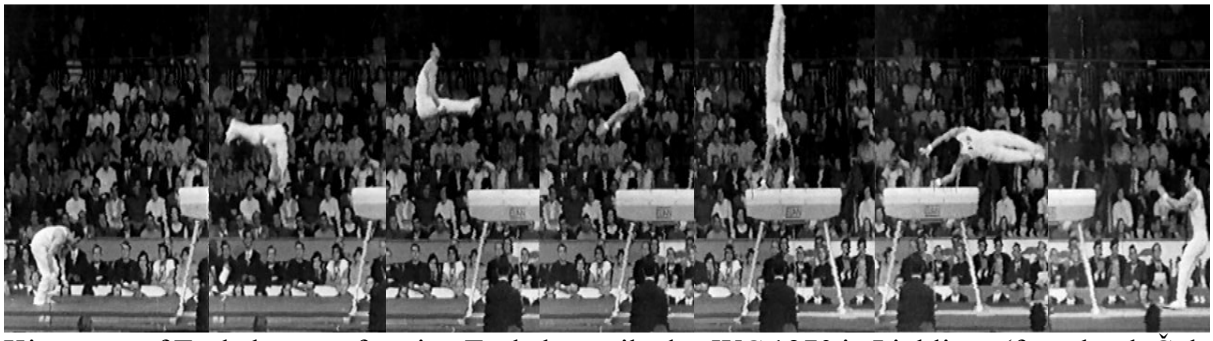
After only eight years of practicing gymnastics he made Olympic debut at Olympic Games in New Mexico with earning team gold medal, while he finished 18th in all around and 4zh on floor.

On left is his photo while performing Yamashita vault. By his words this vault was his weak point and he could not achieve high results. After he thought he could perform something original and overpass weakness of Yamashita and from December 1969 he trained new vault. He started to perform on side horse handstand and roll backward on decline mats, later added salto and as a whole vault wanted to perform handstand with ½ turn with salto backward. As it was quite difficult to do it, new creativity was to use cartwheel with ¼ turn inward and everything was much easier.

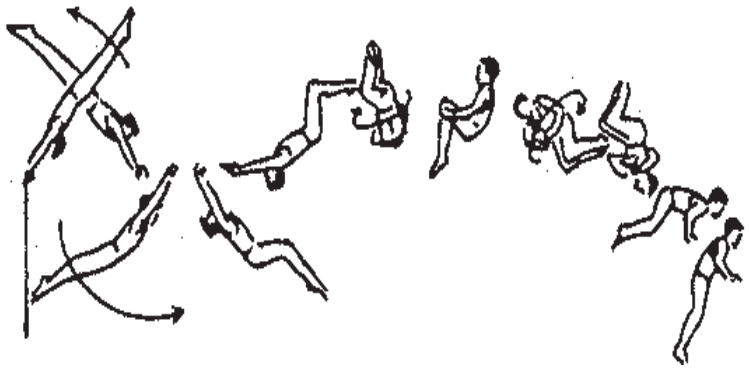
During World Championship in Ljubljana he showed both of his vaults tucked ad piked version (in finals).



Kinogram of Tsukahara performing Tsukahara tucked at WC 1970 in Ljubljana (from book Čuk, Karacsony: Vault, 2004)



Kinogram of Tsukahara performing Tsukahara piked at WC 1970 in Ljubljana (from book Čuk, Karacsony: Vault, 2004)



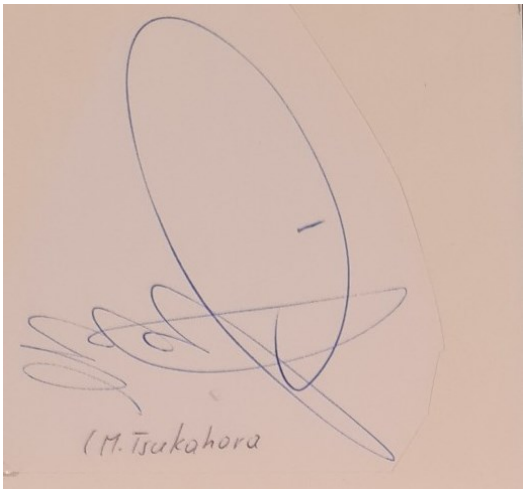
At Olympic Games in München he surprised everyone again with new element. From high bar he performed double salto backward tucked with 1/1 turn. (Kinogram from FIG's Code of Points)

After his gymnastics career he held many different positions in gymnastics, his son (with Chieko Oda, also Olympic gymnast) Naoya was also gymnast who gained gold medal at OG 2004 as team member.

Besides many honors, he was also decorated with Japan Medal of Honor with purple ribbon. For the gymnastics, he is one of the greatest inventors, his name lives every day in all gymnastic halls.

Mitsuo Tsukahara greatest results:

1968	OG	New Mexico (Mexico)	1. Team
1970	WC	Ljubljana (Slovenia)	1. Team, 1. Vault, 2. All Around, 2. Rings
1972	OG	München (Germany)	1. Team, 1. Horizontal bar, 3. Rings
1974	WC	Varna (Bulgaria)	1. Team
1976	OG	Montreal (Canada)	1. Team, 1. Horizontal bar, 2. Vault 3. All Around, 3. Parallel bars
1978	WC	Strasbourg (France)	1. Team



Slovenski izvlečki / Slovene Abstracts

Chih-Yu Chen, Kuang-Hui Chen, Kang-Hao Lu in Hsiu-Ching Chang

ALI BO VIŠANJE TEŽAVNOSTI IZBOLJŠALO MOŽNOSTI ZA ZMAGO? PRIMER NA FINALU ORODNE TELOVADBE

Namen raziskave je bil primerjati ocene težavnosti (D) in končne (F) ocene med predtekmovanji (QR) in finali dogodka (EF) za vsako orodje v zaporedju svetovnih pokalov na posameznih orodjih (IAWCS) 2018–2020 in Svetovnem prvenstvu v orodni telovadbi (WC) 2019. Prav tako smo preučili, če obstaja povezava med strategijo D rezultatov in osvojitvijo medalj ali ne. Predmet sedanje raziskave so bili telovadci in telovadke, ki so sodelovali na EF v IAWCS in WC. Odvisni t test je bil uporabljen za razčlenitev D in F ocen. Hi-kvadrat test je bil izbran za merjenje števil porazdelitve naraščanja/padanja D ocen in osvojitve/izgube medalje, izračunano pa je bilo tudi razmerje obetov. Kaže, da so na vseh orodjih obstajale pomembne razlike v D ocenah med QR in EF za telovadce in telovadke. F ocene za EF so bile bistveno nižje v primerjavi s QR pri moških na konju z ročaji (PH), na bradlji (HB) in ženskah na gredi (BB) ter vajah na parterju (WFX). Če bi zvišali D oceno v EF na PH, HB in WFX, bi lahko znatno izboljšali možnosti za pridobitev medalje. Kolikor vemo, je bila to prva raziskava, ki je primerjala telovadčevo uspešnost med QR in EF. Ugotavljamo tudi različne D ocene in razmerje verjetnosti osvojitve medalje na EF. Pri preučevanju PH, HB, BB in WFX je obstajala težnja po podcenjevanju rezultatov, če je bil razčlenjen samo rezultat EF, vendar brez QR. Zvišanje D ocene ni vedno zagotovilo povečanja možnosti za zmago. Vaditelji in telovadci bi trenutno raziskavo lahko upoštevali za sestavljanje svoje strategije za različna tekmovanja.

Ključne besede: orodna telovadba, končni rezultati, kvalifikacije, finale na orodjih, verjetnost.

Alicia Salas-Morillas, Águeda Gutiérrez-Sánchez, Leopoldo Ariza-Vargas in Mercedes Vernetta-Santana

MOTNJE HRANJENJA ŠPANSKIH TELOVADCEV IN TELOVADK GLEDE NA SPOL IN RAVEN TEKMOVANJA

Cilj raziskave je bil oceniti telesno sestavo in tveganje za razvoj motnje hranjenja (ED) v dveh skupinah španskih vrhunskih akrobatskih telovadcev. Izvedena je bila presečna opisna raziskava, kjer je prostovoljno sodelovalo 130 akrobatskih telovadcev, starih od 9 do 21 let, registriranih pri španski zvezi; 56 jih je tekmovalo na mednarodni in 74 na državni ravni. Meritve višine in teže so bile uporabljene za izračun indeksa telesne mase (ITM), kožne gube pa so bile izmerjene za določitev odstotka telesne maščobe. Za oceno spremenljivk ED je bil uporabljen seznam motenj hranjenja (EDI-3-RF). Rezultati so pokazali, da ima večina telovadk normalno maso (ITM) in nizek % telesne maščobe, telovadci na mednarodni ravni pa imajo nižje vrednosti od tistih na državni ravni. 52,6 % telovadcev v tej raziskavi je bilo izpostavljeno tveganju za razvoj ED. Omembe vredni so rezultati povezani z željo po vitkosti, zlasti pri ženskah, ki tekmujejo na mednarodni ravni, ki so poročale o večji zaskrbljenosti glede mase in podobe telesa. Telovadci mednarodne ravni so izpolnjevali večino meril; zlasti večina starejših telovadcev je izpolnila merilo 3. Obstajal je srednji odstotek telovadcev, pri katerih obstaja tveganje za razvoj ED. Dejavniki tveganja so bili bolj opazni pri telovadkah na mednarodni ravni, ki so pokazale večjo željo po vitkosti in nezadovoljstvu s telesom.

Ključne besede: telovadba, akrobatika, motnje hranjenja, telesne značilnosti.

Alen Miletić, Ana Kezić in Sunčica Delaš Kalinski

PREPOZNAVA ZNAČILNOSTI POJAVA MIŠIČNO-SKELETNE BOLEČINE PRI MLADIH ŠPORTNICAH

Namen raziskave je bil ugotoviti pojavnost bolečine pri mladih športnicah v umetnostnih športih z opredelitvijo deležev bolečinskega stanja štirinajstih predelov telesa. Razčlenili in primerjali smo tri skupine mladih športnic (telovadke, ritmičarke in plesalke sodobnega plesa). Vzorec je sestavljalo skupno 99 športnic. S pomočjo vprašalnika »Samoocenjena delovna nezmožnost zaradi bolečine« (SEFIP) so športnice prosili, naj ocenijo svoje trenutno stanje bolečine v 14 predelih telesa na 5-stopenjski lestvici, pri čemer 0 pomeni, da ni bolečine, 4 pa tako hudo, da ne morejo vaditi. Po Wilkovem testu je bil med telovadkami, ritmičarkami in plesalkami sodobnega plesa pomemben učinek ($F= 4,60$; $p<0,001$) glede izkušenj z vadbo in stanja telesa. Najpogostejše pojave bolečine na celotnem vzorcu oseb so bile v spodnjem delu hrbta (44 %), kolenih (35 %) in gležnjih/stopalih (31 %). Orodne telovadke največ poročajo o bolečinah v gležnjih/stopalih (51,43 %) ter spodnjem (37,14 %) in zgornjem delu hrbta (34,29 %). Ritmičarke iste starosti večinoma poročajo o bolečinah v spodnjem delu hrbta (46,42 %), kolenih (42,86 %), golenih, gležnjih in stopalih (28,57 %)¸ medtem ko plesalke čutijo bolečine večinoma v spodnjem delu hrbta (50 %), zgornjem delu hrbta (44). %) in kolenih (38,89 %). Glede na rezultate hi-kvadrat testa so telovadke poročale o značilno večji pojavnosti bolečine v predelu gležnjev/stopal ($p<0,01$). Zgodnje odkrivanje tudi bolečine nizke jakosti skupaj s prilagoditvijo vadbene obremenitve in uporabo ustreznih varnostnih zahtev lahko prepreči nastanek poškodb pri mladih športnikih.

Ključne besede: orodna telovadba, ritmika, ples, skrb za zdravje, bolečine v hrbtu.

Casey C. Little, David R. Howell, Aubrey Armento, Amanda R. McCarthy, Emily A. Sweeney

SKRBI GLEDE TELESNE MASE IN DUŠEVNEGA ZDRAVJA MED MLADIMI TELOVADKAMI: PREDRAZISKAVA

Zaskrbljenost zaradi mase lahko vpliva na kakovost življenja telovadk. Preučili smo povezavo med zaskrbljenostjo glede mase in stopnjami tesnobe, o katerih so poročale same, ter drugimi osebnostnimi in družbenimi ter menstrualnimi zdravstvenimi značilnostmi med otroki in mladimi telovadkami. Telovadke stare od 8 do 18 let so izpolnile spletni vprašalnik, ki so ga razdelila njihova telovadna društva. Izpolnile so tudi vprašalnik o splošnem strahu (GAD-7). Od 73 telovadk, ki so izpolnile vprašalnik, jih je 15 % poročalo, da jih skrbi njihova masa; bile so precej starejše in so poročale o višjih rezultatih GAD-7 kot tiste, ki niso skrbele za svojo maso. Po prilagoditvi za neodvisni učinek starosti skrb za maso ni bila več pomembno povezana z rezultati GAD-7 (prilagojeno razmerje verjetnosti = 1,13, 95 % IZ = 0,98, 1,30, $p = 0,10$), prepričanji o velikosti njihovega telesa (prilagojeno razmerje verjetnosti razmerje = 6,48, 95 % IZ = 0,84, 50,1; $p = 0,07$), ali menstruacije (prilagojeno razmerje obetov = 0,40, 95 % IZ = 0,04, 4,14, $p = 0,44$). Ugotovili smo povezavo med starostjo, strahom in skrbmi glede mase pri otrocih in mladih telovadkah. Ponudniki zdravstvenih storitev pa bi morali preveriti zaskrbljenost zaradi mase in povečano tesnobo pri starejših telovadkah.

Ključne besede: telovadba, duševno zdravje, zaskrbljenost glede telesne mase, mladostništvo, strah.

Pauline Iglesias Vargas, Mauricio Santos Oliveira in André Mendes Capraro

ODNOS MED TELOVADCI IN VADITELJI V BRAZILSKI MOŠKI ORODNI TELOVADBI

Izkazalo se je, da je obnašanje vaditeljev eden od odločilnih dejavnikov za pozitivno in uspešno športno izkušnjo. Zato smo s to raziskavo želeli opozoriti na značilnosti odnosa telovadec – vaditelj z vidika športnikov brazilske moške orodne telovadbe (MAG) (2013-2021). Za dosego raziskovalnega cilja je bila uporabljena kakovostno-raziskovalna metodologija. Podatki so bili zbrani iz polvodenih pogovorov s petimi telovadci brazilskega moštva MAG. Prepisi pogovorov so bili razčlenjeni in organizirani v tri tematske sklope: zlorabe vaditeljskih praks v preteklosti; spremembe v obnašanju vaditelja; in pozitivni odnosi med vaditeljem in športnikom. Ugotovljeno je bilo, da je trenutno vedenje vaditeljev moralno, čeprav športniki niso zanikali zgodovine zlorab. Športniki so opazili spremembe v obnašanju vaditeljev, potem ko so državni in mednarodni upravni organi ustanovili odbore za nadzor in boj proti zlorabam v športu. Športniki so poročali tudi o medsebojno spoštljivem odnosu s svojimi vaditelji v današnjem času in jim je bilo žal za premajhno cenjenje vaditeljskega poklica v Braziliji.

Ključne besede: Olimpijske igre, telovadci, vaditeljstvo, vrhunski šport.

Luciana Ferreira Melo de Sá, Amanda Batista Santos, Maria de Lurdes, Tristão Ávila Carvalho

SPOSOBNOST IZVEDBE SKOKA IN PREREZ SILA-HITROST V RITMIKI

Skok je najpomembnejše gibanje v ritmiki (RG). Za pravilno izvedbo morajo ritmičarke razviti ustrezne stopnje sile in hitrosti, da dosežejo dovolj višine skoka, da pokažejo poseben položaj telesa med letom, kot je opredeljeno v Pravilniku točkovanja RG. Na zmogljivost skakanja vplivata prerez mehanske sile in hitrosti (F-V) in največja moč, ki jo ustvarijo spodnji udi. Osebni prerez F-V lahko zagotovi natančnejšo in popolnejšo mehansko predstavitev njegovih zmogljivosti in potreb. Namen te raziskave je bil razčleniti prerez F-V med skokom v nasprotnem gibanju, ugotoviti velikost in smer neravnovesja med obema spremenljivkama (silo in hitrost) ter primerjati sposobnost skakanja in mehanske spremenljivke različnih starostnih skupin. Ocenjenih je bilo 18 portugalskih ritmičark (povprečna starost 12,2±1,8 leta) glede na starostne skupine: začetnice in mladinke (G1- od 10 do 12 let) ter mladinke in starejše ritmičarke (G2 - od 13 do 16 let); in glede na F-V zaznano neravnovesje prereza. Zbiranje podatkov je bilo izvedeno po obdobju osamitve zaradi covida-19. Rezultati so pokazali razlike v telesnih značilnostih med starostnimi skupinami, vendar nobenih razlik v spremenljivkah, povezanih s prerezom F-V. Pri primerjavi ritmičark glede na primanjkljaj so bile ugotovljene razlike v spremenljivkah sila in hitrost. Poleg tega je 72,3 % ritmičark pokazalo primanjkljaj sile, 11 % primanjkljaj hitrosti in 16,6 % rimtičark je imelo uravnotežene rezultate. Glede na ugotovljene primanjkljaje, zahteve športa in vsakega športnika, je nujno vključiti vadbo moči v redno vadbo ritmičark.

Ključne besede: ritmika, prerez, skok, sila, hitrost.

Adis Tabaković, Muhamed Tabaković in Almir Atiković

UČINKI 12-TEDENSKE IZOKINETIČNE VADBE ZA MOČ STABILIZATORJEV KOLENA IN UČINKOVITOST IZVEDBE TELOVADNIH PRESKOKOV

Namen raziskave je bil preveriti učinke izokinetične vadbe za moč mišic stabilizatorjev kolena in ali ta poveča učinkovitost izvajanja osnovnih telovadnih preskokov. Vključenih je bilo 60 merjencev, študentov Fakultete za šport in telesno vzgojo (povprečna starost 19,7±1,5 let, teža 75,3±2,9 kg, višina 179,8±6,7 cm). Preiskovanci so bili razdeljeni v dve skupini, poskusno (EG) (n=30) in nadzorno (KG) (n=30). V okviru 12-tedenske vadbe je poskusna skupina (EG) poleg vaj v okviru rednega pouka na univerzi imela dodatno koncentrično izokinetično vadbo 3x tedensko na dinamometru Biodex System 3, medtem ko je nadzorna skupina (CG) imela samo vaje v okviru rednega pouka na univerzi. Rezultati so pokazali pomembne razlike ($p < 0,05$) med EG in CG, tako v povečanju moči mišic stabilizatorjev kolena kot v izvedbi telovadnih preskokov v korist EG. Zaključimo lahko, da je dodatna izokinetična vadba povzročila večji porast moči in tudi boljšo izvedbo telovadnih preskokov. Rezultate raziskave lahko uporabimo kot smernice za načrtovanje izokinetične vadbe moči mišic stabilizatorjev kolena, ki bodo pripomogle k boljši izvedbi telovadnih preskokov. Ker je na temo tega dela malo raziskav, ta raziskava predstavlja dober temelj in osnovo za nekatere prihodnje raziskave o učinkih izokinetične vadbe v orodni telovadbi.

Ključne besede: orodna telovadba, izokinetika, preskok, mišična vadba.

Fernanda Raffi Menegaldo, Marco Antonio Coelho Bortoleto in Mercè Mateu Serra

UMETNIŠKO-IZRAZNA RAZSEŽNOST TELOVADBE ZA VSE

Izrazno in poetično razsežnost Telovadbe za vse (GfA) pogosto prepoznavamo v sestavah na telovadnih predstavah, s čimer poudarjamo njeno sporazumevalno in uporabno vrednost. Namen te raziskave je bil razpravljati o umetniško-izrazni razsežnosti GfA na podlagi teorije Pierra Parlebasa in v družboslovnem pojmu športizacije. Posebna in nedokončana športizacija delovanja GfA vključuje odsotnost uradnih izražanj čustev z rokami, ki označujejo umetniško-izrazno razsežnost kot »moč«, ki je torej lahko ali pa tudi ne del dejavnosti GfA, glede na odločitev posamezne skupine. Ta razčlenitev nam omogoča razlikovanje GfA od drugih umetniških športov, kot sta ritmika in umetnostno drsanje, ter od drugih oblik umetnosti, kot sta ples in cirkus.

Ključne besede: telovadba; gibanje, umetniški šport, športizacija.

Lucas Machado de Oliveira, Vitor Ciampolini, Michel Milistetd, Ieda Parra Barbosa-Rinaldi in Juliana Pizani

GRED KOT TELOVADNO ORODJE ZA ŽENSKE: OD IZVORA DO UTRDITVE

Članek želi povečati razumevanje zgodovinskega razvoja orodne telovadbe, zlasti udeležbe žensk v tem športu. Skozi zgodovinsko raziskavo smo razčlenili nastanek in vključitev gredi kot jedrnega dela te telovadne panoge. Obdobje, ki ga proučujemo, sega od olimpijskih iger 1896 do let med 1952 in 1964, ki so znana po utrditvi tekmovalnih značilnosti ženske telovadbe. Opazili smo, da so bile na začetku, tako kot v športu na splošno, ženske iz te kulturne izkušnje izključene. Vendar pa smo skozi zgodovino opazili, da je gred postala predstavnik orodne telovadbe, postala je oder za utrjevanje in soočanje, kaj ženske v tej telovadni panogi smejo in česa ne.

Ključne besede: Ženske, telovadba, zgodovina športa.

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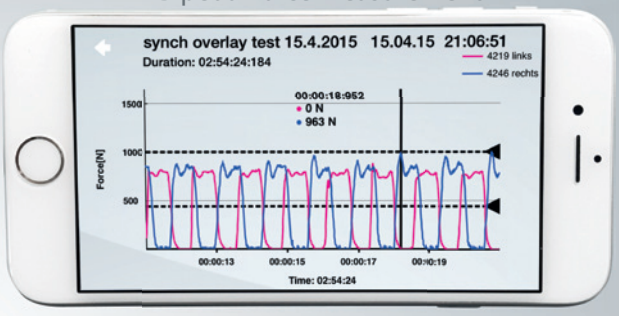

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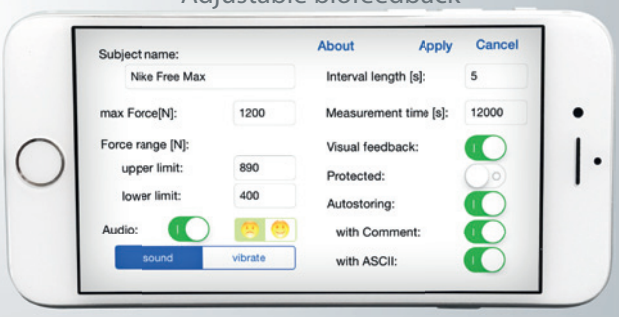

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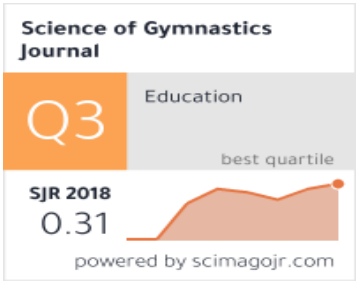

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