Science of Gymnastics Journal

vol. 14, num. 1, year 2022

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

Science of Gymnastics Journal (ScGYM®)

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

Front page design: Sandi Radovan, Slovenia.

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

Fundacija za šport

Slovenian Research Agency

F.I.G.

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EDITORIAL

Dear friends,

We are well into 2022 and it is late for New Year wishes, nevertheless, I hope you will have a happy and healthy 2022. The pandemic has slowed down a little and has so far not put any limits on our work and research. May it end soon in all parts of the world.

It has been 100 years since the World Championship in Artistic Gymnastics was held in Ljubljana, Slovenia, in 1922. It was the first international competition for Leon Štukelj who later made history at the OG in Paris in 1924 and won gold medals in the all-around and high bar. The first article in the journal is by French historians Tony Froissart and Thierry Terret. They are analyzing Leon Štukelj's legacy on modern artistic gymnastics. I believe Leon Štukelj would be delighted by their paper.

Other contributing authors in this issue come from Brazil, Germany, Japan, Bulgaria, Turkey and Greece. Again, many different aspects of gymnastics are presented.

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

Anton Gajdoš and Michal Babela drafted the 23rd short historical note introducing Silvester Csolany from Hungary who passed away in January after a long illness caused by COVID-19.

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

LEON ŠTUKELJ, OLYMPIC CHAMPION 1924 IN GYMNASTICS. PERFORMANCES AND LEGACY

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Original article *DOI:10.52165/sgj.14.1.5-15*

Abstract

Olympic champion in the general event in gymnastics at the 8th Olympiad in 1924, Leon Štukelj performed remarkably in international competitions. This article proposes to analyze the innovative character of the performance carried out by the gymnast of the Yugoslavian team, to appreciate the context of its realization and to evaluate his legacies. Through his performance, Štukelj paved the way to major evolutions in gymnastics, especially in the rings event where he excelled. Certain technical regulations of international gymnastics seem to have been especially inspired by the elements he performed in 1924. Štukelj was also considered an emblematic figure of the educational method developed by the Yugoslav Sokols. As a consequence, his imprint as a symbol of a moral and physical system of training was also very strong. The paper is positioned in the field of cultural history. It aims to study the evolution of Štukelj's performance and legacy. In addition to the historiography of the 1924 Olympic Games, it uses various primary sources: the French daily press published on the occasion of the 1924 Olympic Games, the archives of the Lausanne Olympic Study Center, the archives of the city of Colombes, the official reports of the 1924, 1928 and 1936 Olympic Games, the archives of the International Gymnastics Federation and Štukelj's autobiography (1989).

Keyswords: *Štukelj, Olympic Games 1924, Gymnastics, Legacy, Sokol.*

INTRODUCTION

The sporting career of Leon Štukelj, Olympic champion in 1924 and multiple medalist later on, was special in many respects. The Slovenian gymnast (Yugoslav at that time) succeeded in remaining at the highest level in his sport for many years. In fourteen years, from 1922 to 1936, he accumulated a remarkable total of seventeen world awards.

The special place of Leon Štukelj in the history of gymnastics led us to analyze the conditions that made his emergence as a champion possible, as well as his role in the evolution of gymnastic techniques: was he an innovator or was he simply a lucky beneficiary of changes in the sport regulations? It is also relevant to go back to the impression made by this Slovenian gymnast in France, a country where he acceded to the international scene for the first time in the beginning of the 1920s. How was he presented and perceived in the French press during the Olympic Games in 1924? Was he valued for his athletic performance? For his nationality? Or was he, rather, presented as the emblematic representative of a special method of

physical and moral education? What is Leon Štukelj's final legacy?

We will first argue that the context of the 1924 Olympic Games was favorable to major changes in the definition of gymnastic excellence and that the new regulations opened opportunities for new profiles of gymnasts. We will then analyze the gymnastic performances by the Slovenian gymnast Leon Štukelj during the Olympic week in 1924. Finally, we will use a media analysis to come to conclusions about the legacy of Leon Štukelj's performances at the 8th Olympic Games.

METHODS

Despite his record, Leon Štukelj has not been the subject of extensive biographical research, neither by historians of Olympism nor by political historians, apart from the two short articles devoted to him by Slovenian historian Vlado Bevc in *Smiling Slovenia* (2008, p. 73 and 74-78). However, the current paper follows and completes a few earlier investigations (Froissart, T., Villaret, S., 2008; Froissart, T., 2008; Froissart, T., 2010). To carry out this study, we used Slovenian works, the proceedings of the 1998 colloquium (Štukelj L. & Francek J., 1998) and the major work in four volumes by French historian Thierry Terret, *Les Paris des Jeux Olympiques de 1924* (2008). Our primary sources include the archives of the Olympic Study Center in Lausanne, the archives of the city of Colombes, the official reports of the Olympic Games of 1924, 1928 and 1936, the archives of the International Gymnastics Federation and Štukelj's autobiography (1989).

The study also includes an analysis of the French daily press published during the 1924 Olympic Games to evaluate the way Štukelj was presented by journalists when the champion was at the peak of his sports career. A study of the main French national dailies of the period has been carried out with a two-fold approach. First, we analyzed a selection of the press articles dealing with the gymnastics events of the 8th Olympic Games published between Thursday 17 and Monday 21 July 1924. Particular attention has been paid to the newspapers published on 20 and 21 July that reported on the day dedicated to gymnastic performances, including: *L'Auto, La Croix, Echo d'Alger, Echo d'Oran, Echo de Paris, Excelsior, Le Figaro, Le Gaulois, Le Grand Echo du Nord, l'Homme libre, l'Humanité, L'intransigeant, Le Journal, La Lanterne, La Liberté, Le Matin, L'Œuvre, Paris midi, Le Petit parisien, Le Populaire, La Presse, Le radical, Le siècle, Le Temps*. These daily newspapers belong either to the general press or to the sporting press. They mirrored the large diversity of France's political orientations at the time. A second investigation was then carried out by searching the same corpus of newspapers for key words (Štukelj, gymnastics, Sokol) in the period when Štukelj took part in competitions as a gymnast or a trainer. This last analysis was based on the Gallica database of the National Library of France.

RESULTS AND DISCUSION

A favorable context for new forms of performances in gymnastics.

The 8th Olympic Games took place in Paris, between March 15 and July 27, 1924. They brought together nearly 6,000 athletes from 45 nations and saw the United States dominating the event. The Yugoslav delegation in Paris did not belong to the most represented nations: with 201 athletes, the country took part in 8 of the 19 sporting events of the Olympic program and finished at the 14th place in the ranking of nations. It however finished third in gymnastics, a result to which Leon Štukelj made a decisive contribution by winning the individual gymnastics event.

It, however, appears that the Olympic title was partly the consequence of favorable circumstances that occurred in

1924. During the Paris Olympic Games, the gymnastics competition included the usual six apparatus (floor exercises, pommel horse, still rings, vault, parallel bars, horizontal bar) to which climbing a rope was added. It is important to mention that the previous World Championships in Ljubljana in 1922 were much more open (Barrull, R., 1984). They included four apparatus (parallel bars, horizontal bar, still rings, pommel horse) and also athletic events: the competitors took part in three group events (Preliminary); they also competed in swimming 50m freestyle, and in track and field disciplines including 100m sprint, high jump with hard springboard and shot put (7.257 kg).

In 1924, the transition from gymnastics which was based on a general and polyvalent physical education concept to gymnastics which was progressively more oriented toward the use of pendular apparatus was engendered by a new generation of champions. By refocusing around two large types of events that required comparable physical qualities, the Paris Olympic program changed the very nature of the expected performances. Whether on apparatus where they swayed while swinging, or in events which favored acrobatic jumps, gymnasts had to extract themselves from gravity. Therefore, those who combined low body weight with thin and protruding muscles were more likely to be successful. With a height of 1.61 m and weight of 51 kg, Štukelj presented the ideal morphotype.

The exclusion of track and field events from the Paris gymnastics program encouraged new athletic profiles of slender and agile men who were able to exploit their body weight / muscle power ratio, and weakened the chances of strong and heavy muscular men. Thus, the official report of the Olympic Games explained the poor results of the Luxembourg team in rope climbing by the fact that these gymnasts "were certainly the heaviest of the group" (Official Report of the 1924 Olympic Games, p. 356). This reorientation was supported by Charles Cazalet, the president of the Union of Gymnastic Societies of France (1896) and the future president of the International Gymnastics Federation in 1924, who gave Štukelj the opportunity to exploit his physical and morphological qualities and to establish himself as the best gymnast of the time.

Štukelj at the Olympic Games of Paris 1924

Leon Štukelj's gymnastic skills were built during childhood, through his education at the Sokol of Novo Mesto. His favorite events were revealed in 1922, during the World Championships organized in his country. In Ljubljana, he won the parallel bars, the horizontal bar and the still rings, finished second on the pommel horse and tenth on the floor exercises. He was second in the rope climbing event. He was, however, less brilliant in the athletic events, especially in the shot put where his performance did not allow him to be ranked or receive a single point.

Luck is part of sport. During the 1924 Olympic Games, circumstances handicapped Štukelj's direct competitors and sometimes even led to their elimination. For example, on the evening of the first day, the weather deteriorated which mattered as the gymnastics events were held outside. The wind and the diminishing temperature considerably hampered the Italian and Swiss teams who were performing in the horizontal bar event at the same time (Official Report of the 1924 Olympic Games, p. 346). Members of both teams who had a real chance of success were interrupted. Later, in the parallel bars event, two members of the Czechoslovak team fell and Jindruch, another direct competitor of Štukelj, was forced to retire with a knee injury. Finally, Leon Štukelj, who did not present himself as the favorite, managed to use all his moral and physical qualities in a situation which turned out to be favorable for him. He thereby revealed another facet of his

talent by showing remarkable tactical intelligence. There, he succeeded on the grassed surface of the stadium of Colombes, using his adaptive qualities and agility he had built during the lessons at Sokol some years earlier.

Table 1
Ranking of Leon Štukelj during the 8th Olympiad (OG Paris 1924).

Horizontal bar	Parallel bars	Still rings	Rope climb	Vault (in length)	Vault (in width)	Pommel horse	General ranking
1st	20th	4th	10th	4th	17th	10th	1rst

Table 2
Score obtained by Leon Štukelj on pendula Apparatus in the Paris 1924 Olympic Games. Source: Official Report of the Olympic Games 1924, pp. 346-366.

Apparatus	Compulsory exercices				Free exercices				Full score
	Walking to apparatus /0,5	Score /10	Return from apparatus /0,5	Total	Walking to apparatus /0,5	Score /10	Return from apparatus /0,5	Total	
Horizontal bar	0,5	9,23	0,5	10,23	0,5	8,50	0,5	9,50	19,73
Parallel bars	0,5	9,27	0,5	10,27	0,5	9,13	0,5	10,13	20,40
Still rings	0,5	9,33	0,5	10,33	0,5	**10***	0,5	11,00	21,33
Pommel horse	0,5	9,17	0,5	10,17	0,5	8,20	0,5	9,20	19,37

*Perfect 10 score.

Table 3.
Individual all-around and pendula Apparatus ranking achieved by L. Štukelj during international events (compulsory + free).

	Parallel bars	Horizontal bar	Pommel horse	Still rings	General ranking
1922 WC Ljubljana	**1**	**1**	**2**	**1**	7
1924 OG Paris	20	1	10	4	**1**
1926 WC Lyon	**3**	**1**	14	**1**	**2**
1928 OG Amsterdam	5	13	13	**1**	**3**
1930 WC Luxembourg	NC	3	NC	NC	
1931 WC Paris	**2**	10	**3**	**2**	**1**
1936 OG Berlin	22	35	39	**2**	32

In bold: the podiums.

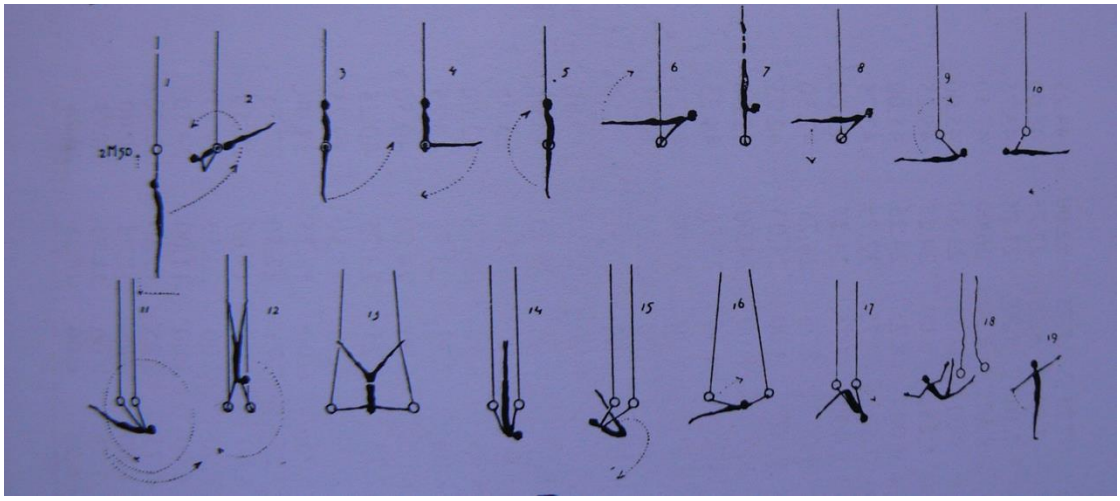

Figure 1. Rings compulsory exercises of the OG 1924. 8th Olympic Games Amsterdam 1928, Executive Committee.

The competition was, however, fierce, especially with the Czechoslovak gymnasts who had also trained as Sokols. Štukelj succeeded on still rings, demonstrating very difficult skills in which, in addition to two horizontal planks and the iron cross, he distinguished himself with the "inverted iron cross", which consisted of a backrest upside down with vertical legs and horizontal arms. Despite his technical prowess, however, Štukelj did not win a medal on still rings. He was slightly behind after the compulsory exercises where he totaled only 9.33 points and lost his chances for the podium. Although he obtained the maximum score of 11 points in free exercises (out of 11 possible points), he finally finished fourth in this event. At least his last performance in free exercises positioned him as an outstanding specialist in this event.

Considering the whole competition, Štukelj's performances were not enough to outclass his Czechoslovak rivals. His Olympic title was actually rather a consequence of other points of the sport regulations. Leon Štukelj obtained the maximum "presentation score" on each apparatus, not only for "walking to the apparatus" where he received the maximum half-point at each passage granted for the quality of this walk, but also for the "return from the apparatus" where he obtained two additional points on four apparatus. His direct competition did not manage to achieve the same. Czechoslovakian Prazack, second in the all-around, was penalized after returning from the fixed bar practice (Reck) where he only obtained 0.47 points. Supcik, another Czechoslovak who was third in the all-around competition, was also penalized for the way back from the imposed fixed bar exercise with a score of 0.43 point, and another time when he returned from the pommel horse where his score was 0.40 point. Leon Štukelj's automaton movement, on the other hand, pushed him far ahead of his opponents, leading to the supreme title. His walking skill even passed down to posterity by the grace of poetry since it was mentioned in the poem *Gymnastics* by Géo Charles, the 1924 Olympic champion in the "art and literature competition": "Who has glimpsed the Yugoslavs, their Štukelj, automatons" (Géo Charles, 1925).

The results indicate that Štukelj and Prazack scored almost identical points. Had the latter obtained the maximum result on the return score he would have been crowned the Olympic champion, since 17 thousandths of a point separated the two competitors: 110.340 points for Štukelj and 110.323 points for Prazack.

In Paris, Leon Štukelj did not shine in acrobatics (floor, vault), nor in the various events where he obtained marks of 10 in the rope climbing with a performance of 8 seconds and 2/5; 9.91 on the vault in length, and 9.60 on the vault in broad. On the other hand, his remarkable capacities in the pendula apparatus (still rings, horizontal bar, parallel bars) played an essential role and helped him shoot ahead of his opponents.

In Amsterdam in 1928, as gymnast teams from Switzerland, Czechoslovakia and Yugoslavia competed for the top steps on the podium, Štukelj excelled in the rings event and won the gold medal as well as two bronze medals in both the individual all-around and the team competition.

During the 1930s, competition became more uncertain with the appearances of Swiss Georges Miez and Czechoslovakians Ladislav Vacha and Jan Gajdos. Leon Štukelj won no event in Luxembourg at the 1930 international tournament nor in the individual competition at the World Championship in Paris in 1931. As a good Sokol member he persevered, however, and obtained a silver medal in the rings event during the final event of the Olympic Games in Berlin in 1936: he finished ahead of the German Mathias Volz in his specialty with a total of 18.867 points, and was only beaten by his compatriot Alois Hudec by a very small margin. On this occasion, Yugoslavia lost the leadership it shared with Czechoslovakia, but Štukelj's sport longevity remained remarkable.

What is Štukelj's legacy in France?

Paris was the land of Štukelj's first Olympic consecration. What remained of the Slovenian gymnast in France?

Does Štukelj leave a sporting legacy?

Štukelj was only the sixth member to be selected for the national team at the World Championship won by the Czechoslovakian team over Yugoslavia and France in Ljubljana on August 11 and 12, 1922. He finished seventh overall but was victorious in the unofficial rankings established on rings (19.75), parallel bars (20) and horizontal bar (19.75) (Barrull R., p. 376). During the competition he obtained a total of 124.25 points or 82.83% of the maximum possible total. This performance was, however, insufficient to win him a medal. Štukelj was outpaced by his teammates Peter Šumi, Stane Derganc and Stane Vidmar (Štukelj, L., 1989, 86) and did not even position himself as the leader of his team. In addition, Czechoslovakia performed extremely well and won the Championships with two of their gymnasts on the podium: Frantisek Pechacek shared the first place with Peter Šumi, Miroslav Klinger finished third and Miroslav Jindruch fifth. The domination of the Slavs and the superiority of the Sokols were absolute since the first ten places were all taken by these two nations. Two years later, during the Olympic Games in Paris, these two countries again featured as favorites.

The gymnastic heritage of the Slavic nations can be appreciated through the testimony of French gymnast R. Morin who finished 26th at the competition in Ljubljana. He provided an analysis of the transformations in modern gymnastics as discovered by the public during the 8th Olympic Games in 1924. For him, the evolution toward momentum rather than strength was "already consistent among foreign competitors who presented free exercises that were more linked, more flexible" from 1922 onward (Morin, 1948, 241). This was enough to feature on the front page of the newspaper *Le Matin* (July 20, 1924) with headline "Honor to gymnastics at the Olympic games" and praise for the "seven champions" and the "super champion" Štukelj.

Štukelj thus embodied the image of the modern gymnast. The particular influence he exerted can be analyzed in particular on his specialty: the rings event. Štukelj was one of the first to perform the

static "overturned iron cross" in competition. When comparing the exercises in the rings event and the relevant regulations in 1924 and in 1928, it can be concluded that the official regulations took notice of his innovations. In 1924, the compulsory exercises were mainly static postures: three planks, a square, two balances and the iron cross. Strength prevailed and two exercises only were carried out with momentum (Official Report 1924, 353). Four years later, the dominant techniques in the rings event seemed to have changed: the entry (1, 2, 3) was carried by momentum, followed by a series of strength exercises (4 to 10) including the reversed cross with the feet on the cables; exercises with momentum (11 to 19), and the exit in rotation. The required movement was therefore composed of an alternation of static and dynamic elements.

A careful observation of the compulsory exercises in 1928 shows that the construction and organization of the elements in the rings event reveals similarities with the free exercise carried out by Štukelj in 1924. This is especially the case for elements 1, 2, 3, 6, 7, 9, 10, 12, and 13 listed in the following diagram which represent the compulsory exercises in 1928. Only the exit (elements 14 to 19) was actually different from the compulsory one in 1928.

We find neither the iron cross nor the overturned iron cross among the 1928 compulsory exercises. Yet element 13 of the diagram still requires to perform the "reversed cross" with, the possibility of not maintaining the position. Thus, it seems that the compulsory exercises were seen as an anticipation of the coming evolution of gymnastic techniques: to propose not to maintain the position and to require that the feet touch the cables for help were a clear encouragement for the gymnasts to perform this difficult element. Without generalizing, this example shows that Leon Štukelj contributed to the evolution of gymnastics through the compulsory exercises on the rings event. Could such influence on the sport regulations be also found in the press?

The image of Štukelj in the French press

Astonishingly enough for a country with a gymnastic tradition, the French press did not really pay too much attention to gymnastics during the Olympic Games in Paris. This was partly due to the low popularity of this competition where the number of spectators was relatively low. According to the official report of the Games, there were only 1911 spectators, including 707 who paid for their seat who, for instance, attended the gymnastics events on July 17. There were 1863 spectators (654 with a paid ticket) on July 18, even fewer the next day, and finally 4553 spectators on Sunday, July 20, including 3276 who paid for their ticket. This result led the newspaper *La Liberté* (July 21, 1924) to claim that gymnastics failed to become popular: "Gymnastics is completely neglected by the public which pays attention to gymnasts only very rarely". However, despite this very modest media covering, Leon Štukelj received special attention, with at least two types of media treatment.

The first series of journalistic chronicles focused on Štukelj's exemplary performances and techniques. For example, famous French gymnast and promoter of the Hebertist physical education method D. Strohl regretted in *L'intransigeant* (July 25, 1924, 4) that the conditions needed for high performances were not appropriate, but he presented Štukelj as a brilliant gymnast whose practice augured the qualities of the gymnasts of the future: "Why this immense desert of Colombes? A beautiful gymnasium would have been a better setting to showcase the most robust fellows that the games have produced: Štukels (sic) the Yugoslav, so powerful and so flexible, […]".

Another media register was used to associate the Slovenian champion with the

Sokol movement of which he was described as an emblematic representative. The image of Štukelj as the man of the Sokols was even more emphasized than his sporting image. Thus, when the daily newspaper *Le matin* decided to put the Olympic champion of the individual all-around on the front page of its edition of July 21, 1924, the decision was made not to use a photograph of the gymnast in action. Rather, Štukelj appeared on a medallion, in bust, wearing the hat with the falcon plume, i.e., the emblem of the Sokols. Likewise, in the July 23 edition (p.4), *L'indépendant des Basses Pyrénée*s mentions Štukelj's performance, but the newspaper amalgamates the different Slavic nations where the Sokols were active and claims that "Czech-Slovak Štukels (so spelled) won the individual tournament in front of two of his compatriots".

This association of Štukelj with the Sokol movement in the French press could also be seen in the suggestive slip of the newspaper *La Croix* (July 20, 1924, p.3) which changed the spelling of the champion's name to "Štukols", i.e., a contraction of both the gymnast's name and the Slavic gymnastic movement: Stu [kelj] [So] kol. Beyond this anecdote it should be remembered that the very popular sports daily newspaper *L'Auto* regularly underlined the action of the Sokols for the development of national identity and consciousness in the Slavic countries (Busseuil, 2020; Thiesse, 1999) at the time. The exemplarity (Saint-Martin, 2002, 43-57) of the Yugoslav Sokols was frequently praised (*L'Auto*, November 14, 1935, p. 6; *L'Auto*, August 2, 1935, p. 1 and 4, August 3, 1935, p. 1 and 5 and 2 August 1936, p. 5). It is true that the links between the promoters of French gymnastics and those of the Sokols had been forged a long time before (Cesky Svet Sokol, 1912), as recalled by Smutny, the president of the Czechoslovak Sokol in Paris, who was the first to invite a section of the Czech Sokol to the Federal Festival of Vincennes in 1889 (*L'auto*, August 27, 1929).

This close relationship between France and the Sokol movement was still extremely strong in the early 1930. Delegations of the Czech and Yugoslav Sokols were thus invited to the Federal Festival of the Union of Gymnastic Societies of France in 1931. Conversely, the French gymnastics leaders went to Prague to attend the mass performances of the Sokols (Slets) in 1932 when Under-Secretary of State for Physical Education and Professor at the University of Lyon André Latarjet was accompanied by several delegations from large cities (Paris, Marseille and Lille) (Saint-Martin J., 2002).

During these encounters, the Sokols and Štukelj were sometimes glorified. This was, for instance. the case during the World Championship in 1931, when the newspaper *Le Petit Parisien* on July 12, 1931 (p 4.) analyzed the French chances. They observed the Slavs in training and to journalists the Sokols appeared once again as the favorites. Especially when "among them are eight gymnastic champions including Štukelj, the World Champion at the 1924 Olympics, and Primožič, winner of the International Gymnastics Championships which took place last year in Luxembourg". Thus, Štukelj was still considered a formidable opponent and the gymnastics he practiced with strength and flexibility still an example to follow. The champion's impact on the press in France seemed to last a very long time: 15 years after his victory at the 1924 Olympic Games, he was still presented as a talented coach during a meeting at the Pierre de Coubertin stadium in Paris (*L'Auto*, May 13, 1939).

CONCLUSION

The innovative nature of Štukelj's practice is indisputable, partly because the gymnastics he performed was different in the sense that certain elements such as the

"inverted iron cross" were previously unrecognized, but also because he knew how to use his Sokol education to optimize the opportunities of the sport regulation at a time of technical changes.

Štukelj did not transform the practice of gymnastics as a whole. He nevertheless inaugurated a change in the ring techniques. He indeed made the most of the alternation of strength and momentum as well as new qualities, which were identified in the official report of the 1924 Olympic Games as follows "[...] an incomparable lightness and flexibility at the service of superior technique, considerable endurance and strength of will" (J. Dalbanne, *Official Report of the 1924 Olympic Games*, p. 339). Štukelj's technique and strength were transcended by the values he held as a Sokol. He himself explained how much he was carried by the education he received within the Sokols; it strengthened his patriotic convictions and also built the rigor and stubbornness needed later for training. Sokol education was the basis of Štukelj's remarkable will mentioned by J. Dalbanne.

As a champion without spectators in Paris in 1924, then as a champion underestimated in regards of the gigantism of the Games in Berlin in 1936, Štukelj remained relatively unknown to the general public. His symbolic rebirth came later and dates back to the end of the 20th century. His fame was revived with Slovenia's independence in the 1990s (25 June 1991). The country, freed from communism, caught the attention of Western countries. The context oversized the symbols of identity of the new nation. Now the oldest Olympic champion, and still very valiant, Leon Štukelj offered a positive evocation of non-violent combativeness. He also cultivated this image, and liked to recall that he had always wanted, through his membership in the Sokols, to train his body and his mind, and not to subscribe to any political orientation.

Everything suggests that the iconic power of a champion like Štukelj, who had been educated in the Sokol of Novo Mesto, was thus reinforced. After the fall of the Berlin Wall and the collapse of the Eastern Bloc, Štukelj was approached to become one of the founding members of the Slovenian Olympic Committee, finally created on October 19, 1991, and recognized by the IOC in February 1992. This is also why when in 1994, on the occasion of the hundredth anniversary of the Olympic movement, the IOC wished to honor those who have contributed to the development of Olympism, Štukelj re-emerged. After fifty years in the shadow, he embarked on a second career in sports and became an ambassador of both the values of Olympism and the virtues of physical practice. As he grew older, he attracted admiration of observers who were seduced by his dynamism. As the oldest living Olympic champion, he was invited to the opening ceremony of the 1996 Atlanta Olympic Games where he carried the Olympic torch. In 1997, at the age of 98, he was inducted into the International Gymnastics Hall of Fame as the longest-serving Olympic gold medalist alive. The following year, a few months before he passed away, his hometown of Novo Mesto organized a ceremony in his honor, the Ave Triumphator, to celebrate his one hundredth anniversary (Berger, Kuljaj, 1998). On top of this, various events were organized, including a scientific conference on the theme "Sport, Health and Old Age" (International scientific meeting at the centenary of the Olympic champion Leon Štukelj: "Sport - Health - Old Age", 11-18 November 1998).

Like Hungarian gymnast Agnes Keleti, who is the current oldest Olympic champion (David & Dobor 2020), Leon Štukelj's legacy is undoubtedly linked to his longevity and vitality in view of his age and not only to his remarkable sports career and to its past performances. Through these values, it is more the impact of the Sokol education than our

remembrance of his gymnastic achievements that still live on.

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Article received: 4.9.2021
Article accepted: 26.9.2021

WOMEN'S ARTISTIC GYMNASTICS ROUTINE COMPOSITION AT RIO 2016 OLYMPIC GAMES: A TECHNICAL ANALYSIS OF BALANCE BEAM AND FLOOR EXERCISE ROUTINES

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Original article *DOI:10.52165/sgj.14.1.17-28*

Abstract

Artistic gymnastics is a sport comprising a variety of movements performed on apparatus, connected by the art of movement. The Code of Points is a document that brings together all the rules of this sport; it guides the work of coaches and gymnasts, helping to compose the routines presented in competitions. This study focuses on women's artistic gymnastics and the implementation of its rules, established by the Code of Points 2013-2016. It aims to analyze the elements that composed the gymnasts' routines during the last Olympic Games (Rio 2016) and identify the possible technical relations between the composition of the balance beam and the floor exercises in line with the current Code. For this purpose, we carried out a video analysis of 82 balance beam routines and 82 floor exercise routines, in total 164 routines performed by athletes competing in women's artistic gymnastics at the Rio 2016 Olympic Games qualifying competition. We observed that the Code of Points is still little explored, and gymnasts use only a few of the elements available. In this sense, the International Gymnastics Federation and, more specifically, the Code of Points, which regulates the sport, should devise strategies for better usage of the elements available within the stipulated rules.

Keyswords: *Routine composition, Code of Points, Olympic Games.*

INTRODUCTION

Artistic gymnastics (AG) is a sport formed by a variety of movements performed on apparatus with different motor requirements, and according to Arkhaev & Suchlin (2004, p.11), "gymnastics is connected by the art of movement". In this modality, the judges' judgment is based on the perfect execution of the movements that require substantial daily training. Also, Nunomura *et al.* (2009) points out that, like other sports, AG is characterized by complex and daring exercises, and gymnasts constantly challenge laws of physics, trying to reach and exceed their bodies' and apparatus' limits while executing increasingly audacious and complex movements.

AG requires that gymnasts demonstrate neuromuscular control, rhythmic sense, complete body balance control, and a technical posture for performing its elements. Besides, gymnasts have to demonstrate security and confidence through different exercises with

different degrees of difficulty that need to be executed in a harmonious and precise manner. Aesthetics and art, associated with performance, give AG its artistic quality, also found in other artistic manifestations (Sarsfield, 1959). In the last decade, we have seen a notable evolution and modification in AG's competitive methods.

In AG, gymnast's results are the sum of two scores, the difficulty and the execution score, awarded for each apparatus and in comparison with other competitors. The Code of Points (CoP) is a document that defines the AG rules. It is considered the single most important instrument that influences the development of AG. Pastor *et al.* (2003) refers to the CoP as the main regulator of coaches', judges', and gymnasts' work.

Thus, the CoP defines the parameters and criteria to differentiate gymnasts' executions, the scoring attributions and judging methods; as such, it functions as the parameter for score elaboration by judges (judgment), and routines composition and training guidance by coaches (Robin & Santos, 2014). These arguments are supported by the changes made to the CoP updated every four years. According to Arkaev & Suchilin (2004), the changes made to the CoP havr not always been the most adequate; nevertheless, most of them have been quite positive and beneficial for the development of the sport and at the same time have guided the development of the modality as we know today.

In women's artistic gymnastics (WAG), four apparatus are officially recognized by the International Gymnastics Federation (FIG): the vault, the uneven bars, the balance beam and the floor exercise. However, gymnasts are expected to include acrobatic and dance elements in their routines only on the balance beam (BB) and the floor (FX) apparatus (FIG, 2017; Donti *et al.*, 2014). These elements are combined to maximize their performance and increase the final score, as specific to each apparatus.

On the balance beam, every routine begins with a mount (taken off from the board or the mat); during the routine gymnasts perform leaps, jumps and hops, turns, holds and acrobatic elements with or without flight phase and hand support. The evaluation of the routine begins with a mount and finishes with landing a dismount. After finishing the routine, whether with a dismount or with a fall that lasted more than 10 seconds, judges award two scores: difficulty value (DV) score and execution value (EV) score. The DV score is calculated as the sum of maximum 8 highest difficulties including the dismount (maximum 5 acrobatic and minimum 3 dance elements), the prescribed composition requirements (CR) (Table 1), and the values that gymnasts get for directly connecting acrobatic elements, turns and/or acrobatic-dance elements. The EV score is given for the quality of the skills performed and the gymnast's artistic performance (FIG, 2013), and has an initial value of 10.00 points if the gymnast performs at least 7 elements. From the value of 10.00 points judges deduct errors that occur during the performance of a routine. The final score (FS) is calculated as the sum of DV and EV minus neutral deductions.

Just as on the BB, the DV and EV scores for the floor exercise are calculated in the same way. On this apparatus, the gymnast performs leaps, jumps, hops, turns, hand support elements and saltos in different directions (forward, sideward and backward). The FX is the only WAG apparatus that has musical accompaniment, which is of major importance for the development of the routine. The gymnast will be evaluated from her first movement, which does not necessarily have to be at the beginning of the music but must end exactly at the end of the music. During this Olympiad, the artistic aspects for this apparatus have been significantly changed, including providing a different understanding and bringing forward a great discussion about what should be evaluated

in terms of choreographic composition, expression, music and musicality (Donti *et al.*, 2014; Kerr & Obel, 2015).

Acrobatic and dance elements have different scores and possible combinations between them, and, together with the execution of each element, they make up the gymnast's final score at competitions. Therefore, the evaluation of competitive WAG is based on the quantitative and the qualitative index, with technical rigor in the execution of acrobatic and dance movements and valorization of expressiveness and creativity in the choreography (FIG, 2015; Donti *et al.*, 2014). Sterkowicz-Przybcién (2004, p. 49) presents a model for the composition and fundamental elements of BB and FX routines in accordance with the CoP definitions :

The balance beam routine may not exceed 90 seconds and must include acrobatic (tumbles, balance holds, handsprings, saltos) and dance (steps, jumps, skip jumps, rotations, body waves, balance holds) elements. The balance beam is very characteristic of women's gymnastics and the routines must emphasize femininity, grace, diversity of movements, harmony between acrobatic and dance elements, presentation and artistry. Balance beam requires accurate movements, intensive concentration and perfect balance. Any lack of these means a point deduction. A serious mistake is getting hold of the apparatus to avoid a fall. The floor exercise routine, like balance beam, may not exceed 90 seconds. This event is a combination of acrobatic and dance movements choreographed to music. The important elements are harmony of acrobatic and dance movements, integration between the movements and music, grace, rhythm, presentation and artistry. The gymnasts must make versatile use of the entire floor space, changing the pace and direction of performed elements.

Another factor that should directly influence the routine composition and configuration is the setup of the routines according to each apparatus's specific requirements, called "Compositional Requirements" (Kalinski *et al.*, 2011; Donti *et al.*, 2014). Gymnasts who perform elements that meet these requirements are awarded a bonus of 0.5 points in their final difficulty score. This means that gymnasts tend to include some elements in their routines only to meet these requirements and not necessarily to count toward the eight elements that make up the calculation of the difficulty[1] score, thus increasing the maximum possible score to be achieved (FIG, 2013). The Compositional Requirements stipulated by the CoP 2013-2016 for both apparatus are shown in Table 1.

Thus, in order to deepen the theme and assist coaches, judges, technical committees and subsequent scientific works, we analyzed the elements that made up the routines of WAG gymnasts as they were presented at the Olympic Games (Rio 2016), and to identify possible technical relations between the composition of the BB and the FX routines, according to the CoP used during the 2013-2016 Olympiad (FIG, 2013). The purpose of this study is to identify possible patterns of routine composition to provide better guidance for the modality, both for the evolution of the CoP and better work of those involved with the practice (coaches, judges, athletes and sports managers).

METHODS

This study has a quantitative exploratory design developed through the videographic research technique (Penafria, 2009). The videographic research was carried out between October and

[1] According to CoP (2013-2016) for the composition of the difficulty value of Balance Beam and Floor Exercise routines, the eight most valuable elements performed by the gymnasts are counted, with a maximum of five acrobatic elements and a minimum of three dance elements (FIG, 2015).

November 2019, analyzing the images generated by the French broadcasting channel "FranceTV Sports®" through their official account on the online video platform YouTube®.

We analyzed 164 routines, 82 on BB and 82 on FX, from WAG gymnasts competing at the Rio 2016 Olympic Games qualifying competition. We analyzed all female gymnasts from all countries who passed through on these two apparatus. Qualified and up-to-date national and international judges carried out the video analysis.

The video analysis was performed in two steps:

1. The videos were analyzed separately to identify each of the acrobatic and dance elements that composed the routines. After identification, the difficulty value for each element was checked in the Table of Elements of the CoP (2013-2016);

2. Acrobatic, dance, and mixed connections[2] were analyzed. Also, falls and neutral deductions[3] were noted in each routine. The analyzed elements were quantified according to the gymnasts' skills (acrobatic, dance, connection, etc.), as described in the CoP in force at the time of the competition (2013-2016).

The data obtained through the videographic analysis were organized and accounted for according to the type of element (acrobatic or dance), connection (acrobatic, dance or mixed), neutral deductions and falls. In total, 1883 gymnastic elements were analyzed (between acrobatic and dance) in 164 routines, 82 on BB and 82 on FX. For the data analysis, we used the categorization methods for different types of elements according to the CoP division, in addition to descriptive statistics, using mean and mode values of the elements in the routines.

For this research, we considered only the elements with some difficulty value, while other elements performed were considered choreographic elements. From this analysis, we compared the routines' elements on the same apparatus to the descriptions available in the CoP according to their group elements, and also a general analysis between the BB and the FX apparatus, comparing the total amount and type of movements per routine, and reflecting on the composition of the routines on each apparatus.

In the analyses of the FX apparatus, the handspring forward, the round-off and the flic-flac elements were not considered since such movements were not included in the DV as they are preparatory elements for the acrobatic elements of higher value. On the BB, however, these elements in some cases were included in the DV and they feature in the movements for the CR (Table 1) complements and CV bonus. Elements performed more than once were counted in their entirety, although their second execution is not counted toward the DV.

RESULTS

The following results were divided into tables according to different forms of quantification and typification of the elements presented by the gymnasts. The total sum of different types of elements (acrobatic and dance), connections of elements (acrobatic, dance and mixed), number of falls and neutral deductions, as well as the incidence of each of the elements, its respective group and its respective value are presented in the Table

[2] The connections, whether acrobatic (only with acrobatic elements), dance (only with dance elements), or mixed (with acrobatic and dance elements), are characterized by gymnastic elements that are directly or indirectly performed subsequently within the same sequence/passage and can be used either to fulfill the composition requirements of an apparatus or to gain a bonus in the difficulty score.

[3] These are deductions related to specific problems during the gymnast's performance, such as exceeding the time limit of the routines, stepping outside the defined areas of the apparatus, or not presenting properly to the judges' panel.

of Elements. Finally, a list of how many elements from each of the groups were performed during the CI stage of the competition are presented in Table 5.

Table 1
Composition Requirements defined by FIG for Balance Beam and Floor Exercise.

Balance Beam	Floor exercise
● One connection at least 2 different dance elements, 1 being a leap or a jump with 180º split (cross or side), or straddle position; ● Turn (May be from Group 3); ● One acrobatic series, min. of 2 flight elements (with or without hand support), 1 being a salto (elements may be the same); ● Acrobatic elements in different directions (fwd/swd and bwd); ● Acrobatic dismount with the minimum value of D.	● A dance passage composed of two different leaps or hops, (from the Code) connected directly or indirectly (with running steps, small leaps, hops, chassé, chainé turns), one of them with 190º cross/side split or straddle position; ● Salto with longitudinal axis turn (min. 360º); ● Salto with double breadth axis; ● Salto bwd and salto fwd in the same or different acrobatic line; ● Acrobatic dismount with the minimum value of D

Table 2
Quantity and type of elements performed in the qualifiers of BB and FX at the 2016 Olympic Games.

Qualification – Balance Beam		Qualification – Floor Exercise	
Acrobatic elements	583	Acrobatic elements	391
Dance elements	476	Dance elements	433
Total elements (acrobatic + dance)	1059	Total elements (acrobatic + dance)	824
Acrobatic connections	147	Acrobatic connections	71
Dance connections	102	Dance connections	112
Mixed connections	90	Mixed connections	10
Falls	12	Falls	12
Neutral deductions for exceeding the routine's time	6	Neutral deductions for going out of bounds	17

Table 3
Incidence of elements in Balance Beam.

Gymnastics leaps, jumps and hops	Gymnastics turns	Acrobatic flight elements	Acrobatic Dismounts
Switch leap with ½ turn (D) – 48	2/1 turn on one leg with free leg optional below horizontal (D) – 13	Salto bwd stretched step-out (C) – 41	Salto bwd stretched with 2/1 twists (C) – 2
Switch ring leap (E) – 22	2/1 turn in tuck stand on one leg (D) – 2	Salto fwd tucked (D) – 33	Salto bwd stretched with 2 ½ twists (D) – 9
Johnson leap (C) – 15	2 ½ turn in tuck stand on one leg (E) – 2	Free aerial round-off tucked (E) – 1	Double salto bwd piked (E) – 32
Switch leap (C) – 62	2/1 turn with heel of free leg fwd at horizontal throughout turn (E) – 1	Salto bwd tucked (C) – 22	Double salto bwd tucked (D) – 11
Straddle pike jump (A) – 9	1/1 turn with heel of free leg fwd at horizontal throughout turn (C) – 14	Salto bwd tucked with 1/1 twist (F) – 7	Arabian double salto fwd tucked (G) – 1
Sheep Jump (D) – 25	1/1 turn with free leg held upward in 180º Split position throughout turn (C) – 11	Salto fwd piked (E) – 12	Salto bwd stretched with 1 ½ twists (C) – 1
Split leap with 1/1 turn (D) – 3	1/1 turn on one leg with free leg optional below horizontal (A) – 47	Salto bwd piked (C) – 7	Salto fwd stretched with 1/1 twist (B) – 1
Split jump (A) – 68	1/1 Illusion turn (D) – 2	Salto bwd stretched with legs together (E) – 28	Gainer salto piked at the end of the beam (C) – 1
Stretched jump/hop with 1/1 turn (B) – 1	3/1 turn on one leg with free leg optional below horizontal (E) – 1	Salto bwd stretched with 1/1 twist (G) – 1	Gainer salto stretched at the end of the beam (D) – 10
Wolf hop/jump (A) – 53		Free Aerial Cartwheel (D) – 56	Gainer salto stretched with 1/1 twists at the end of the beam (E) – 5
Wolf hop/jump with 1/1 turn (C) – 3		Free aerial walkover (D) – 60	Salto bwd stretched with 3/1 twists (F) – 6
Split leap fwd (A) – 41		Salto swd tucked to side stand (D) – 39	Double salto bwd tucked with 1/1 twist (G) – 1
Sissone (A) – 8		Salto swd tucked with ½ turn to side stand (E) – 1	
		Flic-Flac with ½ turn (D) – 8	
		Flic-flac with 1/1 twist (D) – 3	
		Flic-flac with min. ¾ twist before hand support (D) – 2	
		Arabian salto tucked (F) – 2	
		Flic-flac (B) – 82	
		Flic-flac with high flight phase and swing down to cross straddle sit (B) – 1	
		Round-off (B) – 61	

Legend: fwd: forward; bwd: backward; swd: sideward.

Table 4
Incidence of elements in Floor Exercise.

Gymnastics leaps, jumps and hops	Gymnastics turns	Saltos forward and sideward	Saltos backward
Switch leap with ½ turn (C) – 35	2/1 turn in tuck stand on one leg (D) – 6	Salto fwd stretched with 2/1 twists (D) – 4	Salto bwd stretched with 2 ½ twists (D) – 37
Switch ring leap with ½ turn (D) – 2	2/1 turn with heel or free leg fwd at horizontal throughout turn (D) – 19	Double salto fwd tucked (F) – 2	Salto bwd stretched with 2/1 twists (C) – 11
Switch ring leap (C) – 35	2/1 turn with free leg held upward in 180º Split position throughout turn (D) – 24	Arabian double salto fwd piked (F) – 3	Double salto bwd piked (D) – 48
Switch leap with 1/1 turn (D) – 30	2/1 turn on one leg with free leg below horizontal (B) – 30	Arabian double salto fwd tucked (E) – 8	Double salto bwd tucked with 2/1 twists (H) – 10
Johnson leap (B) – 6	1/1 turn in tuck stand on one leg (B) – 1	Aerial Cartwheel (A) – 15	Double salto bwd stretched with legs together (F) – 23
Johnson leap with ½ turn (C) – 14	1/1 turn with heel or free leg fwd at horizontal throughout turn (B) – 4	Salto fwd piked (A) - 3	Double salto bwd stretched with ½ turn (F) – 1
Switch leap (B) – 15	1/1 turn with free leg held upward in 180º Split position throughout turn (B) – 10	Salto fwd piked with ½ turn (B) – 3	Double salto bwd tucked (D) – 53
Split leap to ring position with 1/1 turn (D) – 7	2/1 turn on one leg with free leg below horizontal – 20	Salto fwd stretched with legs together (B) - 6	Whip back (A) – 12
Split leap with 1/1 turn (C) – 43	1/1 Illusion turn (B) – 4	Salto fwd stretched with ½ turn (B) – 3	Salto bwd stretched with legs together (A) - 1
Split leap with 1 ½ turn (D) – 26	4/1 turn on one leg with free leg below horizontal (E) – 2	Salto fwd tucked (A) – 8	Salto bwd tucked (A) – 1
Split ring leap (C) – 13	2/1 turn in back attitude (D) – 2	Salto swd tucked or piked (A) – 4	Salto bwd stretched with 1 ½ twists (C) – 25
Split leap fwd (A) – 15	3/1 turn on one leg with free leg below horizontal (C) – 14	Salto fwd stretched with 1 ½ twists (C) – 3	Salto bwd stretched with 3/1 twists (E) – 17
Split leap fwd with 1/1 turn (C) – 16	3/1 turn with free leg held upward in 180º Split position throughout turn (E) – 1	Salto fwd tucked with 1/1 twist (B) – 1	Salto bwd stretched with 3 ½ twists (A) - 2
Wolf jump (A) – 2		Salto fwd stretched with 1/1 twist (C) – 11	Double salto bwd piked with 1/1 twist (E) – 7
Wolf jump with 1/1 turn (B) – 1		Aerial walkover (A) – 16	Double salto bwd stretched with 1/1 twist (H) – 6
Straddle pike jump with 1/1 turn (C) – 26			Double salto bwd tucked with 1/1 twist (E) – 22
Stag jump (A) – 10			

Legend: fwd: forward; bwd: backward; swd: sideward.

Table 5
Quantification of the types of exercises present in the apparatus.

Balance Beam			Floor Exercise		
Type of exercise	N˚ of exercises in the CoP	N˚ of exercises performed	Type of exercise	N˚ of exercises in the CoP	N˚ of exercises performed
Gymnastics Turns	22	9 (41%)	Gymnastics Turns	19	13 (68,5%)
Gymnastics Leaps, Jumps and Hops	35	13 (37%)	Gymnastics Leaps, Jumps and Hops	39	17 (43,5%)
Acrobatic Flight	36	21 (58%)	Saltos Forward and Sideward	16	14 (87,5%)
Dismounts	29	12 (41%)	Saltos Backward	19	15 (79%)

DISCUSSION

The first information from this data was the average of exercises performed by gymnasts on each apparatus (Table 2). The average was calculated by summing all performed elements on each apparatus (1059 elements on BB and 824 elements on FX), then dividing them by the number of routines performed on each apparatus in the competition analyzed individually (82 on each). Thus, we have an average of 12.91 elements per routine on BB and 10.04 on FX. The average number of elements has been increasing over the years, despite the time limit for the routines, as shown in the study by Seeman-Sinn *et al.* (2021), Kalinski *et al.* (2021) and Kezic *et al.* (2021); this has been directly influenced by the changes and adaptations of the CoP for each edition of the Games.

Considering that both BB and FX have the same total execution time - 1 minute and 30 seconds - we can infer that the FX, due to its lower average of elements compared to the BB, presents a greater concern in terms of the time devoted to the choreographic execution of the routine. This can probably be justified by the greater space to be covered and occupied on the FX platform (a 12 x 12-meter square) compared to the BB (5 meters long and only 10 centimeters wide), allowing greater freedom of movement in terms of dimension and a greater need for passages and choreographic elements in FX.

Also, the FX musical accompaniment seems to influence the smaller number of elements compared to the BB, given that the gymnast's movement needs to accompany the music throughout the performance. For such a difference between these apparatuses to be adequately evaluated, there are evaluation criteria such as Music and Musicality, for example, included in the FX execution score (Kezic *et al.*, 2021). Gymnasts can be appropriately judged for their artistic presentation using those criteria, although some recent studies have pointed out the difficulty of understanding and applying the concept of the artistic component that some coaches and judges have (Pajek *et al.*, 2013; 2014; Pajek, 2015).

In addition, a frequency analysis of acrobatic and dance elements in the routines was also carried out (Tables 3 and 4). For this analysis, 82 routines on both apparatus were considered. According to the CoP Table of Elements (FIG, 2013) divisions, the elements were grouped into 4 groups. Each element can be performed only once for the routine's difficulty count (Tables 2, 3 and 4), but elements can be performed more than once to create acrobatic, dance and mixed connections and the sum is added to the connection values, but not to the total element count.

On BB (Table 3), the elements in each group that most frequently appeared were the "split jump" (gymnastics leap - present in 83% of all routines), "1/1 turn on one leg with free leg optional below horizontal " (gymnastics turn - present in 57% of all routines), "flic-flac" (acrobatic elements - present in 100% of the routines), and the "double salto bwd piked" (acrobatic dismount - present in 39% of the routines).

On FX (Table 4), the elements in each group that most frequently appeared were the "split leap with 1/1 turn" (gymnastics leap - appears in 52.5% of all routines), "2/1 turn with free leg held upward in 180º split position throughout turn " (gymnastics turn - appears in 29% of all routines), "aerial walkover" (forward / side acrobatics - appears in 19.5% of all routines) and "double salto bwd tucked" (backward acrobatics - appears in 64.5% of all routines).

There is a greater variability of different types of leaps, jumps, hops, turns, and acrobatic elements on the FX apparatus (Table 5). It demonstrates greater versatility not only in the composition of the routines but also in terms of teaching and learning new elements throughout the gymnast's lifespan in the sport, given its development phases and important physical and psychological variables that AG involves (Nunomura *et al.*, 2010; Kalinski *et al.*, 2011).

Thus, it is clear that the composition of routines has a greater focus on competitive performance since the elements chosen and developed throughout gymnasts' sports career have a development line focused on the final difficulty and execution scores calculation (Cuk & Forbes, 2010), and the choreographic aspects take a secondary role. Erceg *et al.* (2014), Nunomura *et al.* (2019) and Atikovic & Kamenjasevic (2021) claim that practice time, experience in the sport and going through different configurations of structuring a routine according to the CoP in different Olympiads favor the development of complex variation of gymnastics skills in search of higher values and higher difficulty scores.

According to a study conducted by Oliveira *et al.* (2017), in the view of the judges, gymnasts consequently present very similar routines, with little innovation and no evident or described appreciation of this aspect, and with low variation in the discounts. Pizzol et al., (2017) present data on the average artistic discount suffered by the gymnasts who competed in Rio 2016 both on BB and on FX, demonstrating that there is in fact a low variation of these artistic discounts at all stages of the competition, supporting the hypothesis that the routines may be in line with the CoP concepts, or that the judges may not be evaluating them adequately. Such views agree with views related to the composition of the routines raised in our study, and in studies related to the artistic component carried out in other competitions, with different methods of analysis. (Pajek *et al.*, 2014; Pajek, 2015. The next CoP (2017-2021) brought some interesting innovations in this sense, such as withdrawal of the requirement of minimum D value for dismounts which allows gymnasts to perform a higher range of elements at the end of their routines, even if this element does not necessarily count toward the eight elements of greatest difficulty in the score (FIG, 2017; Atikovic & Kamenjasevic, 2021; Kalinski et al., 2021; Kezic et al., 2021).

Kalinski *et al.* (2011), Kerr & Obel (2015), Grossfeld (2014), Cuk (2016), and Nunomura *et al.* (2019) highlight the importance of specific types of exercises for the composition of routines and, consequently, for the difficulty value of the routines presented by WAG athletes. Despite the constant changes in the CoP in order to attach more value to the movement executions and ensure greater safety of the gymnasts, better interpretation for the judges on the specificity of each of the movements performed, and also for better appreciation of the sport by the media (Oliveira & Bortoleto, 2009; Grossfeld, 2014; Nunomura *et al.*, 2019), there is still an increased appetite for high difficulty scores. This leads us to think that performance in the sport is linked to this component.

Since the change of the "closed" code (with a maximum score of 10 points), which occurred in 2005, to the "open" code with no maximum possible score for a gymnast (Oliveira & Bortoleto, 2009; Kerr & Obel, 2015; Grossfeld, 2014; Nunomura *et al.*, 2019), the difficulty value has been given more attention in the CoP and can be calculated in different ways, with different numbers of elements and with different compositional requirements. Such changes have created an incessant search for an ideal method for this calculation that can value both the difficulty of the gymnasts' elements and how they are carried out in a balanced and coherent way.

In addition, the CoP undergoes evaluations and modifications by the Technical Committee of the FIG throughout each Olympiad and tries to improve the organization and structure of AG worldwide and to make it safe and fair for its practitioners while also trying to keep up with the demands from the public and the media. As such, it serves as the foundation for training, judgment, and evolution of the sport (Oliveira & Bortoleto, 2009; Ferreirinha & Barata, 2009).

It is evident that the composition of routines by top gymnasts follow the changing trends of the CoP. Gymnasts adapt their training, learning and routines to the document, and follow the changing aspects of the elements that will be part of their routines in terms of value, form of execution and compliance with requirements, for example. This makes their routines even more similar.

Hence, the artistic component of AG is fundamental for competitions since it is the main component that clearly differentiates not only one routine from another but also the entire process that gymnasts undergo to arrive at a given competitive moment. It therefore also deserves special attention from coaches, technical committees, spectators, and the academic community.

CONCLUSION

Our data analysis has verified that almost all the routines analyzed in the qualifying phase in WAG at the Rio 2016 Olympic Games met the FIG standards as regulated by the CoP. It has shown that the CoP also has the purpose of influencing gymnasts' routines through the years between the Olympics, guiding the process and, training.

We can also infer that there is an assembly line of routines repeated by several gymnasts of different nationalities, due to the CoP regulations. The most difficult acrobatics, dance elements, connections, and uses of different elements end up repeating themselves, even if involuntarily, probably due to the valorization or devaluation of a particular group of elements that occurs with each re-edition of the CoP. In this sense, the FIG, responsible for directing the sport through the CoP, could devise strategies to better use the elements present within its stipulated rules.

The updated values, forms of execution, and observations of the execution failures in exercises end up

guiding the composition of the routines and the execution of certain elements inserted in them. Therefore, both coaches and gymnasts must be aware of the CoP changes and thus be able to compose their routines in the best possible way, exploring the various possibilities within the sport's rules and prerequisites.

Finally, we highlight the need for further research of the ways FIG regulations play a role in each Olympiad for gymnasts, coaches, judges, and others involved with the sport. We also highlight the existing gaps in the "rules" of the sport that deserve to be better analyzed and restructured for subsequent Olympiads. It has been observed that many routines follow the same pattern from the setup to the execution in order to meet the requirements of the CoP and get the least penalty.

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Article received: 22.4.2021
Article accepted: 19.10.2021

EXAMINATION OF MOVEMENT PATTERNS THAT REFLECT THE PROFICIENCY LEVEL IN STRADDLE VAULT FOR ELEMENTARY SCHOOL CHILDREN

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Original article *DOI:10.52165/sgj.14.1.29-44*

Abstract

The purpose of the present study was to examine movement patterns that reflect the proficiency of straddle vault in elementary school students and to clarify the differences in the movement of technique depending on gender, grade, and height of the vaulting box. The subjects were 453 children (220 boys, 233 girls) from the 3rd-6th grade. Their straddle vault movements were recorded from the left and front sides and scored by the observational evaluation criterion. Latent class analysis was used to extract the movement patterns of straddle vault. The probability of belonging to each movement pattern was tabulated by gender, grade, and height of the vaulting box. To investigate the characteristics of the movements for gender, grade, and height of the box, we performed a $\chi 2$ test and residual analysis. As a result of identifying the movement patterns by latent class analysis, it became clear that the straddle vault movements of elementary school children can be categorized into five groups: Failure vaulting, Arm dependent vaulting, Unstable landing vaulting, Stable vaulting, and Strong push-off vaulting. There was no difference between boys and girls in the appearance rate of the movement patterns ($\chi 2=7.707$, $p>0.05$). Although there was a significant difference in the appearance rate of patterns between grades ($\chi 2=42.615$, $p<0.01$), but highly proficient movements didn't tend to increase as the grades increased. The five movement patterns clarified in this study are thought to lead to the detailed evaluation of children's straddle vault movements and the enhancement of instruction according to their proficiency.

Keywords: *physical education, proficiency, vault, elementary school, latent class analysis.*

INTRODUCTION

Gymnastics enhances muscular and functional fitness, cultivates the movement exhibition of the learner (Hedbávný et al., 2017), and develops their physical self-concept (Rudd et al., 2017). In school education, gymnastics, including frequent changes in body position and movements in different directions, is considered to be the key type of movements in children's motor development (Pajek et al., 2010). Even in Japan, gymnastics is positioned as one of the areas of exercise that make up physical education (PE), and in the course of study, gymnastics is said to be an exercise that allows children to enjoy acquiring skills by engaging in various movements and challenging basic and advanced techniques that suit their abilities (Ministry of education, 2017). Gymnastics in PE of the elementary school consists of three contents: mat exercise, horizontal bar exercise, and vaulting box exercise.

Looking at the vaulting box exercise, the most rudimentary and basic technique is straddle vault (Kaneko, 1987). In other words, straddle vault has the same technical tasks as the advanced techniques learned in PE (e.g. squat vault), and it is desirable to acquire it at the elementary school stage.

One of the characteristics of gymnastics is that children who can perform the technique and children who cannot do it are separated. For straddle vault, the success or failure of jumping over the box is greatly different. Thus, the technical factors necessary for jumping over the box have been examined by comparing the success and the failure groups (Hisamoto et al., 1986; Hanai, and Maeno, 2014), and in many cases, the instruction focused only on jumping over the box. On the other hand, in gymnastics, it is important to give guidance and tasks by evaluating in detail the proficiency level of the technique (Hosogoe et al., 2001; Pehkonen, 2010), including the viewpoint of not only success or failure but the performance of the movement itself. Regarding fundamental movements (e.g. running, jumping, and throwing) mainly for infants and elementary school children, the movement patterns and evaluation criteria according to motor development have been clarified (Takamoto et al., 2003; Nakamura et al., 2011). However, for the movement technique in the vaulting box exercise, the movement patterns and evaluation viewpoints according to the proficiency level are not obvious. By clarifying the image of the proficiency level of movement and evaluation criteria for straddle vault that are learned in many elementary schools, it is considered that individually optimized instruction based on the proficiency level will be enhanced and the quality of vaulting box exercise class will improve.

In research on exercise movement and motor development, gender and grade or age differences are often examined (Kevin et al., 2013; Shinohara et al., 2016). However, no studies have explained the gender or grade differences in the movement of straddle vault. Besides, it is possible in gymnastics that performing the movement may differ depending on the setting of the instrument. In the vaulting box exercise, the height of the box can make a major difference in the setting of the equipment, but the differences in movement depending on the height of the vaulting box have not been sufficiently examined. Understanding the features of movements caused by differences in gender, grade, and equipment settings will lead to step-by-step instruction and appropriate environment setting to suit individual skills.

The purpose of this study is to identify movement patterns that indicate the proficiency level of straddle vault in elementary school children and to identify the differences in the movement technique in dependence of gender, grade, and height of the vaulting box.

METHODS

Straddle vault is listed as a learning content in the 3rd to 6th grade (3rd: 8-9-year-old, 4th: 9-10-year-old, 5th: 10-11-years-old, 6th: 11-12-year-old) in the Japanese physical education curriculum guidelines (Ministry of Education, 2017). Therefore, the subjects of this study were 453 children from 3rd to 6th grade (220 boys, 233 girls) in three elementary schools in Hyogo prefecture, Japan. These three schools were selected from the general public elementary schools that do not have special physical education programs, taking into consideration the number of children. The survey period was from September 2016 to November 2017, when the vaulting box exercise class was held in the target schools. Prior to the survey, the research content was explained to the principal of the target school and the person in charge of the class. Documents and consent forms regarding the purpose, method, safety and ethics of the research

were also distributed to the parents of the children, and consent forms were obtained. The research was approved by the local Research Ethics Committee (No: 211).

In the trial, after warming up and the practice trial of straddle vault twice, the actual trial was videotaped. A video camera was installed in front of and 7.5m to the left of the vaulting box, and fixed shooting was performed at 60 frames per second and a shutter speed of 1/500 second. The vaulting box was a small vaulting box (length: 80cm, height: 60cm (4-box), 70cm (5-box), 80cm (6-box) standardized by the Ministry of Education. The orientation of the vaulting box was set to be vertical, and the height of the vaulting box was decided to be selected from the 4-box to 6-box by children themselves.

Qualitative evaluation by observing movements has come to be widely used in physical education research (Čepička, 2003; Kovač, 2012; Majerič et al., 2016). In this study, the movements of straddle vault performed by elementary school children were evaluated using an observational evaluation criterion. Vaulting in artistic gymnastics is often divided into seven distinctive phases; running, jumping on take-off board, take-off board support, first flight phase, table support, second flight phase, and landing (Čuk and Karacsony, 2004; Atiković and Smajlović, 2009; Atiković, 2012). And, Kovač and Čuk (2003) present a description of the straddle vault technique in seven motion phases: run-up; hurdle step onto the springboard; take-off from the springboard; first flight phase; approach and push-off from the vaulting buck; second flight phase, and landing. In this study, referring to these previous studies, we decided to set six phases that integrate the running and the jumping on the springboard: [1] run-up and hurdle step onto the springboard; [2] take-off from the springboard; [3] first flight phase; [4] approach and push-off from the vaulting box; [5] second flight phase; and [6] landing. The captured video was played back in normal, slow, and frame-by-frame format for evaluation. In consideration of individual differences in approach distance and speed, the range of skills to be evaluated was from 3 steps before the take-off to landing. Table 1 and Table 2 show the observational evaluation criteria for straddle vault. When the children stopped on the vaulting box, the scores of the movements after the second fright phase were set to 0 (not appear). The evaluation was carried out by two graduate students who are engaged with a laboratory specializing in physical education and have experience in observational evaluation of running, jumping, and throwing movements of elementary school children.

To extract movement patterns of straddle vault, we categorized the movement of elementary school children by latent class analysis. The latent class analysis assumes multiple subgroups behind the subject group and extracts different response patterns to categorical observed variables as latent classes. It is possible to estimate the composition ratio of each class and the conditional-response probability to each category of the observed variables. We interpreted the movement patterns from the conditional-response probabilities to each evaluation item and the motion factors that characterize the pattern. Masyn (2013) cites that the conditional-response probability to a certain category is close to 1.0 (0.7 or more) as a condition of the items that characterize the extracted class.

In latent class analysis, increasing the number of estimated parameters may make the model indistinguishable (Miwa, 2009). Therefore, evaluation items that are effective for analysis were selected by the following steps A)- C).

A) We specified a 2-class model with all 30 items and confirmed that failure type and success type of jumping over the box were extracted as the patterns with the clearest difference.
B) Regarding the failure type, items with

the conditional-response probability of 0.7 or more to the highest evaluation category were excluded as items that were easy to achieve even in low-proficiency movements.

C) For the success type, items with the conditional-response probability of 0.7 or more to the lowest evaluation category were excluded as items that were particularly difficult to achieve.

Using the selected items, model estimation was performed while increasing the number of classes by 1, and the optimum number of classes was determined based on the information criteria (Akaike Information Criterion: AIC, Bayesian information criterion: BIC) and likelihood ratio chi-squared statistics (G^2). The movement patterns were interpreted from the conditional-response probabilities of the evaluation items. The poLCA package (Linzer and Lewis, 2011) of statistical software R version 3.6.1 was used for latent class analysis. Considering the problem of the local solution, the estimated number of repetitions with different initial values was specified as 100 times.

The probabilities of belonging to each movement pattern (the class membership probabilities) were tabulated by gender, grade, and height of the vaulting box. The latent class analysis has a feature of soft clustering, and does not uniquely determine the class to which the subjects belong but shows the class membership probabilities, ie., the probabilities that an individual belongs to each class. Therefore, in this study, the number of children in each movement patterns were weighted on the basis of class membership probabilities at the time of aggregation. For example, if the class membership probabilities of student A is 0.7 for class A, 0.2 for class B, and 0.1 for class C, 0.7 in total will be added to class A, 0.2 to class B, and 0.1 to class C. By doing so, the appearance rate of the movement pattern can be examined in more detail based on the estimation result, as compared with the case where the subject belongs to one class. After totaling, to investigate the characteristics of the movements for each gender, grade, and height of the vaulting box, we performed a χ^2 test and residual analysis. The significance level was 0.05, and Cramer's V was used as the effect size of the χ^2 test.

RESULTS

Item selection for Latent class analysis

When a 2-class model was specified using all 30 items, two patterns were extracted: failure type that rides on the vaulting box, and success type that succeeded in jumping over the box. In the failure type, the conditional-response probabilities to the highest evaluation category exceeded 0.7 for 4 items: Item1 (Stride adjustment), Item2 (Speed adjustment), Item4 (Pushing by stepping leg) and Item18 (Aligning both hands). In the success type, the conditional-response probabilities to the lowest evaluation category exceeded 0.7 for 3 items: Item7 (Swing the arm backward), Item10 (Attracting arms) and Item12 (Swing up arms). These 7 items were excluded, and 23 items were used for the latent class analysis.

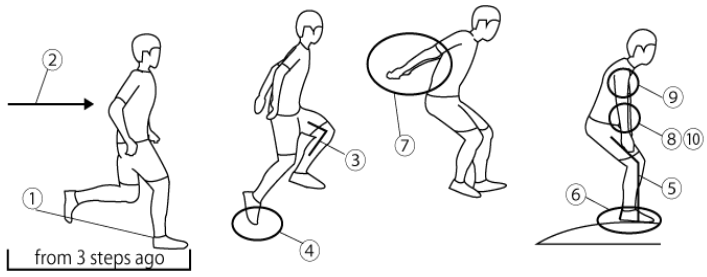
Table 3 shows the information criteria and likelihood ratio chi-squared statistics when estimating up to 6 class models. The BIC showed the minimum value when the 5-class model was estimated. Therefore, we decided to use a 5-class model in this study.

Identification of straddle vault movement patterns by latent class analysis

Table 4, Table 5, and Table 6 show the conditional-response probabilities of the 5-class model. As a result of interpreting the movement patterns based on the probabilities, movement patterns and their composition ratios were *Failure vaulting* (FV) (0.12), *Arm dependent vaulting* (ADV) (0.27), *Unstable landing vaulting* (ULV) (0.31), *Stable vaulting* (SV) (0.24) and *Strong push-off vaulting* (SPV) (0.06).

Table 1
Observational evaluation criterion for straddle vault movement of phase [1]-[3].

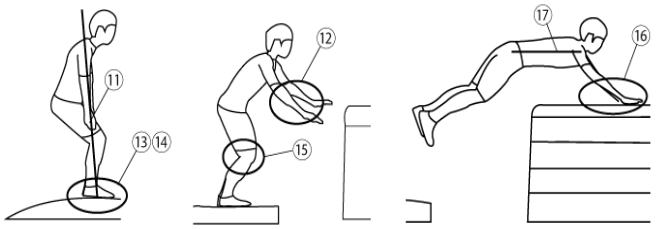
[1] Run-up and hurdle step onto the springboard



1 Stride adjustment
2 Speed adjustment
3 Leading by free leg
4 Pushing by stepping leg
5 Adjusting free leg flexion
6 Aligning legs
7 Swing arms backward
8 Aligning arms
9 Tightening aside
10 Attracting arms

Item		Category/Score		
		3	2	1
[1]	1	-	Smooth stride	Stride becomes smaller
	2	-	Smooth speed	Speed slows down
	3	-	Knee angle ≦ 90°	Knee angle ＞ 90°
	4	-	There is a flight period	There is no flight period
	5	-	Center of foot below the knee	Heels below the knee
	6	-	Aligned	Not aligned
	7	Stretch and pull arms	Bend and pull arms	Not pull arms
	8	-	Aligned	Not aligned
	9	-	Sides are tight	Sides are open
	10	-	Hands are below the waist	Hands are above the waist

[2] Take-off from the springboard & [3] First flight phase

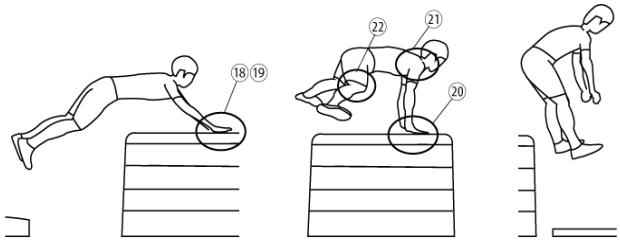


11 Making a body axis
12 Swing up arms
13 Preemption of grounding
14 Timing of grounding
15 Rebound jump
16 Aligning legs
17 Swing arms backward

Item		Category/Score		
		3	2	1
[2]	11	-	Shoulders, knees, feet are in a straight line	Not in a straight line
	12	Swing up big	Swing up small	Not swing up or swing down
	13	Step on forefoot	Put weight on forefoot	Ground sequentially from heel
	14	-	Ground at the same time	Not ground at the same time
	15	Knees extend at the same time as ground	Knee flexion fixed	Knees flex after ground
[3]	16	Touch box after leg extension	Touch box at the same time as legs extension	Touch box before leg extension
	17	Above shoulder	Above midpoint of shoulders and elbows	Below midpoint of shoulders and elbows

Table 2
Observational evaluation criterion for straddle vault movement of phase [4]-[6].

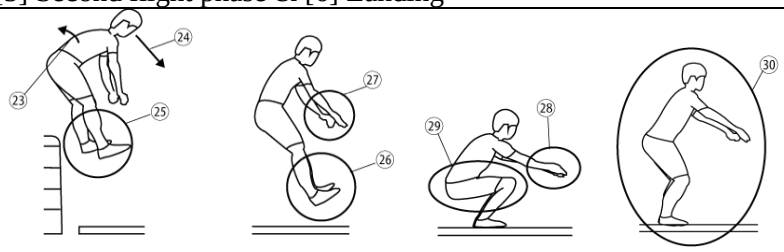
[4] Approach and push-off from the vaulting box



18 Aligning both hands
19 Timing of putting hands
20 Push-off
21 Raising shoulders
22 Keeping legs extended

Item		Category/Score		
		3	2	1
[4]	18	-	Aligned	Not aligned
	19	-	Touch at the same time	Not touch at the same time
	20	Push-off	Push backwards	Stop or buffer by hand
	21	Shoulders go up	Shoulders move forward	Shoulders stop at the position of hands
	22	-	Open legs with legs extended	Open legs with knees bent

[5] Second flight phase & [6] Landing



23 Rotating backward
24 Looking to the landing position
25 Control of leg swing
26 Closing legs
27 Raising arms
28 Swing down arms
29 Flexing lower limbs
30 Stopping firmly

Item		Category/Score			
		3	2	1	0
[5]	23	-	Turn back the rotation	Not turn back the rotation	Not appear
	24	-	Look at the landing position	Looking straight down	Not appear
	25	-	Control the swing	Swing legs forward	Not appear
	26	-	Legs are closed and aligned	Not closed and aligned	Not appear
	27	Raise forward	On the side of body	Behind the body	Not appear
[6]	28	Swing arms down	Raise arms	Not swing down or raise	Not appear
	29	Flex hips and knees	Flex knees	Stretch knees	Not appear
	30	-	Stop firmly	Not stop firmly	Not appear

Table 3
Criteria to assess model for latent class analysis.

Number of class	AIC	BIC	G^2	DF	P-value
2	13267.28	13600.66	7576.42	372	p<0.001
3	12711.75	13213.89	6938.89	331	p<0.001
4	12400.22	13071.11	6545.36	290	p<0.001
5	12214.81	13054.45	6277.95	249	p<0.001
6	12159.35	13167.75	6140.49	208	p<0.001

AIC: Akaike Information Criterion
BIC: Bayesian Information Criterion
G^2: Likelihood ratio chi-square statistics
DF: Degree of Freedom

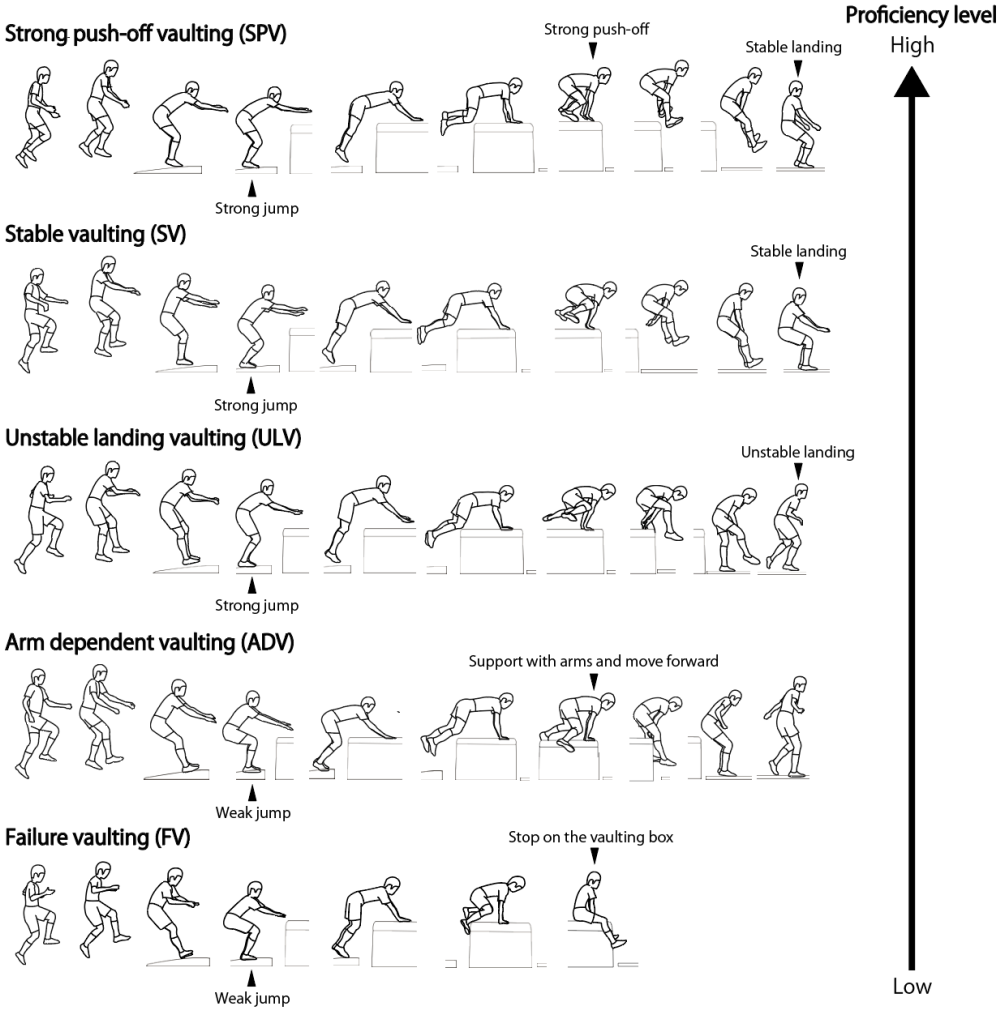


Figure 1. Movement patterns of straddle vault drawn based on the response probabilities.

Table 4
Conditional-response probabilities for latent class analysis of phase [1]-[3].

Item	Category/Score	Failure vaulting	Arm dependent vaulting	Unstable landing vaulting	Stable vaulting	Strong push-off vaulting
[1] Run-up and hurdle step onto the springboard						
3	Leading by free leg					
	2 Knee angle ≦ 90°	0.44	0.53	0.69	0.70	0.73
	1 Knee angle > 90°	0.56	0.47	0.31	0.30	0.27
5	Adjusting free leg flexion					
	2 Center of foot below knee	0.20	0.09	0.88	0.93	0.66
	1 Heels below knee	0.80	0.91	0.12	0.07	0.34
6	Aligning legs					
	2 Aligned	0.57	0.60	0.68	0.74	0.78
	1 Not aligned	0.43	0.40	0.32	0.26	0.22
8	Aligning arms					
	2 Aligned	0.46	0.70	0.64	0.68	0.70
	1 Not aligned	0.54	0.30	0.36	0.32	0.30
9	Tightening aside					
	2 Sides are tight	0.41	0.42	0.56	0.49	0.69
	1 Sides are open	0.59	0.58	0.44	0.51	0.31
[2] Take-off from the springboard						
11	Making a body axis					
	2 Shoulders, knees, feet are in a straight line	0.20	0.30	0.80	0.86	0.87
	1 Not in a straight line	0.80	0.70	0.20	0.14	0.13
13	Preemption of grounding					
	3 Step on forefoot	0.00	0.00	0.11	0.17	0.15
	2 Put weight on forefoot	0.20	0.13	0.85	0.76	0.63
	1 Ground sequentially from heel	0.80	0.87	0.03	0.06	0.22
14	Timing of grounding					
	2 Ground at the same time	0.48	0.54	0.78	0.85	0.81
	1 Not ground at the same time	0.52	0.46	0.22	0.15	0.19
15	Rebound jump					
	3 Knees extend at the same time as ground	0.00	0.00	0.15	0.31	0.26
	2 Knee flexion fixed	0.13	0.11	0.79	0.65	0.58
	1 Knees flex after ground	0.87	0.89	0.05	0.04	0.16
[3] First flight phase						
16	Swing arms forward					
	3 Touch box after leg extension	0.09	0.09	0.20	0.37	0.34
	2 Touch box at the same time as legs extension	0.15	0.39	0.48	0.40	0.44
	1 Touch box before leg extension	0.76	0.52	0.32	0.23	0.22
17	Raising hips					
	3 Above shoulder	0.00	0.04	0.03	0.05	0.11
	2 Above midpoint of shoulders and elbows	0.06	0.61	0.74	0.67	0.77
	1 Below midpoint of shoulders and elbows	0.94	0.34	0.23	0.29	0.12

Table 5
Conditional-response probabilities for latent class analysis of phase [4]-[5].

Item	Category/Score	Failure vaulting	Arm dependent vaulting	Unstable landing vaulting	Stable vaulting	Strong push-off vaulting
[4] Approach and push-off from the vaulting box						
19	Timing of putting hands					
	2 Touch at the same time	0.67	0.75	0.71	0.82	0.89
	1 Not touch at the same time	0.33	0.25	0.29	0.18	0.11
20	Push-off					
	3 Push-off	0.00	0.04	0.02	0.01	0.82
	2 Push backwards	0.00	0.95	0.98	0.99	0.18
	1 Stop or buffer by hand	1.00	0.01	0.00	0.00	0.00
21	Raising shoulders					
	3 Shoulders go up	0.00	0.11	0.04	0.16	0.96
	2 Shoulders move forward	0.00	0.88	0.96	0.84	0.04
	1 Shoulders stop at the position of hands	1.00	0.01	0.00	0.00	0.00
22	Keeping legs extended					
	2 Open legs with legs extended	0.41	0.80	0.73	0.86	0.93
	1 Open legs with knees bent	0.59	0.20	0.27	0.14	0.07
[5] Second flight phase						
23	Rotating backward					
	2 Turn back the rotation	0.00	0.00	0.00	0.00	0.67
	1 Not turn back the rotation	0.00	1.00	1.00	1.00	0.33
	0 Not appear	1.00	0.00	0.00	0.00	0.00
24	Looking to the landing position					
	2 Look at the landing position	0.00	0.65	0.40	0.67	0.93
	1 Looking straight down	0.00	0.35	0.60	0.33	0.07
	0 Not appear	1.00	0.00	0.00	0.00	0.00
25	Control of leg swing					
	2 Control the swing	0.00	0.07	0.02	0.00	0.67
	1 Swing legs forward	0.54	0.93	0.98	1.00	0.33
	0 Not appear	0.46	0.00	0.00	0.00	0.00
26	Closing legs					
	2 Legs are closed and aligned	0.00	0.57	0.40	0.91	0.93
	1 Legs are not closed and aligned	0.00	0.43	0.60	0.09	0.07
	0 Not appear	1.00	0.00	0.00	0.00	0.00
27	Raising arms					
	3 Raise forward	0.00	0.03	0.00	0.00	0.28
	2 On the side of the body	0.00	0.16	0.14	0.24	0.68
	1 Behind the body	0.00	0.81	0.86	0.76	0.04
	0 Not appear	1.00	0.00	0.00	0.00	0.00

Table 6
Conditional-response probabilities for latent class analysis of phase [6].

Item	Category/Score	Failure vaulting	Arm dependent vaulting	Unstable landing vaulting	Stable vaulting	Strong push-off vaulting
[6] Landing						
28	Swing down the arms					
	3 Swing arms down	0.00	0.03	0.00	0.12	0.14
	2 Raise arms	0.00	0.39	0.25	0.44	0.45
	1 Not swing down or raise	0.00	0.57	0.75	0.44	0.41
	0 Not appear	1.00	0.00	0.00	0.00	0.00
29	Flexing the lower limbs					
	3 Flex hips and knees	0.00	0.11	0.01	0.40	0.07
	2 Flex knees	0.00	0.60	0.39	0.60	0.78
	1 Stretch knees	0.00	0.28	0.59	0.00	0.15
	0 Not appear	1.00	0.00	0.00	0.00	0.00
30	Stopping firmly					
	2 Stop firmly	0.00	0.34	0.00	0.84	0.67
	1 Not stop firmly	0.00	0.66	1.00	0.16	0.33
	0 Not appear	1.00	0.00	0.00	0.00	0.00

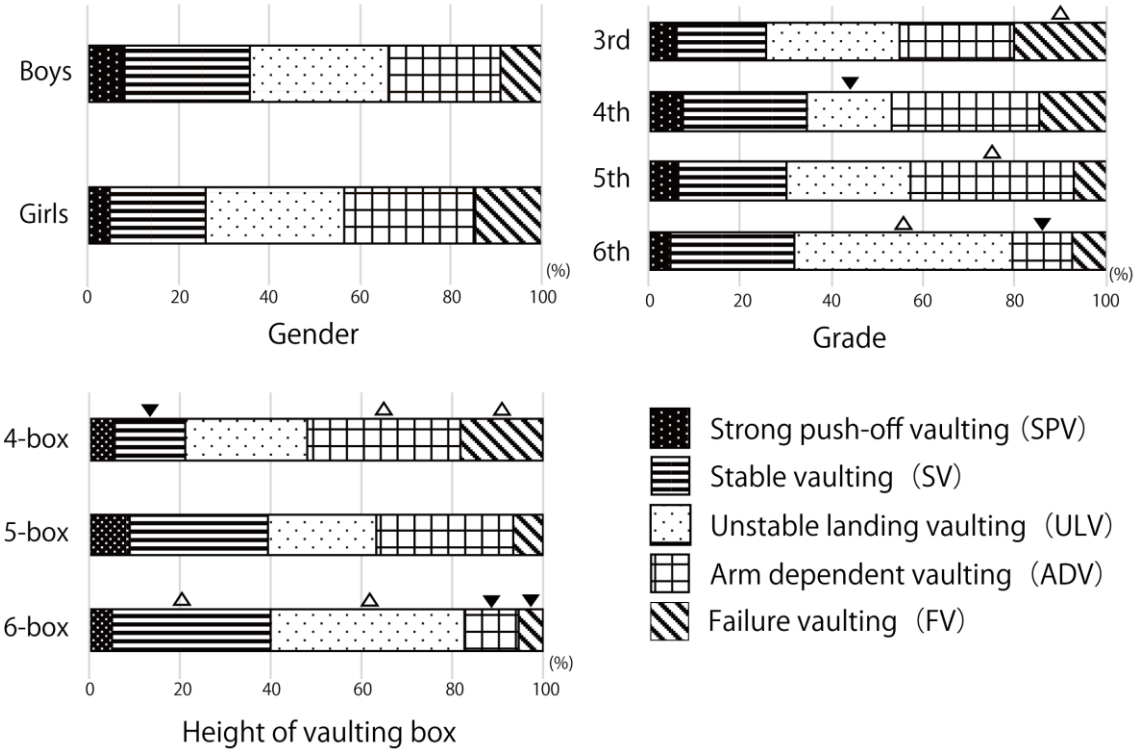


Figure 2. Appearance rates of straddle vaulting patterns by gender, grade, height of vaulting box. The white triangles indicate that the appearance rate is significantly higher than in the other groups. The black triangles indicate that the incidence is significantly lower than in the other groups. The significance level was 0.05.

FV showed a movement to stop on the vaulting box because the response probabilities to score 0 were 1.00 for the evaluation items after the second flight phase: from Item23 to Item30. Since the response probabilities to score 1 were 1.00 for the two items: Item20 (Push-off) and Item21 (Raising shoulders), FV cannot move the weight forward with arm support. Also, the response probabilities to score 1 were high in Item13 (Preemption of grounding: 0.80), Item15 (Rebound jump: 0.87), and Item17 (Raising hips: 0.94). Therefore, in FV, the movement was such that the heel touched the springboard, the knees bend deeply in take-off, and the hips were not sufficiently raised.

In ADV, the response probabilities to score 2 were high in Item20 (Push-off: 0.95) and Item21 (Raising shoulders: 0.88). Therefore, weight transfer by arm support was achieved, and jumping over the box was successful. However, as with FV, the response probabilities to score 1 were high in Item13 (Preemption of grounding: 0.87), Item15 (Rebound jump: 0.89), so the bouncy take-off movement was still not achieved. In ULV, weight transfer by arm support was achieved as in ADV. Since the response probabilities to score 2 were high in Item13 (Preemption of grounding: 0.85), Item15 (Rebound jump: 0.79), a bouncy take-off movement was achieved. On the other hand, the response probabilities of score 1 evaluation were high in Item28 (Swing down the arms: 0.75), Item29 (Flexing the lower limbs: 0.59), and Item30 (Stopping firmly: 1.00) in the landing phase, so the landing was unstable.

SV achieved bouncy jumping and weight transfer. Furthermore, the response probabilities to score 2 were high in Item29 (Flexing the lower limbs: 0.59) and Item30 (Stopping firmly: 0.84), so the desired landing posture was achieved. In SPV, the probabilities to the highest evaluation of score 3 were high in Item20 (Push-off: 0.82) and Item21 (Raising shoulders: 0.96). From this, unlike other patterns, stronger hand push-off was accompanied.

Figure 1 shows an illustration of each movement pattern based on the response probabilities of 23 evaluation items.

Appearance rate of movement patterns by gender, grade, and height of the vaulting box

Figure 2 shows the appearance rates of straddle vaulting patterns by gender, grade, and height of the vaulting box. As a result of the $\chi 2$ test, no significant difference was found in the appearance rate of movement patterns depending on gender ($\chi 2 = 7.707$, $p > 0.05$, Cramer's $V = 0.130$).

Regarding the appearance rate by grade, a significant difference was found in the appearance rate of the movement patterns ($\chi 2 = 42.615$, $p < 0.01$, Cramer's $V = 0.177$). As a result of residual analysis, the appearance rate was significantly higher for FV in the 3rd grade and significantly lower for ULV in the 4th grade. In the 5th grade, ADV was significantly higher. In the 6th grade, ULV was significantly higher and ADV was significantly lower.

A significant difference was found in the appearance rate of the movement patterns depending on the height of the vaulting box ($\chi 2 = 54.144$, $p < 0.01$, Cramer's $V = 0.364$). As a result of the residual analysis, SV and ULV were significantly higher, ADV and FV were significantly lower in the 6-box set. ADV and FV were significantly higher, and SV was significantly lower in the 4-box set.

DISCUSSION

Item selection and movement patterns of straddle vault

As a result of estimating the number of classes based on the BIC, the 5-class model was judged the most suitable. From this, it is not sufficient to evaluate the proficiency level of straddle vault movement of children based only on the success or failure of jumping over the box. It is also shown that it is easier to explain

by considering that some qualitatively different movement patterns are latent among the movements that support jumping over the box.

The movement patterns of straddle vault derived by the latent class analysis were *failure vaulting*, *arm dependent vaulting*, *unstable landing vaulting*, *stable vaulting*, and *strong push-off vaulting*. The five movement patterns were classified by the degree of achievement of the take-off skill, the support and push-off skill, and the landing skill, which Kaneko (1987) cites as the basic skills of the vaulting box movement. Weight transfer by arm support, which is seen in ADV, is said to be a movement seen in the early stage of learning to straddle vault when the take-off is not yet strong (Yamashita, 1996). Therefore, ADV was considered to be a valid next proficiency stage for FV. ULV achieves a one-legged take-off from the run-up and a bouncy jumping on the springboard. Hedbávný and Kalichová (2015) reported that one of the common characteristics of high-performing gymnasts in the vault is an acceleration in the phase of leaving the springboard and it leads to optimal preparation for the first flight phase. At the stage of ADV, the knees are bent deeply at the take-off and the momentum is stopped, while at ULV, it accelerates smoothly and enteres the first flight phase vigorously. It is thought that this difference in movement can be evaluated from the two movement patterns. If the momentum at the take-off can be secured, the next problem is landing. Mills (2005) stated that there is a trade-off between the difficulty of the technique and the stable landing, and the higher the difficulty of the technique, the more difficult it is to land. It is thought that the point of distinguishing ULV and SV is whether or not the magnificent performance that makes use of the momentum of the take-off is well balanced with the stability of landing. To achieve SPV, it is essential to push the vaulting box strongly with both hands. In the vault, Gervais (1994) cited the variables of height and distance of the second flight phase as factors to minimize the deduction of the technique. Koha and Jennings (2007) also stated an increase in the vertical horse take-off velocity of the center of mass at the end of impact as one of the important factors for maintaining a perfect body layout position in the second flight phase. The push-off motion is exactly what allows jumping upwards from the vaulting box, so SPV is considered to be extracted as a movement pattern that includes the most important and most proficient skills. In this way, the five straddle vault movement patterns derived by the latent class analysis not only show the quality of the statistical index (BIC), but also it reflects the achievement of movements important to the vaulting technique pointed out in previous studies at each stage. Therefore, it seems that the five movement patterns have content validity.

The composition ratio of FV was 0.12, so 1 in 10 children could not jump over the vaulting box. The ratios of ADV, ULV, and SV ranged from 0.2 to 0.3. These three patterns are distinguished by the degree of achievement of the take-off, the push-off, and the landing, which are the basic skills of the vaulting box exercise. Therefore, it is important to select a practice method and provide feedback according to each movement pattern. On the other hand, SPV that allowed the vaulting box to be strongly pushed out by hand to sharply turn back the rotation had a low composition ratio of 0.06. From this, it can be deduced that most children did not learn the strong push-off movement at the elementary school stage. However, it is important to gradually acquire a sense of the strong push-off movement because it is necessary for learning advanced techniques after junior high school.

Appearance rate of movement patterns by gender, grade, and height of the vaulting box

There was no significant difference in the

appearance rate of movement patterns by gender. Kato et al. (2014) reported that there was no gender difference between the forward and backward roll movements of the mat exercise, which is the learning content of gymnastics as well as the vaulting box exercise. It is suggested that the technique of gymnastics involves extraordinary movements, and there are few elements of exerting muscular strength and power exertion. Therefore, even in the straddle vault, gender did not significantly affect the proficiency level of the movement.

The appearance rate of FV was higher than 20% in the 3rd grade and less than 10% in the 5th and 6th grades. From this, the achievement rate improves as the grade progresses from the viewpoint of success or failure of jumping over the box. On the other hand, the appearance rates of the highly proficient SV and SPV were slightly higher in the 4th grade, so it cannot be said that highly proficient movements increase with the grade. Kokudo (2017) reported that there may be a phenomenon called "adolescent awkwardness" in which physical balance is lost due to rapid development and motor movements become awkward during puberty. Especially in boys, the 5-6th grade approach the rapid growth period, so it is also possible that the imbalance of the body leads to a disturbance of the aerial posture and landing, which is likely to be a factor in the increase of ULV.

About the height of the vaulting box, the appearance rates of ULV and SV, which were movement patterns with a bouncy take-off, were high at the 6-box set. Jumping too strong leads to an unstable landing in ULV. Many injuries during gymnastics have been reported to occur on landing (Paschalis et al., 2015). Considering safety, when trying to challenge a high vaulting box, it is necessary to sufficiently improve the skill for stable landing. On the other hand, there are many FV in the 4-box vaulting box, so children with low skill levels often selected 4-box in the survey. However, since there were also many ADV at the 4-box set, to develop the movement with a strong take-off, it is effective to encourage the challenge of a higher vaulting box while considering the physique of the children.

Limitations and future research

In this study, we evaluated the straddle vault movements for children enrolled in three elementary schools in Hyogo prefecture, selected the optimum number of classes based on the information criterion, and identified the movement patterns. However, when the number of samples is increased or other groups are targeted, the number of extracted classes and movement patterns may differ. Therefore, in the future, it will be necessary to conduct additional tests for children.

It has been pointed out that physique and body composition affect the performance of exercise (Laura et al, 2018), which also applies to vaulting box exercise. The children themselves chose the height of the vaulting box in this study. Therefore, they may have selected a height that does not suit their physique. Since the incompatibility between their physique and the height of the vaulting box may be related to the appearance of movement patterns, it will be necessary to examine the relationship between the student's physique and the movement of the technique.

CONCLUSION

The purpose of the present study was to examine movement patterns that reflect the proficiency of straddle vault movements in elementary school children. As a result of identifying the movement patterns by latent class analysis, straddle vault movements of elementary school children can be categorized into five: *failure vaulting*, *arm dependent vaulting*, *unstable landing vaulting*, *stable vaulting* and *strong push-off vaulting*. The

movement patterns extracted by the latent class analysis in this study correspond to the findings of previous studies on techniques and are considered to be useful for evaluating the proficiency level.

There is no difference between boys and girls in the appearance rate of the movement patterns. As the grades increase, the incidence of *failure vaulting* decreases, but there is no consistent tendency for the appearance of highly proficient movements (*stable vaulting* and *strong push-off vaulting*) to increase. It is also clarified that when the height of the vaulting box is 6-box, the appearance rate of the movement patterns with a strong take-off is high (*unstable landing vaulting* and *stable vaulting*).

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Article received: 16.5.2021
Article accepted: 19.10.2021

PHYSICAL LITERACY OF FEMALE RECREATIONAL GYMNASTS

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Original article *DOI:10.52165/sgj.14.1.45-57*

Abstract

Children, especially girls, do not demonstrate physical activity (PA) and physical literacy (PL) levels associated with sufficient health benefits. Gymnastics is thought to be a suitable field for reinforcing children's PL and related elements, such as PA. This study aimed at assessing the PL level of female recreational gymnasts to detect areas of sufficient and insufficient development in their PL. For that, 101 8-12-year-old girls (M_{age}=10.1±1.4), who participated in recreational gymnastics programs for at least one year (M_{years}=3.7±2.0), were assessed by using the Canadian Assessment of Physical Literacy (CAPL-2). Average scores (M±SD) for total PL and its related elements were calculated for all participants. Accordingly, each of them was classified into one out of the four CAPL-2's interpretive categories, indicating whether she was at a non-recommended ("beginning", "progressing") or recommended level ("achieving", excelling"). Regression analysis examined the association of total PL score with participants' age and years of participation in gymnastics. Although the female gymnasts, similarly to same-age children worldwide, did not present adequate PL level, their fitness was sufficiently developed and they were excessively motivated/confident for PA. Adversely, other PL elements, i.e., their motor competence, PA knowledge, PA participation, were below the recommended levels, indicating deficiencies in their PL development. Age was associated with total PL (b=.440, p=.0001), whereas the years of gymnastics' participation were not (b=.090, p=.325). Participation in recreational gymnastics is important for enhancing several PL elements of female gymnasts; however, for developing the entire range of PL elements, the implementation of multicomponent gymnastics programs must be prioritized.

Keywords: *Motor competence, Physical fitness, Physical activity, Health-related fitness knowledge, Motivation.*

INTRODUCTION

Physical literacy (PL), i.e., the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life (International Physical Literacy Association, 2017), is recognized as an essential pathway to enhance physical activity (PA) participation and holistic development (Whitehead, 2010). Being comprised of multiple interacting elements, PL is a multidimensional

concept, aiming at creating not only competent but also motivated, empowered and knowledgeable movers, who choose to be physically active throughout life. In line with the PL concept, this all-round developmental process is a personal life journey, which begins in childhood by providing children with holistic PA experiences (Whitehead, 2010).

During the last years, research on the PL construct has made considerable progress, since assessment tools for children and youth were designed (Edwards et al., 2018) and implemented for population assessment (Kaioglou, Dania, & Venetsanou, 2020; Ramayudha, 2019; Tremblay et al., 2014, 2018) and program evaluation (Hennessy et al., 2018). According to preliminary research evidence, PL improves during childhood (Kaioglou et al., 2020; Tremblay et al., 2018); however, overall, children have been found to be insufficiently physically literate and greatly inactive (Kaioglou et al., 2020; Li et al., 2020; Ramayudha, 2019; Tremblay et al., 2014, 2018). Interestingly, girls are reported to be more inactive (Chen, Hammond-Bennett, Hypnar, & Mason, 2018; De Meester et al., 2016) and less physically literate than boys (Kaioglou et al., 2020; Li et al., 2020; Tremblay et al., 2018), indicating a population that possibly needs additional support along the PL journey. Moreover, findings manifest that physical education (PE) programs, focusing on affective, physical, cognitive, and behavioral outcomes, could enhance children' PL (Telford, Olive, Keegan, & Barnett, 2019), while participation in sport (at a non-elite level) is associated with elevated levels in certain PL elements, such as physical competence and daily PA participation (Damiris, Selemidi, Venetsanou, & Kaioglou, 2021). Even though the accumulation of past sport/PA experiences are thought to be critical to support children's PL journey (Whitehead, 2010), it is currently unknown if a child's previous engagement in a certain sport, i.e., years of sport-specific participation, is positively associated with his/her PL level. Considering that lifelong PA is the major outcome of PL (International Physical Literacy Association, 2017) and that years of consistent sport participation in adolescence are associated with the PA engagement of young adults (Bélanger et al., 2015), we can assume a positive linkage between sport-specific participation and PL level, which is interesting to explore. Apart from this potential behavioral correlate of PL (i.e., long-term participation in sport), age has been suggested as a likely biological correlate (Kaioglou et al., 2020), however, due to the limited relevant studies. the strength of the latter has not been confirmed yet.

In reference to a sport that may have a positive effect on children's PL, gymnastics, which targets the all-round development of children (Werner, Williams, & Hall, 2012), has been proposed to be a suitable field for reinforcing children's PL (Baumgarten & Pagnano-Richardson, 2010; Flemons, 2013). That was based on the assumption that participation in gymnastics programs can significantly contribute to the development of children's essential PL elements, such as motor competence (Karachle, Dania, & Venetsanou, 2017; Rudd et al., 2017) and physical fitness (Lyulina, Zakharova, & Vetrova, 2013; Trajković, Madić, Sporiš, Aleksić, & Živčić-Marković, 2016). Furthermore, gymnastics positively influences the cultivation of other distinctive elements that physically literate individuals demonstrate, such as self-expression, interaction, creativity as well as other affective, cognitive (Baumgarten & Pagnano-Richardson, 2010; Flemons, 2013) and social skills (Shamshiri, Bagheri, Hashemy, Doostan, & Yazdani, 2013). Given the fact that all individuals develop PL at their own level, regardless of their physical condition or personal capabilities, through the acquisition of

challenging PA experiences (Whitehead, 2010), gymnastics can be useful in that direction, since it can be a challenging recreational activity suitable to all children's needs (Lulla, 2011).

Taking into consideration the gymnastics' potential contribution to PL enhancement (Baumgarten & Pagnano-Richardson, 2010; Flemons, 2013) and the assumption that girls need special attention in comparison to boys in that field due to the lower PA (Chen et al., 2018; De Meester et al., 2016) and PL levels they present (Kaioglou et al., 2020; Li et al., 2020; Tremblay et al., 2018), the current study recorded the overall PL status of female recreational gymnasts with the aim of detecting areas of sufficient and insufficient development on their PL journey. In addition, two related factors, i.e., age and the years of participation in gymnastics, were examined for their potential association with gymnasts' PL development.

Among the available PL assessment tools, the CAPL-2 (Healthy Active Living and Obesity Research Group [HALO], 2017; Longmuir et al., 2018) was selected in this study, because it is better supported for its psychometrics (Kaioglou & Venetsanou, 2020). This specific tool has been cross-culturally adapted for the Greek population of 8-12-year-olds (Dania, Kaioglou, & Venetsanou, 2020), while several aspects of its validity and reliability have been sufficiently supported (Dania, Kaioglou, & Venetsanou, 2019; Dania et al., 2020).

To our knowledge, this is the first study aiming to assess the entire PL construct in girls participating in gymnastics. Its findings will provide useful information about the potential of the specific PA to boost girls' PL development and, hopefully, it will unveil possible correlates of PL in childhood.

METHODS

Participants were 101 8-12-year-old female recreational gymnasts (M_{age}=10.1±1.4) recruited from sport clubs located in Athens, Greece. According to participants' self-reports, they were engaged in some form of gymnastics (artistic, rhythmic, acrobatics) for at least one year (M_{years}=3.7±2.0) and they were training three to four times per week. Moreover, they reported that they did not participate in any other organized sport/PA. Convenience sampling techniques were followed to recruit the participants of the study. Each participant's parent or legal guardian was informed about the research purposes/procedures and subsequently he/she was asked to submit a written consent, while each girl gave her verbal consent before data collection.

According to the CAPL-2 manual (HALO], 2017), participants' PL is measured across four intercorrelated domains, i.e., Daily Behavior, Physical Competence, Motivation and Confidence, and Knowledge and Understanding. The Daily Behavior domain contains two measures of children's PA participation: (a) weekly self-perceived engagement in moderate to vigorous PA (MVPA), obtained by one item in the CAPL-2 questionnaire, and (b) the average amount of daily PA, recorded by pedometers. The Physical Competence domain is evaluated through both motor competence and physical fitness measures. Particularly, motor competence is assessed by the Canadian Agility and Movement Skill Assessment (CAMSA, Longmuir et al., 2017); a valid and reliable obstacle-type protocol of fundamental (jumping on two feet, sliding sideways, catching, overhand throw, skipping, hopping on one foot, kicking a ball) and complex movement skills (acceleration, deceleration, dynamic balance, transitions), which scores both the time the participants need to complete the protocol and the accuracy/quality of their

performance according to specific criteria (HALO, 2017). The 15m/20m Progressive Aerobic Cardiovascular Endurance Run (PACER) is used for assessing cardiovascular endurance. Specifically, for this study the 20m PACER was utilized. Muscular endurance is recorded by the plank protocol, for which the participants are asked to obtain and maintain the correct plank position for as long as possible. The Motivation & Confidence domain encompasses children's motivation and confidence to participate in PA; for their assessment, children respond to 12 items in the CAPL-2 questionnaire. Lastly, the Knowledge & Understanding domain, reflecting children's PA knowledge and autonomy to engage in PA, is assessed by five items in the corresponding questionnaire. The measures of Motivation & Confidence, Knowledge & Understanding as well as the self-perceived MVPA constitute the 18-item CAPL-2 questionnaire.

The CAPL-2 scoring system provides: (a) individual measure scores (raw scores converted to point scores), (b) domain scores, and (c) a total PL score. The total PL score (max of 100 points) is the sum of the four domains scores (Daily Behavior: max of 30 points, Physical Competence: max of 30 points, Motivation & Confidence: max of 30 points, Knowledge & Understanding: max of 10 points). Interpretation, based on gender and age, is facilitated by a four-category system, which stipulates the classification of participants as: (a) "beginning" (low level compared to same-age peers), (b) "progressing" (similar level compared to typical same-age peers), (c) "achieving" (meets minimum level recommended/ association with expected health benefits), and (d) "excelling" (exceeds minimum level recommended/association with expected health benefits) (HALO, 2017).

The assessments were conducted at the sport clubs' facilities by members of the research team in accordance with instructions included in the CAPL-2 manual (HALO, 2017). For a group of 20 participants, the administration of all measures required approximately 60 min and three appraisers. Before data collection, examiners presented each measure to participants and each participant was allowed to perform a few familiarization trials. At the beginning, participants were split into two smaller groups, and they were simultaneously assessed in CAMSA and plank. After a 5-min rest period, the assessment of PACER followed. Upon the completion of the above three measures, all the participants were asked to fill in the CAPL-2 questionnaire, and at the end of the 60-min session the pedometers were handed to them. Participants were informed that these electronic devices should be worn constantly (except when they participate in water activities, take a bath or sleep) for seven consecutive days over the hip bone on the right-hand side of their body. It should be noted that a valid day of pedometer data entails at least ten-hour wear time and a range of recorded steps between 1,000 - 30,000; for calculating a pedometer score, three valid days are required (HALO, 2017).

Participants' average scores for total PL, domain and individual Daily Behavior and Physical Competence measures were determined according to the information provided by the CAPL-2 manual (HALO, 2017). Based on this manual, all participants were assigned to the corresponding CAPL-2 interpretive category for each of the above scores and percentages of them (%) across these categories were computed.

To examine the association of age and years of participation in gymnastics with total PL score, linear regression analysis was conducted. The proportion of total PL variance explained by the independent variables (coefficient of determination; R^2), and the Beta standardized coefficients (b), which indicate the relative importance of each independent variable in the prediction of the dependent one, were used

for interpreting the results of the analysis. Before the application of the regression analysis, Pearson's product-moment correlation coefficients (*r*) were calculated to examine the associations among the variables. Preliminary checks proved that the regression analysis assumptions were met. Results were evaluated at $p < .05$. The IBM SPSS 26.0 statistical software was used for data analysis.

RESULTS

Participants' total PL, domain and individual Daily Behavior and Physical Competence scores are summarized in Table 1. Based on these scores, participants were assigned to the "progressing" category for their total PL as well as for the domains of Daily Behavior, Physical Competence and Knowledge & Understanding. In contrast, they were classified as "excelling" for the Motivation & Confidence domain. In respect of the individual measures, participants were characterized as "progressing" for daily PA and CAMSA; "achieving" for self-perceived MVPA and plank; "excelling" for PACER. Figures 1 and 2 present the distribution (%) of participants across the CAPL-2 interpretive categories for all the CAPL-2 scores.

Table 1.
Means, standard deviations for total PL, domain, and individual measures scores.

N=101	M±SD
DB[a]	13.42± 6.61
Self-perceived MVPA[b] (days/week)	4.79±1.77
Daily PA (steps/day)	8552.7± 3550.72
PC[c]	18.98± 5.28
CAMSA[d] (total score)	18.53± 4.07
20m PACER[e] (laps)	31.99± 20.09
Plank (sec)	94.95± 49.65
M & C[f]	26.22± 2.95
K & U[g]	6.37± 2.03
Total PL	64.98± 11.67

Legend:
Total PL score, domain scores, individual measure (point or raw) scores. Maximum CAMSA point score is 28 points. For Self-perceived MVPA, daily PA, 20m PACER and plank raw scores are reported.
[a]DB: Daily Behavior
[b]MVPA: Moderate to Vigorous Physical Activity
[c]PC: Physical Competence
[d]CAMSA: Canadian Agility and Movement Skill Assessment
[e]PACER: Progressive Aerobic Cardiovascular Endurance Run
[f]M & C: Motivation & Confidence
[g]K & U: Knowledge & Understanding

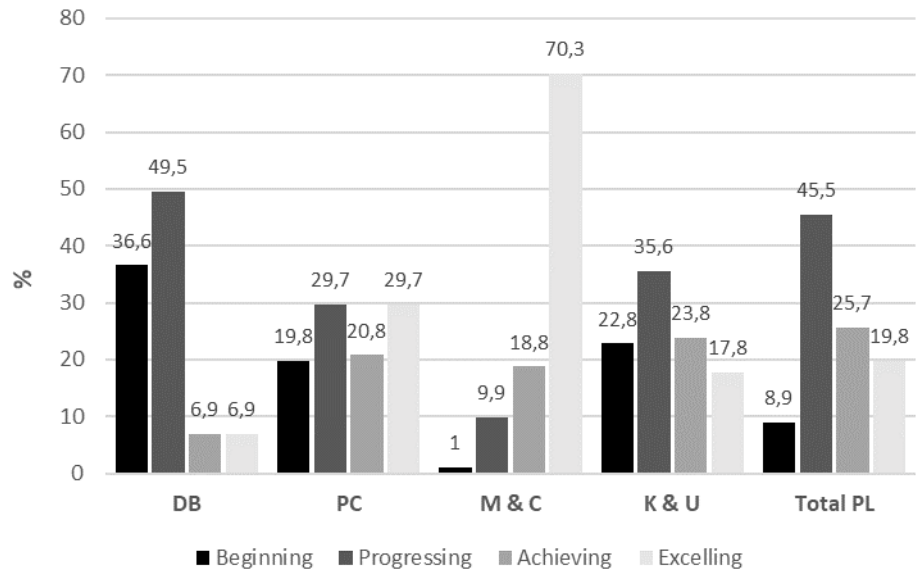

Figure 1. Distribution (%) of participants across the CAPL-2 interpretive categories for total PL and domain scores (DB: Daily Behavior, PC: Physical Competence, M & C: Motivation and Confidence, K & U: Knowledge and Understanding).

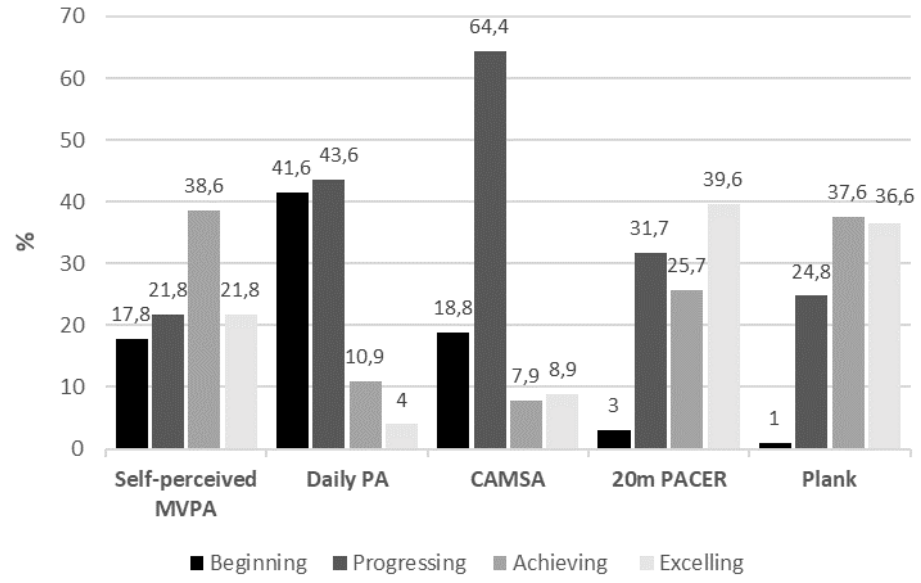

Figure 2. Distribution (%) of participants across the CAPL-2 interpretive categories for individual measure scores.

Both independent variables; age (r=.458) and years of participation in gymnastics (r=.176), were significantly and positively correlated with the total PL score (p<.05). The regression model found to be statistically significant (F=13.626 p<.05). The two independent variables predicted 21.8% (R^2=.218) of the total PL variance. According to Beta coefficients, the effect of age was significant (t=4.834, b=.440, p=.0001), whereas the years of participation in gymnastics effect were not (t=.989, b=.090, p=.325).

DISCUSSION

Nowadays, children, especially girls, do not demonstrate PA levels (Chen et al., 2018; De Meester et al., 2016) and PL levels associated with sufficient health benefits (Kaioglou et al., 2020; Li et al., 2020; Tremblay et al., 2018). Considering the gymnastics' positive effect on developing certain PL elements, such as motor competence (Karachle, et al., 2017; Rudd et al., 2017), physical fitness (Lyulina et al., 2013; Trajković et al., 2016) affective, cognitive (Baumgarten & Pagnano-Richardson, 2010; Flemons, 2013) and social skills (Shamshiri et al., 2013), this study attempted to get a glimpse of the PL journey of female recreational gymnasts to recognize areas of sufficient and insufficient development in their PL. Our main finding was that, although these girls, similarly to other same-age children worldwide, did not present an adequate PL level, their fitness was sufficiently developed and, most importantly, they were excessively motivated and confident for PA. Adversely, the rest of their PL elements, such as their motor competence, PA knowledge and daily participation in PA, were below the recommended levels, indicating the presence of some deficiencies in their PL development. Their age was positively associated with the total PL level; however, their previous engagement in gymnastics was not. Overall, it seems that participation in gymnastics, even at a recreational level, is important for enhancing several PL elements of female gymnasts; however, for developing the entire range of PL elements, the implementation of multicomponent gymnastics programs must be prioritized for them.

Due to a lack of similar studies, our findings will be discussed in the light of the current PL literature. A comparison of female gymnasts with typical same-age children would give an idea about the possibility of gymnastics to contribute to the improvement of total PL and its elements. Up to the present, only a few studies have recorded children's PL level; however, the information they add is indicative, as they represent populations of great cultural diversity. According to their findings, selected populations of Greek (Kaioglou et al., 2020), Canadian (Tremblay et al., 2018), Chinese (Li et al., 2020), Kenyan (Tremblay et al., 2014), and Indonesian (Ramayudha, 2019) children, measured by the CAPL, are presenting "progressing" level, meaning that they are currently deprived of the health benefits associated with the recommended "achieving" and "excelling" PL levels (CAPL's interpretation system; HALO, 2017). It is interesting that girls in this study received higher average total PL score (65±11.7) than the above population samples (either considering only female samples, e.g., Greek: 61.3; Canadian: 62.2 or mixed gender ones, e.g., Kenyan: 59.0, Indonesian: 58.27). However, regardless of their superiority in the total PL score, they are still classified as "progressing", further confirming the insufficient PL level of children nowadays. The above finding suggests that girls' PL can benefit from engaging in recreational gymnastics; nevertheless, it should not be ignored that they need additional support along their PL journey, similarly to other same-age children worldwide.

With the aim of obtaining a more comprehensive picture about our female gymnasts' PL status, it is useful to look closely at the development of their individual PL domains and elements. For the Physical Competence domain, although they were found to be "progressing" both for the entire domain and the measure of motor competence (CAMSA), they demonstrated sufficient fitness levels, as measured by the two fitness protocols (PACER and plank). The finding that gymnasts presented low motor competence level (83.2% of them were below the recommended level) is also confirmed by the study of Damiris et al. (2021) in which

same-age gymnasts were examined by the same motor assessment test. However, this is in contrast with the findings of other studies concerning girls, though non-gymnasts (Khodaverdi, Bahram, Stodden, & Kazemnejad, 2016; Li et al., 2020; Tremblay et al., 2018). Our finding is quite unexpected, considering that participation in gymnastics is positively associated with the development of children's motor competence (Karachle et al., 2017; Rudd et al., 2017). Attempting to critically interpret this outcome, we should keep in mind that some of the motor skills assessed by CAMSA, i.e., the object control skills, are not common in gymnastics' practice. As such, although gymnasts, especially those participating in artistic gymnastics, adequately develop their locomotor skills through a variety of relative activities included in their practice, their object control skills are not similarly developed as they are given limited opportunities to do so in their practice (Šalaj, Milčić, & Šimunović, 2019). This is probably the reason why our female gymnasts performed low in this test. Importantly, given that motor competence is linked to girls' PA participation (Venetsanou & Kambas, 2017), female gymnasts' inadequate motor competence level found in this study should be an alarming issue. To make progress in this field, gymnastic programs offered to girls should not only target to improve gymnastics skills but also enhance skills such as catching, throwing, kicking (Šalaj et al., 2019). In essence, programs combining sport-specific practice with practice in a wide range of movement situations should be the best way ahead.

On the other hand, commenting on the sufficient fitness levels that the female gymnasts of this study presented (65.3% and 74.2% were either "achieving" or "excelling" for PACER and plank, respectively), it should be mentioned that this outcome was anticipated for two reasons. Firstly, there is enough evidence to support the positive association between gymnastics and children's fitness (Lyulina et al., 2013; Trajković et al., 2016), and secondly, a similar finding was also detected in another relative study concerning gymnasts (Damiris et al., 2021). Considering that fitness fosters adoption of an active lifestyle (Chen & Gu, 2018) and favors children's overall PL development (Caldwell et al., 2020), it becomes clear that gymnasts are well equipped in that field. No doubt, this is not enough to help develop a physically literate child; however, fitness is an important element of the PL construct, and therefore it needs to be nurtured to actuate further improvements in PL.

In reference to the Daily Behavior domain, our findings are underwhelming, describing a noticeably inactive population. Particularly for their daily PA, a considerably large number (85.2%) of them were found to present inadequate level, with recorded daily steps (8552±3550) far below the recommended PA guidelines for their age (i.e., 12000 steps/day: Colley, Janssen, & Tremblay, 2012). The insufficient PA level of gymnasts has been previously reported (Damiris et al., 2021). What is more, the above finding is highlighted in several reports concerning children, especially girls, who have been found to be more inactive than boys (Chen et al., 2018; De Meester et al., 2016), implying that this population is in greater need for relative actions to promote their PA behavior.

Regarding the Knowledge & Understanding domain, results similarly indicate that our female gymnasts did not display the recommended levels. This finding is common in most of the studies that recorded children's PL (Kaioglou et al., 2020; Ramayudha, 2019; Tremblay et al., 2014); however, it is opposite to the findings of the relative Canadian study, which revealed that children acquire sufficient knowledge related to PA (Tremblay et al., 2018). A justification for this may be the fact that the CAPL knowledge questionnaire is designed

according to PE content taught in Canada and therefore children are familiar with it. To interpret the finding of our study, it can be assumed that the Greek PE curriculum is primarily focused on performance outcomes, putting limited emphasis on reinforcing knowledge related to lifelong PA participation (Karandaidou, 2005). Probably this is true for recreational programs, too; however, no research has examined the goals of such programs so far. Given that there is a positive relationship between PA knowledge and PA participation (Demetriou, Sudeck, Thiel, & Honer, 2015), the perspective of gymnastics programs in Greece and elsewhere should be more holistic, encompassing cognitive goals, too.

Interestingly, contrary to the above unsatisfying findings, an impressive percentage of our female gymnasts (70.3%) demonstrated the highest level for the Motivation & Confidence domain, denoting girls' desire, and self-assurance to participate in PA. Since most of the reference PL studies report opposite results (Ramayudha, 2019; Tremblay et al., 2014, 2018), the above finding implies that recreational gymnastics is not just about learning sport techniques but is also an enjoyable experience for children, building commitment and positive attitudes towards PA (Cale, Waring, Webb, & Duncombe, 2011). The feeling of enjoyment related to gymnastics' participation is one of the reasons that parents enroll their children in such programs (Kurnik, Kajtna, Bedenik, & Kovac, 2013). Gymnasts' high motivational levels are probably also related to the fact that they enjoy participating in activities which encourage the development of skills, such as creativity and interaction with peers (Baumgarten & Pagnano-Richardson, 2010; Flemons, 2013), not to mention that they feel confident and competent engaging in such a challenging PA, which can be adjusted to their needs (Lulla, 2011). Furthermore, the finding that girls adopt more positive attitudes towards gymnastics than boys (Cale et al., 2011) can further explain the excessive motivation that the participants of this study showed. Given that the affective elements of PL are thought to be essential for the interaction of elements within the PL construct (Whitehead, 2010), and that specifically children's intrinsic motivation has been shown to be associated with their participation in PA (Sebire, Jago, Fox, Edwards, & Thompson, 2013), recreational gymnastics programs can be considered an effective means for triggering their PA and PL levels.

In reference to the potential PL correlates examined in this study, it was revealed that during childhood the PL journey is positively influenced by age. The association of age with children's (both boys' and girls') PL development is also supported in the literature (Kaioglou et al., 2020; Tremblay et al., 2018). As shown in the reference studies, the overall PL level increases with age mainly due to improvements in children's motor competence and fitness (Kaioglou et al., 2020; Tremblay et al., 2018). On the other hand, the number of years girls participated in gymnastic programs did not have a positive effect on their total PL level. Since this factor has not been previously examined, our finding cannot be easily interpreted. However, considering that participation in PA/sport during adolescence has been found to positively relate to adult' PA engagement (Smith, Gardner, Aggio, & Hamer, 2015), it can be assumed that during childhood this effect is not as important as it can be later in life, Also, it should be noted that the specific information was obtained via children's self-reports and was not verified by their parents/guardians.

This study has its strengths and limitations. Referring to its strengths, this is the first study to have investigated the PL status of female recreational gymnasts, with the aim of detecting areas of sufficient and insufficient development on their PL journey, and thus to evaluate the

possibility of the specific PA to boost girls' PL development. Furthermore, it expands the evolving PL research, contributing valuable information about the development of PL elements in childhood. Undoubtfully, the use of a valid and reliable PL tool, which addresses the entire PL construct (HALO, 2017), adds credibility to its results. On the other hand, although we should not ignore the significance of cross-sectional designs, given the everlasting nature of PL, longitudinal studies should be conducted in the future to better reflect gymnasts' PL journey. Furthermore, since this study concerned only female gymnasts, gender is another factor that should be examined by future research. Additionally, future studies should focus on comparing different forms of gymnastics for their association with the PL development.

The key message of this study is that participation in recreational gymnastics programs can be beneficial for girls, as it is associated with sufficient levels in important PL elements, such physical fitness and motivation and confidence for PA. Currently, their total PL level is not adequate; however, these girls are at the beginning of their PL journey, and they have ample time to develop the skills and characteristics needed as this journey proceeds. However, for this to be possible they should be encouraged to engage in gymnastics programs, which will be multidimensional in nature, focusing not only on physical but also affective, cognitive, and behavioral goals (Whitehead, 2010).

CONCLUSION

This is the first study that examined the PL status of female recreational gymnasts with the aim of recognizing areas of sufficient and insufficient development on their PL journey. Our main finding was that although these girls, similarly to other same-age children worldwide, did not present an adequate PL level, their fitness was sufficiently developed and, most importantly, they were excessively motivated and confident for PA. Conversely, the rest of their PL elements, such as their motor competence, PA knowledge and daily participation in PA were below the recommended levels, indicating the presence of some deficiencies in their PL development. Their age was positively associated with the total PL level; however, their previous engagement in gymnastics was not. Overall, it seems that participation in gymnastics, even at a recreational level, is important for enhancing several PL elements of female gymnasts; however, for developing the entire range of PL elements, the implementation of multicomponent gymnastics programs must be prioritized for them.

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Article received: 20.8.2021
Article accepted: 7.12.2021

ACUTE EFFECTS OF BILATERAL AND UNILATERAL WHOLE BODY VIBRATION TRAINING ON JUMPING ABILITY, ASYMMETRY, AND BILATERAL DEFICIT ON FORMER ARTISTIC GYMNASTS

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Original article *DOI:10.52165/sgj.14.1.59-71*

Abstract
Whole-body vibration (WBV) has been used to improve jumping ability, muscle strength, power, and performance in various sports. Bilateral deficit (BLD) is defined as the difference in the magnitude of the maximum force during single or double support. The present study investigated the effect of unilateral and bilateral whole-body vibration (WBV) exercise on jumping ability, asymmetry and BLD on former artistic gymnasts. Twenty-eight former artistic gymnasts volunteered to participate in this study. Participants performed 4 experimental protocols on nonconsecutive days in a random order. Each protocol included a 3-min-warm-up running on the treadmill at 2.22 m.s $^{-1}$, followed by a 2-min rest. The intervention protocols were: a) WBV with feet [bipedal] (WBVB), b) WBV with single foot [unilateral] (WBVU), c) WBVB with the device turn-off (NWBVB), and d) WBVU with the device turn-off (NWBVU). The dependent variables were the squat jump (SJ) and counter movement jump (CMJ) with both feet (bilateral) and with single leg (unilateral). Results showed a significant interaction effect between the condition and time on SJ on both condition (bilateral and unilateral) and CMJ, whereas significant main effect was found for the condition and for time on SJ. Conclusively, the WBV unilateral condition improves significantly lower limbs symmetry during SJ performance. Further, bilateral WBV (WBV B) was the most effective condition on bilateral and unilateral SJ and CMJ performance.

Keywords: *Bilateral deficit, Single leg vertical jump, Asymmetry.*

INTRODUCTION

Coaches use different types of training methods to enhance the muscle power of athletes on different sports. Plyometric training has been extensively applied using muscles' stretch reflexes and stretch-shortening cycles to enhance muscular function and power (Chelly, Ghenem, Abid, Hermassi, Tabka, Shephard, 2010; Park, Lee, Lee, 2014). Recently, whole-body vibration (WBV) has been used to improve jumping ability, muscle strength, power, and performance in various sports (Dallas, Kirialanis, 2013; Dallas, Paradisis, Mellos, 2013; Dallas, Paradisis, Kirialanis, Mellos, Argitaki, Smirniotou, 2015; Dallas, Tsopani, Papouliakos, Riga, Korres, 2016; Kim, et al., 2016; Petit, Pensini, Tessaro, Desnuelle, Legros,

Colson, 2010; Tsopani et al., 2014). During vibration, the lower extremities of the subjects receive repeated alternating concentric – eccentric stimulations affecting the muscular and nervous system. Furthermore, during WBV training, subjects usually stand on both legs to improve leg strength and/or flexibility (Dallas, Kirialanis, 2013; Dallas, Paradisis, Mellos, 2013). Factors such as enhanced motor excitability (Cardinale, Bosco, 2003), recruitment of previously inactive motor units (Mischi, Cardinale, 2009), increased muscle temperature and blood flow (Bosco, Cardinale, Tsarpela, 1999) as well as facilitating neural functions resulting from tonic vibration reflex (Lapole, Perot, 2010) are responsible for the upcoming improvement. The difference in the magnitude of the maximum force during single or double support is referred to as the bilateral deficit (BLD) and is defined as the decrease in the magnitude of the force produced from bilateral movements of the limbs compared to the sum of forces produced by the right and left limbs when acting separately (Sale, 1992). Examining the lower limbs' strength during maximal or submaximal intensities (Kuruganti, Murphy, 2008) is subject to incorporating a simultaneous activation of numerus muscle groups. However, it is well known that the recruitment of motor units during bilateral contractions is lower compared to unilateral contractions, and that the uni-lateral training increases one's ability to generate maximal strength in relation to the bilateral training (Rejc, Lazzer, Antonutto, Isola, di Prampero, 2010). McCurdy et al. (2005) indicated that unilateral training was more effective during unilateral testing of vertical jump height compared to bilateral training, whereas during bilateral testing, the improvements in jumping ability were similar in both groups.

Functional asymmetry (FA) or bilateral strength asymmetry (BSA) is a phenomenon that is often observed in sports and characterize the side-to-side differences in kinetics and/or kinematics during task performance (Newton et al., 2006). FA is responsible for the occurrence of injuries (Croisier, Ganteaume, Binet, Genty, Ferret, 2008; Murphy, Connolly, Beynnon, 2003) or re-injuries (Myer, Brent, Ford, Hewett, 2011), while also adversely affecting performance (Young, James, Montgomery, 2002). Possible reasons for FA / BSA might be specific motor demands of different sports and training methods (Mayer, Schlumberger, Van Cingel, Henrotin, Laube, Schmidtbleicher, 2003; Newton et al., 2005) and differences in neural control and/or how the body may learn to perform a motor skill as well. The concept of inter-limb asymmetries compares the performance of one limb in respect to the other (Keeley, Plummer, Oliver, 2011) quantifying these inter-limb differences between the dominant vs. non-dominant (Rouissi et al., 2016), the stronger vs. weaker (Sato, & Heise, 2012) the right vs. left (Atkins, Bentley, Hurst, Sinclair, Hesketh, 2016), showing that inter-limb asymmetries of about 10% result in reductions in jump height (Bell, Sanfilippo, Binkley, & Heiderscheit, 2014; Lilley, Bradshaw, Rice, 2007). More specifically, as Ford and colleagues stated, uneven lower limb loading patterns during jumping and landing have been previously thought of as a mechanism of injury (Ford, Myer, Smith, Hewett, 2003). In another study, Newton et al. (2005) found a difference of 8% in force production during the single leg vertical jump between the dominant and non-dominant leg in college-level athletes, whereas Stephens, Lawson, De Voe, and Reiser. (2007) revealed a similar difference between legs in volleyball players. Furthermore, previous data by Ceroni, Martin, Delhumeau, Farpour-Lambert, 2012) showed a difference of 8.8% and 8.95% in force production in female and male teenagers, respectively.

Given the asymmetry of the lower limbs, it is possible that the amount of vibratory stimulation that each limb receives is different during body weight support, and the magnitude of this effect depends on the condition of each limb. Therefore, training using unilateral vibratory stimulation can be a suitable method of improving the functional ability of a weak lower limb and the asymmetry of functional ability between both lower limbs. There are not many studies concerning the effect of WBV on bilateral deficit or/and lower limbs asymmetry (Marin, Hazell, Garcia-Gutierrez, & Cochrane, 2014; Shin, Lee, Song, 2015; Yapicioglu, Colakoglu, Colakoglou, Gulluoglu, Bademkiran, Ozkaya, 2013). Some of them use 1RM test or isometric contractions to examine the BLD, whereas no study uses isotonic contraction during WBV protocols to examine the BLD (Costa, Moreira, Cavalcanti, Krinski, & Aoki, 2015; Shin, Lee, Song, 2015). Further, findings by Yapicioglu et al. (2013), who examined the short-term performance outcomes and neurological effects of three different warm-up methods (static stretching [SS]; dynamic warm-up [DW]; and tendon vibration combined with SS [TVSS]), found a significant improvement in jump height performance following the DW whereas TVSS did not yield negative effects. Additionally, Marin et al., examined if WBV exposure during one-legged static semi-squat would benefit muscle performance in the non-exposed contralateral leg and found that acute WBV bout augments cross-transfer in neuromuscular performance of explosive power parameters (Marin, Hazell, Garcia-Gutierrez, & Cochrane, 2014). It must be noted that bilateral training increases bilateral force production more than unilateral force production and reduces BLD, while unilateral training increases unilateral force production more than bilateral force production, therefore, increases the BLD (Hakkinen, Kallinen, Linnamo, Pastinen, Kraemer, 1996). To the author's knowledge there is paucity concerning the acute effect of unilateral and bipedal WBV training on jumping ability, asymmetry and BLD on the same sample that performed the same protocols with and without WBV exposure. Furthermore, no studies exist that examined lower limb asymmetry on gymnasts. The present study investigated the effect of unilateral and bilateral WBV exercise on jumping ability, asymmetry and BLD in former artistic gymnasts. It was hypothesized that a BLD would occur during the assessment of jumping testing when using both limbs simultaneously; and that a unilateral WBV exposure would reduce asymmetry between the lower limbs.

METHODS

Twenty-eight former artistic gymnasts with 12 years training experience, aged 22.43 ± 2.44 years; height: 168.73 ± 5.81cm; body mass: 61.66 ± 9.29kg volunteered to participate in this study. Body mass (kg) was measured to the nearest 0.01kg (Seca 770 UK), and body height was measured to the nearest 0.1cm using a stadiometer (Seca Leicester, UK). Former gymnasts who retired more than 4 years ago as well as those who had injury/ies problem in the last 3 months were excluded from the study.

The participants were physically active for 10-12 $h \cdot w^{-1}$ because of the nature of their studies. During the study they were asked to abstain from any activity other than those they required in their university courses. All participants had experience in vertical jumping with one and two legs and were familiarized with the vibration equipment and with the measurements in a preliminary session. Furthermore, a written informed concept was obtained from each participant after an extensive explanation of the purpose and experimental design of the study. The study was approved by the local Institutional Review Board and all

procedures were in accordance with the Declaration of Helsinki.

A randomized, counterbalanced, within-subjects experimental design was conducted in order to investigate the acute effects of unilateral and bipedal WBV training on jumping ability, asymmetry, and BLD. The study was carried out over the course of 4 sessions on nonconsecutive days. Participants performed 4 experimental protocols, at the same time of the day, in a random order. Each protocol included a 3-minute warm up running on the treadmill at 2.22m.s $^{-1}$, followed by a 2-minute rest. Participants attended a total of 5 data-collection sessions including a familiarization session. The intervention protocols were as follows: a) whole body vibration with both feet [bipedal] (WBVB), b) WBV with single foot [unilateral] (WBVU), c) WBVB but the device was turned-off (NWBVB), and d) WBVU but the device was turned-off (NWBVU). Participants in the WBV protocols were exposed to vertical sinusoidal mechanical WBV while standing on the Power Plate® Next Generation WBV platform (Power Plate North America, Northbrook, Illinois), whereas participants in the NWBV protocols performed the same protocol with the WBV device turned off. Vibration platform settings included a frequency of 50Hz with the peak-to-peak displacement of 2.51mm amplitude for a total time of 3 min. A schematic representation of the protocols is presented in Table 1. During performance of each protocol a 30 sec rest was mediated between each set. The rest period of 30 sec is supported by previous study that assessed jumping performance in high level gymnasts (Dallas et al, 2019).

During all conditions, subjects wore the same athletic shoes to standardize the damping of the vibration because of the footwear (Marin, Bunker, Rhea, Ayllon, 2009).

Table 1
A schematic representation of the intervention program (Protocols).

WBVB	WBVU	NWBVB	NWBVU
6 set * 30 sec SSQP	3 set * 30 sec for each leg SSQP	6 set * 30 sec SSQP	3 set * 30 sec for each leg SSQP

SSQP: static semi squat position

Jumping ability was evaluated by the jump height of squat jump (SJ) and counter movement jump (CMJ) with both feet (bilateral) and with single leg (unilateral). Testing was performed before intervention to determine the initial level of performance (baseline values), immediately after, and 8 minutes after the intervention. During the first session, 3 min after the warm-up, participants performed the SJ and CMJ with both legs and with single leg separately on a Chrono Jump platform, in a random order. During the testing, the arms were held on the hips and the participants tried to jump upward, leaving the platform with the knees and ankles extended and landing with straight knees in the upright position. Three trials were made with a 60 sec rest between them and the best trial of JH was recorded for further statistical analysis.

A common test to assess the functional performance ability of both power limbs is the jump test (Petschnig, Baron, Albrecht, 1998) and single leg vertical jump (SLVJ) (Kivlan, Martin, 2012), and the results can be represented using the limb symmetry index (LSI) (Marin, Hazell, Garcia-Gutierrez, & Cochrane, 2014). An LSI ≥ 90% should be considered in the normal range, therefore an asymmetry exists if there is > 10%

difference between the two lower limbs (O'Donnell, Thomas, Marks, 2006). The LSI is calculated by taking the average of any test scores for the affected limb divided by the unaffected limb multiplied by 100 to obtain a percentage difference between limbs.

Statistical analyses were performed using SPSS version 24 (IBM, New York, USA). A two-way (condition x time) ANOVA with repeated measures on the second factor was used for the statistical analysis. The Shapiro-Wilk method was conducted to check the normality of the data. Furthermore, a three-way (condition x time x gender) ANOVA was used to examine the effect of gender. Sphericity was checked using Mauchly's test, and the Greenhouse-Geisser's correction on degrees of freedom was applied when necessary. The Levene's test of equality of error variances was used to check the assumption of homogeneity of variances. In cases where interaction between the condition and time was detected, the simple effects were investigated, and the Bonferonni's correction was used. In the absence of interaction, the main effects of the two factors (condition and time) on the dependent variables were investigated. All statistical significances were tested at $\alpha = 0.05$.

RESULTS

Table 2.
Descriptive statistics in dependent variables among different intervention methods.

		WBV B	WBV U	NWBV B	NWBV U
SJ (cm)	Pre	26.59 ± 4.83	26.30 ± 3.93	27.18 ± 4.47	26.69 ± 4.88
	Post 1	28.86 ± 5.80 ↑	26.55 ± 5.46	28.50 ± 5.45	26.26 ± 5.11
	Post 8	27.43 ± 5.08 ↓	26.22 ± 5.93	27.72 ± 5.37	25.01 ± 4.94 #
RLLLSJ (cm)	Pre	26.25 ± 4.73	25.82 ± 5.29	27.22 ± 3.93	27.54 ± 6.33
	Post 1	27.85 ± 6.47 ↑	25.73 ± 8.70	26.39 ± 6.80	25.43 ± 5.95 ↓
	Post 8	27.51 ± 6.06	24.89 ± 5.75	26.29 ± 5.55	24.75 ± 6.17
CMJ (cm)	Pre	27.56 ± 4.35	27.29 ± 4.81	28.10 ± 4.13	27.72 ± 5.34
	Post 1	28.91 ± 5.99 ↑	27.70 ± 5.77	30.10 ± 5.63	27.54 ± 5.36
	Post 8	28.88 ± 5.83 #	28.14 ± 5.57 #	28.10 ± 5.11	25.92 ± 5.16 #
RLLLCMJ (cm)	Pre	28.02 ±4.85	26.29 ± 5.47	27.63 ± 4.10	27.16 ± 4.82
	Post 1	29.42 ± 7.01	26.15 ± 5.60	28.81 ± 6.16	27.53 ± 5.87
	Post 8	28.84 ± 6.80	26.61 ± 5.88	28.32 ± 5.45	25.73 ± 5.26

WBV B: Whole body vibration bilateral; WBV U: Whole body vibration unilateral;
NWBV B: No Whole-body vibration bilateral; NWBV U: Whole body vibration unilateral; RLLLSJ: Right Leg plus Left Leg Squat Jump;
RLLLCMJ: Right Leg plus Left Leg Counter Movement jump
↑ significant increase between pre- and post-1
↓ Significant reduction between pre and post 1
Significant increase between pre- and post-8

Table 3
Changes in single leg SJ and CMJ performance.

		WBV B	WBV U	NWBV B	NWBV U
RLSJ (SLL)	Pre	13.39 ± 2.56	13.16 ± 2.47	14.23 ± 2.27	14.23 ± 3.22
	Post 1	14.45 ± 3.56 ↑	12.29 ± 3.03 ↓	13.44 ± 3.24	13.14 ± 3.14 ↓
	Post 8	14.05 ± 3.40	12.56 ± 3.10	13.37 ± 2.72	12.79 ± 3.51 ¥
	Post 1 – Pre	1.05 ± 1.54	0.870 ± 1.51	0.78 ± 2.49	1.08 ± 1.16
	Post 8 - Pre	0.66 ± 1.49	0.60 ± 1.52	0.68 ± 1.09	0.34 ± 1.30
LLSJ (WLL)	Pre	13.20 ± 2.07	12.62 ± 2.96	13.06 ± 1.83	13.30 ± 3.27
	Post 1	13.75 ± 3.31	12.28 ± 2.81	13.31 ± 3.33	12.37 ± 2.89 ↓
	Post 8	13.45 ± 2.70	12.32 ± 2.91	13.11 ± 2.69	11.95 ± 2.78
	Post 1 – Pre	0.54 ± 2.35	0.34 ± 1.04	0.24 ± 2.52	0.93 ± 1.07
	Post 8 - Pre	0.24 ± 1.81	0.29 ± 1.92	0.20 ± 0.91	1.35 ± 1.17
RLCMJ (SLL)	Pre	14.60 ± 2.53	13.52 ± 2.67	13.96 ± 2.53	14.03 ± 2.64
	Post 1	15.01 ± 3.24	13.34 ± 3.13	14.72 ± 3.12	14.20 ± 2.90
	Post 8	14.75 ± 3.38	13.80 ± 3.06	13.37 ± 3.08	13.13 ± 2.69 ¥
	Post 1 – Pre	0.41 ± 1.32	0.18 ± 1.47	0.76 ± 1.85	0.17 ± 1.35
	Post 8 - Pre	0.15 ± 1.67	0.45 ± 1.23	1.35 ± 1.17	1.07 ± 1.30
LLCMJ (WLL)	Pre	13.42 ± 2.51	12.76 ± 2.91	13.66 ± 1.92	13.09 ± 2.39
	Post 1	14.40 ± 3.89 ↑	12.80 ± 2.58	14.08 ± 3.26	13.31 ± 3.12
	Post 8	13.81 ± 2.72	12.81 ± 3.01	14.16 ± 3.73	12.59 ± 2.86 ¥
	Post 1 – Pre	0.98 ± 2.33	0.03 ± 0.93	0.42 ± 2.45	0.22 ± 1.19
	Post 8 - Pre	0.38 ± 1.58	0.01± 1.07	0.07± 1.31	0.50 ± 1.16

WBV B: Whole body vibration bilateral; WBV U: Whole body vibration unilateral;
NWBV B: No Whole-body vibration bilateral; NWBV U: Whole body vibration unilateral; RLSJ: Right leg squat jump; LLSJ: Left leg squat jump;
RLCMJ: Right leg counter movement jump; LLCMJ: Left leg counter movement jump
↑ significant increase between pre- and post-1
↓ Significant reduction between pre and post 1
¥ Significant decrease between pre- and post

Table 4
Changes in symmetry.

		WBV B	WBV U	NWBV B	NWBV U
	Pre	97.47 ± 10.28	95.06 ± 8.74	92.54 ± 8.84	94.34 ± 10.82
LSI (%)	Post 1	94.89 ± 7.04	100.55 ± 6.62 *	99.06 ± 5.67 *	95.26 ± 13.47
USJ	Post 1 – Pre	2.57 ± 11.45	-5.49 ± 9.58	-6.52 ± 9.04	-0.91 ± 8.54
	Pre	91.10 ± 6.29	94.08 ± 8.26	99.17 ±12.00	93.40 ± 10.37
LSI (%)	Post 1	94.84 ± 10.02	96.97 ± 8.86	95.99 ± 10.20	93.62 ± 10.06
UCMJ	Post 1 – Pre	3.74 ± 11.47	-2.89 ± 8.28	3.17 ±13.34	-0.21 ± 10.95

Values are expressed as the mean ± standard deviation
LSI: Limb symmetry index; USJ: Unilateral Squat Jump;
UCMJ: Unilateral Counter Movement Jump; WBV B: Whole body vibration bilateral;
WBV U: Whole body vibration unilateral; NWBV B: No Whole-body vibration bilateral; NWBV U: Whole body vibration unilateral;
*Significant difference between the pre- and post-intervention values

Significant interaction effect between condition and time was found on: **SJ**: $F_{(6)} = 5.454$, $p = .001$, $n^2 = .168$, power = .996; **CMJ**: $F_{(6)} = 13.788$, $p = .001$, $n^2 = .168$, power = 1.000; **RLSJ**: $F_{(6)} = 9.987$, $p = .001$, $n^2 = .270$, power = 1.000; **LLSJ:** $F_{(6)} = 3.929$, $p = .001$, $n^2 = .127$, power = .966; **RLCMJ**: $F_{(6)} = 5.308$, $p = .001$, $n^2 = .164$, power = .995.

Furthermore, significant main effect was found for condition on: **SJ**: $F_{(3)} = 6.125$, $p = .001$, $n^2 = .185$, power = .954; **CMJ**: $F_{(3)} = 4.008$, $p = .01$, $n^2 = .129$, power = .821; **RLSJ**: $F_{(3)} = 5.569$, $p = .002$, $n^2 = .171$, power = .933; **LLSJ**: $F_{(3)} = 4.342$, $p = .006$, $n^2 = .141$, power = .860; **RLCMJ:** $F_{(3)} = 10.626$, $p = .001$, $n^2 = .282$, power = .998, and **LLCMJ**: $F_{(3)} = 8.978$, $p = .001$, $n^2 = .250$, power = .994.

Also, significant main effect was found for time on: **SJ:** $F_{(2)} = 8.296$, $p = .001$, $n^2 = .235$, power = .953; **CMJ:** $F_{(2)} = 12.055$, $p = .001$, $n^2 = .309$, power = .993; **RLSJ**: $F_{(2)} = 4.911$, $p = .011$, $n^2 = .154$, power = .784; **RLCMJ**: $F_{(2)} = 5.290$, $p = .008$, $n^2 = .164$, power = .816.

Pairwise comparison revealed statistically significant differences on: **(i)** SJ: condition 1: pre vs post 1 ($p = .001$), and post 1 vs post 8 ($p = .001$); and condition 4 pre vs post 8 ($p = .001$), and post 1 vs post 8 ($p = .001$); **(ii)** on CMJ: condition 1: pre vs post1 ($p=.027$), pre vs post8 = .018; condition 2: pre vs post 8 ($p =.022$); condition 3: pre vs post1 ($p = .001$), post1 vs post8 ($p = .001$); condition 4: pre vs post 8 ($p = .001$), post1 vs post8 ($p = .001$), **(iii)** on RLSJ: condition 1: pre vs post 1 ($p = .004$); condition 2 pre vs post 1 ($p = .016$), and condition 4: pre vs post 1 ($p = .001$), pre vs post8 ($p = .001$), **(iv)** on RLCMJ: condition 3: post1 vs post8 ($p = .001$), condition 4: pre vs. post 8 ($p = .001$); and post1 vs post8 ($p = .001$), **(v)** on LLSJ: condition 4: pre vs post1 ($p = .001$) and pre vs post8 ($p = .001$), and (**vi)** on LLCMJ: condition 4: post1 vs post8 ($p = .020$).

The mean and standard deviation for each dependent variable is presented in table 2.

In addition, the RLSJ showed significant improvement in the WBV B protocol ($p < .05$) (table 3).

The LSI (%) significantly improved only in unilateral condition immediately after the intervention protocols ($p < .05$) (table 4).

DISCUSSION

The results revealed that bilateral WBV (WBV B) was the most effective condition on bilateral and unilateral SJ and CMJ performance. Specifically, a statistically significant improvement was revealed between the pre-test and post 1 measurement with percentage improvement of 8.54%, 4.90% on SJ and CMJ respectively, ($p <.05$) (Table 2). Further, an increase by 7.91% and 7.30% on RLSJ, and LLCMJ performance respectively on WBV B ($p <.05$) (Table 2). Consequently, our hypothesis that a BLD would occur during the assessment of jumping testing when using both limbs simultaneously was rejected. Also, it is mentioned that although a trend appeared in the rest of examined parameters (2.80%, 4.16% on RLCMJ and LLSJ, respectively), the improvement was obvious.

Unilateral WBV (WBV U) produced statistically significant improvement only on CMJ after a rest period of 8 min (Table 2). In contrast, the NWBVU showed a statistically significant reduction ($p >.05$) in CMJ on post 8 (Table 2). In addition, in WBV U there was a significant reduction in post 1 measurement during RLSJ performance - a finding that contradictsthe study of Taniguchi. (1998). However, it should be mentioned that WBV U group had much lower percentage reduction compared to the NWBV group.

A great number of studies have investigated the potential of WBV to enhance subsequent performance. During the stance on the vibration platform, the

subject was under the effect of bilateral vibratory stimulation which transmitted through both lower limbs. The results of our study reinforce data by previous studies that reported an enhancement of bilateral SJ performance (Rhea, Kenn, 2009) and CMJ performance (Cormie, Deane, Triplett, McBride, 2006) following acute WBV power and strength performance, and also those byTorvinen et al. (2002) and Jacobs and Burns (2009) that found an increase in unilateral isometric knee extension force and unilateral knee isokinetic torque, respectively. Our results are in contrast with those of Dallas et al. (2014) who examined young competitive gymnasts and found that the jump height was improved in the vibration group during the CMJ and unilateral (single leg) SJ. Maybe the training status of our participants, and other factors such as the type of measurement, participants' level of physical activity, contraction type, etc., may be responsible for these discrepancies (Botton et al, 2015; Hakkinen et al, 1996; Howard & Enoka, 1991; Kuruganti et al, 2005; McCurdy et al, 2005; Ramirez-Campillo et al, 2015; Speirs et al, 2016). Further, our results failed to support data by Rejc et al. (2010) that favour unilateral training as a way to increase one's ability to generate maximal strength.

According to Shin et al. (2015) the positive effect of WBV, either bilateral or unilateral, may be attributed in the fact that WBV stimulates the Ia afferent tendency of muscle spindles. A continued stimulation of the stretch reflex mechanism activates motor neurons, increasing the sensitivity of primary endings. In addition, more muscles are recruited via the muscle spindles and neuron bundles (Ronnestad, 2004). As Cochrane and Stannard stated, the mechanism by which a higher jump height occurs in SLVJ height is due to the fact that each joint of the lower limbs is flexed for instant extension for a jump, and the stretch-shortening cycle of extended muscles activate the spinal reflex for a burst of concentric contraction, in which the stretch receptors are activated in the eccentric loading phase (Cochrane & Stannard, 2005).

Baseline values showed that there was no BLD under any of the conditions, neither on SJ nor on CMJ. However, on post 1 test, a significant improvement was found in jump height to the sum of the RL and LL in CMJ (RLLLCMJ) by WBV B ($p < .05$) (Table 2) with a percentage improvement of 4.99%. In contrast, there was a slight reduction in the aforementioned parameter on WBV U (-0.34% and -0.53% for RLLLSJ and RLLLCMJ, respectively). It is noteworthy that an improvement was observed only in the RLLLCMJ, as was the case with the execution of the bipedal CMJ under the WBV U condition (table 2). This finding partially supports findings by Shin et al. (2015) who found that SLVJ in both the unilateral and the bilateral group revealed a considerably larger improvement than that in the no vibration group. In addition, our results are in agreement with previous data by Bogdanis et al. (2019) who found that CMJ performance with both legs significantly improved equally when following a 6-week unilateral or bilateral lower limb plyometric training, and that unilateral plyometric training of the lower limbs may be more effective when exercises were performed with each limb separately. However, this finding is in contrast with the principle of specificity which states that unilateral training primarily enhances unilateral performance whereas bilateral training improves bilateral performance (Ramirez-Campillo et al, 2015; Speirs et al, 2016).

According to Bobbert el al. (1996), a possible explanation for this improvement on CMJ may be the fact that the countermovement jump provides the ability to participants to achieve greater joint moments at the start of push-off. Therefore, joint moments were greater over the first part of the range of joint extension in CMJ, so that more work could

be produced than in SJ. According to simulation results, storage and reutilization of elastic energy could be ruled out as an explanation for the enhancement of performance in CMJ over that in SJ. The crucial contribution of the countermovement seemed to be that it allowed the muscles to build up a high level of active state (fraction of attached cross-bridges) and force before the start of shortening, so that they were able to produce more work over the first part of their shortening distance.

In our study there was no obvious asymmetry between the two lower limbs (<10%). An LSI ≥ 90% should be considered in the normal range, therefore an asymmetry exists if there is > 10% difference between the two lower limbs (O'Donnell, Thomas, Marks, 2006). However, asymmetry decreased significantly with WBV U at USJ but not in the WBV B (Table 4), while there was an improvement trend in UCMJ. In addition, an improvement trend was observed in UCMJ with both WBV B and WBV U. This finding adds to the previous data by Shin et al. (2015) who stated that WBV U improved symmetry. The magnitude of the asymmetry may be affected by the type and volume of activity in which the athlete is involved (Hart et al, 2016), which was not taken into account in the present study. In addition, the lack of obvious asymmetry is probably due to the fact that our sample consisted of former gymnasts and also to the fact that the vast majority of exercises performed with the lower limbs are performed using both legs, with the sole exception of a small number of exercises on the balance beam. Nevertheless, this finding is in agreement with the data provided by Bailey et al. (2015) who reported that the presentation of asymmetry is related to be task specific particularly in weaker athletes. However, our results could not be generalized because they refer only to former gymnasts. In this concept, further study is recommended in active gymnasts so that other parameters such as dominant foot, level of sport, etc. could be considered.

CONCLUSION

WBV brings significant improvement in jump height on bilateral and unilateral squat jump and counter movement jump. Bilateral whole-body vibration was the most effective condition on bilateral and unilateral squat jump and counter movement jump performance. In contrast, the unilateral whole-body vibration condition significantly improves lower limbs symmetry during SJ performance.

The findings of the present study have practical applications. Gymnasts should engage in lower extremity training mainly with bipedal exercises, while in cases where technical exercises are performed with one leg, strengthening the other limb using the method of vibration is recommended.

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Article received: 14.10.2021
Article accepted: 7.12.2021

SPORTS PROFILE OF ELITE ATHLETES IN RHYTHMIC GYMNASTICS

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Original article *DOI:10.52165/sgj.14.1.73-83*

Abstract

Elite athletes are competitors who combine in themselves exceptional talent, many years of hard work and distinctive psychological qualities. Highly qualified rhythmic gymnasts do not differ from this definition, as their sports profile includes all these characteristics. The aim of this study is to develop a methodology to create the sports profile of elite competitors in rhythmic gymnastics on the basis of current competitors from the USA, Singapore and Taiwan and to compare the obtained results. This could help us assess the current habits of these gymnasts, the positive or negative impact of those habits on their performance, and the necessary changes that need to be made to optimize the training process. The results of the current study and the statistical data processing from the conducted experiment showed that the three studied teams of elite athletes (total of 63 gymnasts) demonstrated strong commitment and engagement in the training process. Generally, the Singaporean and Taiwanese athletes had difficulties in communication with their coach and lagged behind in the development of technical qualities and mental skills for effective adaptation compared to their colleagues from the United States. At the same time, however, they showed a higher degree of self-awareness for improvement. On the other hand, the athletes from the US demonstrated shortcomings in Consistency in training. The numerical values also showed that some of the US athletes demonstrated limitations in the development of physical qualities which could affect their professional sports development in the future.

Keywords: *Elite rhythmic gymnasts, Sports profile, Characteristics..*

INTRODUCTION

Modern rhythmic gymnastics challenges athletes due to the high standards and requirements for success it sets. Only those who pursue maximum difficulty and perfectionism of performance and manage to conquer the audience with virtuosity and artistry can qualify for a prestigious ranking in this sport. It should not be forgotten that even the smallest inaccuracy is punished severely today. This further brings a great risk and tension and requires specific, not only physical but also mental, characteristics that elite athletes should possess. The abundance of so many training and performance aspects makes rhythmic gymnastics an exciting and appealing discipline for both researchers and athletes.

Who are elite athletes in rhythmic gymnastics?

Elite athletes are those who pursue top results in competitions at the professional or Olympic level. With the number of

medals and awards won, they represent themselves and their country in the world. The responsibilities of elite competitors in this sport are exceptional. The relatively young female gymnasts are expected to perform their competitive routines perfectly in many aspects: technically, artistically, musically, and expressively (Gantcheva, Borysova & Kovalenko, 2021). Highly qualified gymnasts are distinguished by their talent, attitude to the sport, hard work, and by their way of responsing to their surroundings.

Many studies focus on athlete's morphological and physiological characteristics for successful performance (Claessens et al., 1999), but the relevant aspects of elite gymnasts' profile include much more than that. They include genetics, mental state, technical and physical skills, all developed and demonstrated in perfect symmetry and synchrony. The problem of optimal development that covers physical, technical, and mental qualities, simultaneously with the development of recreational opportunities, is multifactorial. This motivates many researchers to analyze it by looking at various indicators and using different methodological tools (Ivanova, 2017; Dimitrova, 2020; Ignatova, 2020; Ignatova & Iliev, 2020). However, all these tools should be adapted to the specifics of this elite sport and the associated long and heavy workloads that include many training hours per week, repetitions of elements, parts and routines of competition exercises, measuring of the total time for each task (Burt et al., 2010), etc.. Successful performance in rhythmic gymnastics requires many years of practice and consistency in training, which usually starts from a very early age (4-5 years) and continues until adolescence (21-25 years). Athletes who wish to reach top competitive levels should develop their cardiovascular and musculoskeletal systems (Douda et al., 2002), but also build their character, show personality, set concrete objectives and know how to achieve them.

Elite gymnasts should be able to plan and organize their time perfectly, which adds another quality to the list. Despite the duration of rhythmic gymnastics trainings and that everything in the gymnasts' professional life is focused on delivering the best possible sports performance at the international level (Verkooijen, Van Hove & Dik, 2012; Cosh & Tully, 2014), academic achievements, adaptation of their social life, and the optimization of the well-being of these girls are an integral part of their life which also needs to be taken into account. This requires strict discipline, perseverance, and an incredible spirit for dealing with challenges.

A gymnast whose sports profile does not include the characteristic features that allow her to withstand heavy loads (both in physical and mental terms) can hardly succeed at the elite, professional, or the Olympic level. Along this line of thinking and according to the studied literature, rhythmic gymnastics scientists have not yet decided what specific percentage of talent, physical and technical qualities are needed to succeed in this sport. However, there seems to be no athlete, coach, or sports researcher who would argue that they are not important. The shortcomings in certain personality traits can help to explain why some gifted individuals don't thrive at the elite level (Dr. Brown from 2017 at ScienceDaily at https://www.sciencedaily.com/releases/2017/08/170815095019.htm, 2021). Unlike athletes who only compete at the international level and represent their countries, the top-ranked gymnasts possess stable mental skills with very high level of self-confidence in their own abilities (Jones & Hardy, 1990). According to DeVenzio (1997), the confidence level is a mirror of the skills level, and this reflects in their performance where the connection between talent, previous achievements, and high level of self-confidence are clearly expressed. Another important characteristics\ of an elite athlete (gymnast) is the ability to manage anxiety.

A number of research studies have shown that handling this kind of pressure is an integral part of sports (Hardy et al., 2018). Of course, there are other distinguishing mental features of successful and highly efficient athletes in gymnastics: a huge inner drive to succeed; continuous setting of realistic achievable goals that have a constructive significance; optimism; sense of belonging to the team; leadership skills and decision-making skills under stress; self-criticism and ability to take criticism; focusing; faith in the process and in the team; resilience and ability to cope with failure; search for perfectionism; determination; and ability to evaluate objectively and be grateful to others.

In summary, we will emphasize that an elite gymnast's profile is a rare combination of talent and its development, many years of hard work, and the right psychological profile. The difference between high potential (international) and elite gymnasts (top-ranked) is very delicate and primarily determined by the personal mental qualities, because there are many girls who have the talent to succeed in rhythmic gymnastics, but very few are motivated to do what it takes to succeed.

A good understanding of rhythmic gymnastics as a sport and the principles of sports training would allow coaches to concentrate more on specific components that affect performance and to select the appropriate criteria for better talent identification (Douda, Toubekis, Avloniti & Tokmakidis, 2008). Trainers should not stop working on creating the ideal profile of elite athletes in rhythmic gymnastics according to their understanding. This can only be done through a recognition of gymnasts' individual personality traits and the peculiarities of the sport. Through personality traits, sports results can be predicted (Allen, Greenlees & Jones, 2013), and through the development of sports profile the current personal habits that positively or negatively affect performance can be assessed. The development of sports profile also helps identify changes that need to be made. Therefore, the development and research of the personal profile of elite rhythmic gymnasts has many advantages in terms of optimizing the individual training methodology and improving sports results (Figure 1).

The current physical, mental, and technical state of an athlete, her strengths and weaknesses compared with the general sports profile determine her specific sports profile. The sports profile helps highlight the features of sports training in relation to the personal qualities, which then draw the overall picture of the competitor's profile. There is a logical bidirectional connection between sports profile and athletes' personal characteristics in the light of the character of training. The study of sports profile points out the individual characteristics (strengths and weaknesses) of the sportsman and of the training. On the other hand, the totality of individual characteristics (of the athlete and of the training) determines the profile of this athlete and explains her results.

METHODS

The aim of this study is to develop a methodology to create sports profile of elite competitors in rhythmic gymnastics on the basis of gymnasts from the USA, Singapore and Taiwan and to compare the obtained results. 63 elite rhythmic gymnasts (14-17 years old) participated in this study. They all competed at the FIG international level. 12 of the gymnasts had 9 years of experience in rhythmic gymnastics, 15 gymnasts 8 years of experience; 25 gymnasts 7 years of experience; and 11 gymnasts had 6 years of experience. The average experience in rhythmic gymnastics for the group was 7.4 years. The number of scheduled training hours per week for each gymnast was 30 hours or 6 days with 5 training hours per day.

The study of the sports profile of representatives from these three countries

is not accidental. The choice was motivated by the personal work with these teams and the possibility to control the research as well as to work with the athletes' coaches. We are also interested in the components of the sports profile of other (leading) teams, but we do not have timely scientificly proven information, experimental data or credible statement from specialists.

Creation of sports profile and assessment of its individual components

The structure of the sports profile of elite RG athletes was created on the basis of 6 components. They were determined after a preliminary survey which included views of leading coaches (15 altogether: some of them are coaches of national teams, others of leading clubs; all of them have higher education) on the 25 most important traits of successful athletes in this sport. 18 traits, mentioned by all coaches, were used in our structure. The most common traits were called indicators and subsequently combined into 6 main components. An assessment of individual components (Figure 2) was made by evaluating all indicators that characterized them. Each coach used a score of 1 to 5 for every indicator. The component score is the average result from coaches' evaluation of all indicators.

The research methods used in this study were observation, discussion, survey, testing, expert evaluation, variation analysis, and comparative analysis. The collected data was statistically analyzed.

RESULTS

Participation and commitment (Component 1 – C1)

Participation and commitment in the training process are measured by two leading indicators. The first indicator (I1) is related to training *attendance* of elite athletes. Minimum score 1 requires a minimum of 90% attendance, and this percentage does not exclude absenteeism due to illness or injury. This means that the gymnasts had to demonstrate at least 90% training attendance for the study period (3 months), regardless of the nature of their absence. Only the planned rest days in these 3 months of testing were not taken into account. The second indicator (I2) determining C1 is *accuracy*. From the results obtained for this indicator (score 5 for the gymnasts from all three countries) it can be concluded that the girls are disciplined in terms of their involvement in the training process. According to the expert evaluation and observation of their coaches, the American gymnasts arrived in good time and often stayed after the training; Singaporean gymnasts were rarely late and always stayed after the training; Taiwanese were rarely late and always stayed after the training as well. The average scores for C1 (Table 1), taken from the arithmetic averages of the two indicators, show that the highest result in *Participation and commitment* was obtained by the Singaporean team (4.92). This score comes from high evaluation Singaporeans received for attendance (4.85).

Table 1
Average final scores for C1 (Participation and commitment).

1.	2.	3.
Singapore:	Taiwan:	USA:
I1-4.85	I1-4.8	I1-4.75
I2-5	I2-5	I2-5
C1-4.92	C1-4.90	C1-4.87

Attitude to the training process (Component 2 – C2)

The second component was measured by evaluating 4 indicators on a scale of 1 to 5. The first indicator refers to *receptiveness to the coach's feedback* (I1). The best average result for this indicator was received by the USA team (3.75 out of maximum of 5) as these girls showed the highest ability for quick self-assessment and reaction after the coach's correction compared to the other two teams. The second indicator *is related to the*

motivation for hard work and improvement of skills (regardless of the coach's current attention focus) – I2. The lowest result in this indicator was shown by the Singaporean team (3.42). According to the coaches' opinions and experts' assessments, these gymnasts do not have such a well-developed sense of quality self-improvement without support. The third indicator refers to the *support for teammates and the creation of a favorable environment for training* (I3). The best score (5) for this indicator was shown by the Taiwan team (4.8). The Taiwanese are well aware that they must contribute to the growth of the team by supporting each other, both in trainings and in competition. The last – 4th indicator, for C2 is related to the *abilities of gymnasts to maintain a certain quality of communication (verbal and nonverbal) with the coach* (I4). The lowest numerical value for this indicator (1.42) was posted by the Singapore team; as shown in Table 2, this result is assessed as very weak. Table 2 clearly displays that the Taiwanese also achieve a weak average score for I4. This gives reason to believe that the traditions in the culture of communication among girls in the two Asian countries create difficulties, expressed in the lack of utterance of opinion and creative initiative. The average scores of all indicators (I1-I4) show that the highest score for C2 was achieved by the US team (4), followed by Taiwan (3.65), and Singapore ranking the last (3.28).

Table 2
Average final scores for C2 (Attitude to the training process).

USA:
I1-3.75; I2-3.75; I3-4;I4-4.5
C2-4
Taiwan:
I1-3.6; I2-3.8; I3-4.8; I4-2.4
C2-3.65
Singapore:
I1-3.71; I2-3.42; I3-4.57;I4-1.42;
C2-3.28

Consistency in training (Component 3 – C3)

The arithmetic mean of the scores of two indicators was used for the assessment of C3: I1 – *Level of concentration in each training*; I2 – *Possibility to fix skills or techniques and their constant performance.* In I1, the highest result was shown by the Taiwan team (3.6), and the lowest by the USA (3). It should be noted that the American gymnasts perform more difficult routines than their colleagues from the other two countries. Their competition program is saturated with elements with an apparatus and body (almost twice as many as those of the Taiwanese), their execution speed and reaction speed is significantly higher compared to the other two researched groups. For this reason, it is more difficult for the American athletes to maintain a stable level of concentration during each training for the period of 3 months. On the second indicator, determining C3, the Taiwanese team is the highest evaluated and the Singaporeans scored the lowest (2.85). The Singaporean athletes experienced difficulties in focusing on the techniques and skills shown by their coaches. During the study period, they failed to perform the tasks set both in trainings and in competitions, without demonstrating anxiety or concern. There was uncertainty in Singaporean gymnasts' implementation of the exercises, which was reflected in the training diaries and in the expert evaluation, accordingly. Table 4 shows that for Component 3 – Consistency in training the Taiwan team achieved the highest score (3.50) from maximum 5, whereas the US team scored the lowest. The difference in scores between the US and the Singaporean team is only 0.01.

Table 3
Average final scores for C3 (Consistensy in training).

Taiwan:
I1-3.6; I2-3.4
C3-3.5
Singapore:
I1-3.42; I2-2.85
C2-3.65
USA:
I1-3; I2-3.25
C3-3.12

Health status (Component 4 – C4)

The Health Status component (C4) is measured by two indicators: The first one (I1) is *Minimal propensity to injury that could disrupt the training process*, and the second one (I2) is *Ability to work with high intensity*. In C4 (Table 4), all studied gymnasts showed minimal propensities to injury and good ability to work with high intensity, i.e., they have enough strength and endurance to train productively throughout the whole training session.

Table 4
Average final scores for C4 (Healthy status).

USA:
I1-4.25; I2-5;
C4-4.62
Taiwan:
I1-4; I2-5
C4-4.5
Singapore:
I1-3.57; I2-4.28
C4-3.92

Technical qualities and skills (Component 5 – C5)

The evaluation of C5 included an examination of 6 indicators. The final result was obtained by calculating the arithmetic mean of the sum of the results for all 6 indicators for each individual gymnast, and for each team. In the first indicator – *Ability to quickly learn new skills with body* (I1), the American team received the highest score (3.5 – Table 5). However, in order to achieve the maximum score of 5, experts pointed out that more expeditious work is needed for learning complicated body difficulties. This is especially valid for rotations, since there is a growing trend to change the body figure during rotation, as the heel remains raised all the time and there are no movements that could interrupt the rotational movement. In the second indicator (I2) for this component – *Ability to quickly learn new skills with apparatus* (rope, ball, hoop, clubs, ribbon), the weakest result was posted to by the Taiwanese group (2.8). It should be noted that most girls managed to do new exercises well in the first few attempts but failed to maintain stability of performance as the training went on. The Taiwanese gymnasts failed to fully understand specific techniques to perform exercises with the apparatus correctly, through well-formed logical connections, and not at random . The third indicator refers to *Ability to perform body difficulties and handlings with the apparatus in one routine as per or close to the "ideal model" as accepted by judges* (I3). Once again, the US team was rated the highest (3.5 – Table 5). In the control trainings, these gymnasts received higher final scores for their routines than the Singaporean and Taiwanese teams. Ultimately, the goal at competitions is this – to perform as many elements as possible correctly in a single routine. Indicator number 4 (I4) is *Ability to perform routines with a high level of musicality and expressiveness*. In I4 the gymnasts from the two Asian countries showed very poor results (Taiwan – 1.4; Singapore – 1.42). Most of the tested athletes experienced extreme difficulties when trying to express emotion through face or body. They did not manage to reproduce the character of the music, and this led to lack of expressiveness of movements. One reason for this could be the fact that gymnasts from Singapore and Taiwan do not work constantly under supervision of a ballet teacher, which could help them develop rhythm and musicality. Indicator 5 – *Potential for*

future development based on physical qualities (I5) was evaluated by experts after preliminary testing (which included a total of 10 tests, 2 for each motor quality – Ivanova, I., 2016); they also provided their overall impression of the gymnasts. The highest score was given to the United States (3 – Table 5). According to Table 1, the US team result is average, which comes to show that a large number of physical qualities of the tested gymnasts are not optimally developed which could limit also their potential for excellence in this sport. The last indicator for C5 was *ability to perform a wide range of valid exercises with body and apparatus* (I6). The lowest result in this indicator was achieved by the Taiwan team (2.4). This underlines the current inability of the Taiwanese to perform a wide variety of mistake-free exercises. Eventually, this will lead to lack of variability of exercises, attractiveness, and a variety of differently structured motor activities in their competition programs that will certainly be taken into account by judges during competitions. Despite these deficiencies, the Taiwanese girls tried to be competitive with the set scores for difficulty (D) in their routines. It should be noted that according to the requirements of the Code of Points, non-performance of exercises leads to penalties and to lower scores for execution (E).

Table 5
Average final scores for C5 (Technical qualities and skills).

USA:	
	I1-3.5; I2-4; I3-3.5 I4-4; I5-3; I6-3.5; *C5-3.58*
Taiwan:	
	I1-2.85; I2-3.42; I3-2.71 I4-1.42; I5-2.85; I6-2.85; *C5-2.68*
Singapore:	
	I1-2.8; I2-2.8; I3-2.2 I4-1.4; I5-2.4; I6-2.4; *C5-2.33*

Mental skills for effective adaptation (Component 6 – C6)

Two indicators were used to assess the mental skills for effective sports adaptation in the studied gymnasts: *Ability to cope with stress and pressure* (I1) and *Ability to demonstrate resilience in difficult situations* (I2). The competitors from the US team were rated the highest in each indicator (I1-4; I2-3.5) and as a result, the average score of their sum was the best score for C6 (Table 6). The gymnasts from Singapore received the lowest marks in both indicators (I1-2.85; I2-2.57). Most of them failed to stay calm and focused in the face of difficulties, both in training and in competition. Moreover, this group did not show a distinct fighting spirit in the crucial or most challenging moments.

Table 6
Average final scores for C6 (Mental skills for effective adaptation).

USA:	
	I1-4; I2-3.5; *C6-3.75*
Taiwan:	
	I1-3.4; I2-3.2; *C6-3.3*
Singapore:	
	I1-2.85; I2-2.57; *C6-2.71*

DISCUSSION

The studied gymnasts from the US showed the highest results in all 19 indicators and 3.79 average result score for a single criterion from a maximum score of 5 (Figure 3 & Figure 4).

As evidenced by the results above, the gymnasts from the three groups need to work on improving each of the mentioned indicators of individual components in order to optimize their performance. Achieving best results for certain indicators (I) as parts of the components (C) of sports profile cannot guarantee that these results will last over time. According to O'Donoghue (2005), individual athletes'

indicators are not stable. They vary, depending on the current physical and mental readiness, motivation for the set goals, and the right approach for their realization.

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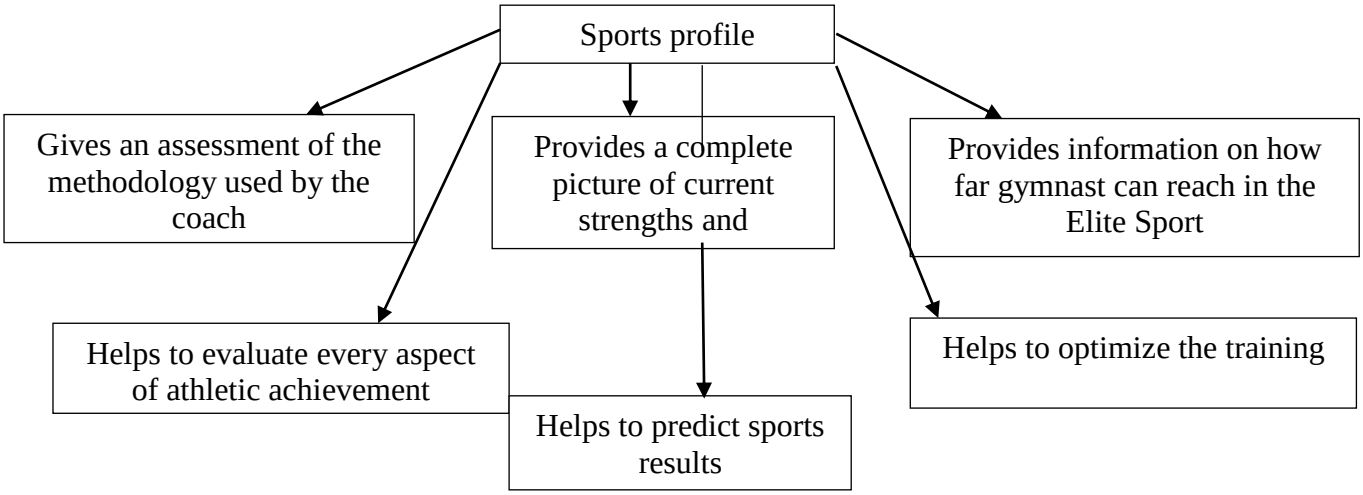

Figure 1. Advantages of creating sports profile.

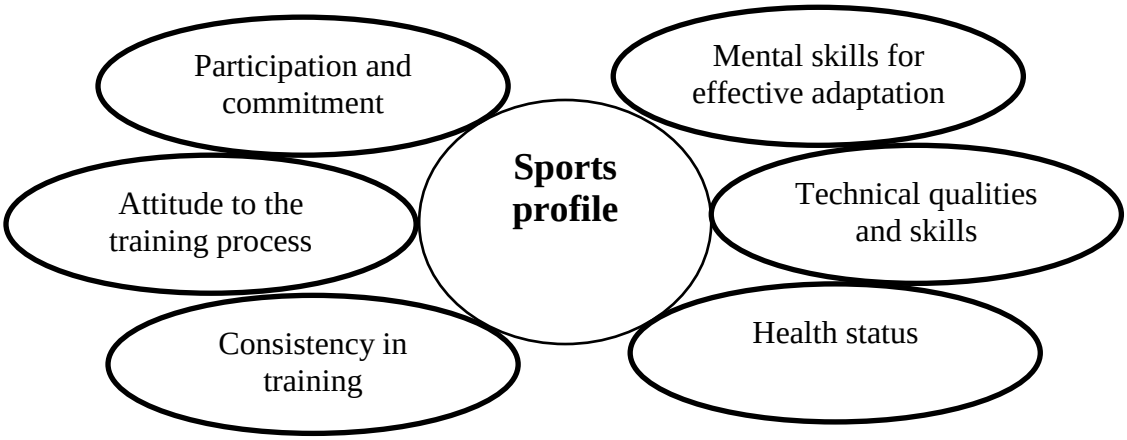

Figure 2. Components of sports profile.

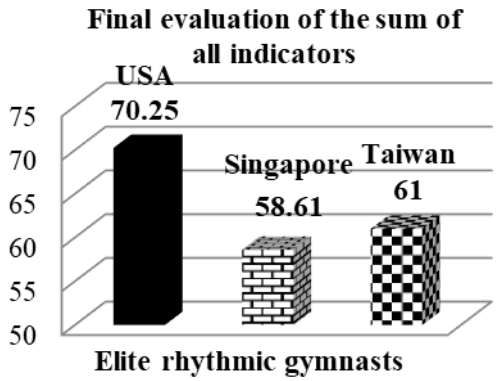

Figure 3. Sum of the C1-C6 indicators.

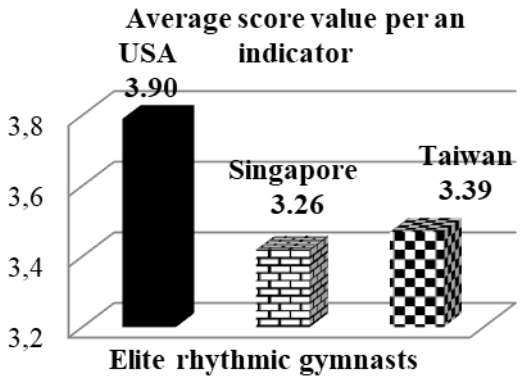

Figure 4. Average score value per an indicator.

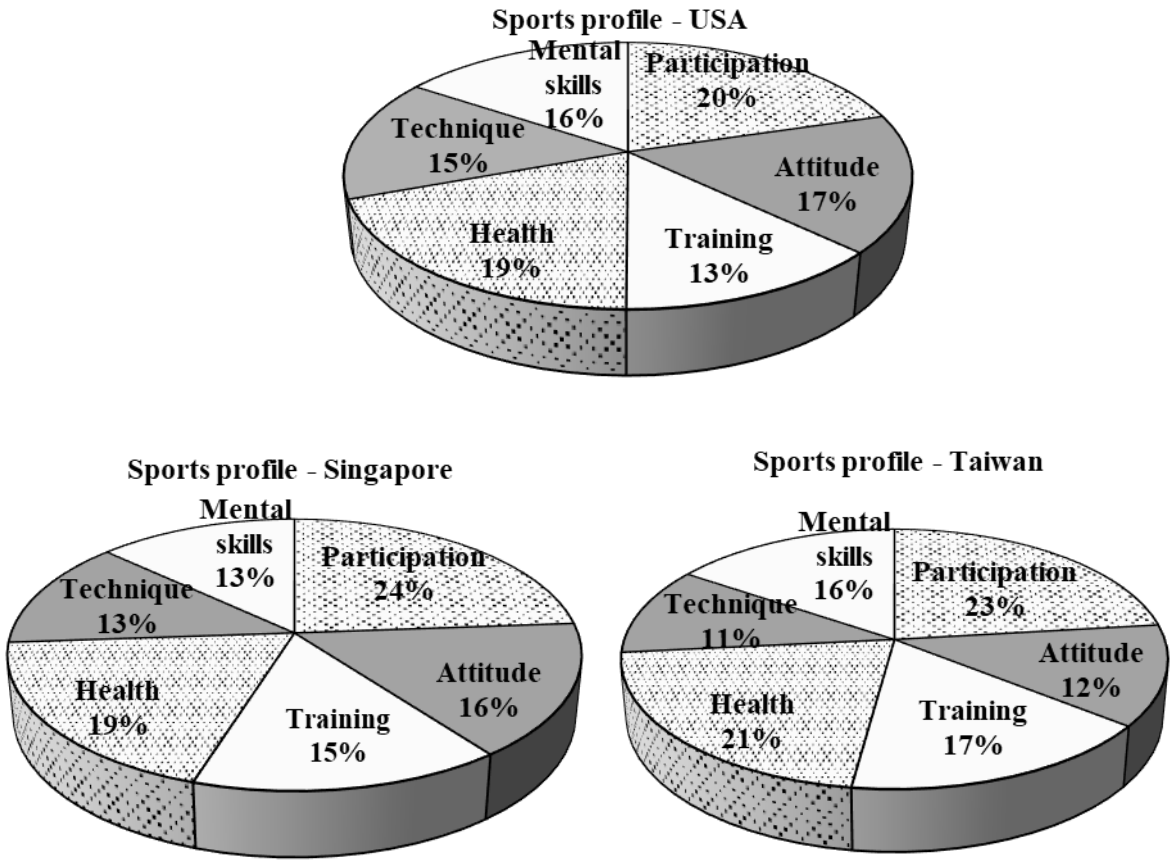

Figure 5. Percentage proportion of the components of the sports profile.

Figure 5 clearly shows the differences in percentages for individual components in the profiles of the study groups. For the United States group, the lowest percentage is achieved in *Consistency in training* (C3). Consistency in training is an extremely important component for building and optimizing sports results in any sport. Training programs are designed to improve performance by developing appropriate physical and technical qualities (muscle groups, neuromuscular skills, energy sources etc.), as well as mental skills for successful handling of stressful situations during training and competition. The Singaporean gymnasts obtained the

lowest percentage in *Mental skills for effective adaptation* (C6) and *Technical skills* (C5), while the Taiwanese gymnasts got the lowest percentage in *Technical skills* (C5). Technical skills can only be improved by *optimizing technical training*. According to C. E. Moraru et al. (2015), the optimization of technical training is an essential requirement; it is represented by a precise approach to the structure of the training process in rhythmic gymnastics. It is founded on the sports training principles, on the set of means and methods to be used, and on the athletes' actual abilities.

We believe that by developing and implementing a tailor-made methodology for optimization of the underdeveloped components in the sports profiles of gymnasts (emphasizing the individual approach), their sports results can improve.

CONCLUSION

Our analysis of the results shows that the studied elite gymnasts demonstrated strong commitment and engagement in the training process. The final values of C2 (I4), C5, and C6 indicate that the gymnasts from the two Asian countries have communication problems in their relationship with their coach and progress slower in the development of technical qualities and mental skills for effective adaptation compared to their colleagues from the USA. Nevertheless, the Singaporean and Taiwanese athletes showed high level of self-awareness for improvement. The studied US gymnasts have certain gaps and received scores that are far from the maximum (5) for *Consistency in the training process* (C3). Most of them demonstrated limitations in the development of natural qualities (C5 – I5) which could limit their potential in the future. On the other hand, the American athletes succeeded to maintain quality communication (verbal and nonverbal) with their coach.

The author's methodology for development of a sports profile helps identify the negative traits in gymnasts' approach to the sport. By mitigating these shortcomings, the training process of elite athletes in rhythmic gymnastics could be optimized while the positive traits that need further development could bring out each gymnast's sports potential to the greatest possible extent. The benefits of the current methodology are that it can be applied to every sport and can also be adapted to different spheres of other professional activities.

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Article received: 21.4..2021
Article accepted: 1.10.2021

RISKS OF EATING AND IMAGE DISORDERS ARE CORRELATED WITH ENERGY AND MACRONUTRIENT INADEQUACIES IN YOUTH RHYTHMIC GYMNASTICS

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Original article *DOI:10.52165/sgj.14.1.85-96*

Abstract

Rhythmic Gymnastics is an aesthetic sport with specific requirements that can enhance the development of eating disorders, leading to important nutritional inadequacies potentially compromising sports performance and health. Thus, this work aims to analyze associations between the risk of eating disorders and the perception of body image and eating habits in Brazilian national-level rhythmic gymnastics athletes. Eighteen female athletes aged between 12 and 19 responded to two 24-hour food recalls, the standardized Eating Attitudes Test (EAT-26), the Body Esteem Scale (BES), and the Body Shape Questionnaire (BSQ). There was an association between the risk of eating disorders, distortion of body image, and body mass index (0.51; p = 0.025 and -0.50; p = 0.029). Inverse correlations were found between carbohydrate and lipid intake per kilogram with the risk of eating disorders (-0.69; p = 0.001, and -0.49; p = 0.03) and with body image distortion (-0.63; p = 0.004, and -0.63; p = 0.04). Also, inverse correlations between energy intake per kilogram and the risk of eating disorders (-0.62; p = 0.004) and body image distortion (-0.70; p = 0.001) were found. Our results highlight the importance of a multidisciplinary approach to increase awareness and prevent possible eating disorders in this population.

Keywords: *Eating behavior, Dietary habits, Mental health, Sports psychology.*

INTRODUCTION

Rhythmic gymnastics is an Olympic sport characterized by body movements that show harmony, elegance, gracefulness and lightness while following the rhythm of music (Moubarac, Parra, Cannon, & Monteiro, 2014). As an aesthetic sport, rhythmic gymnastics requires a specific biotype, with flexibility and low body weight index being the main factors that determine success for gymnasts in their presentations (Moubarac et al., 2014). Thus, dietary restrictions are common among its practitioners which could be related to a higher occurrence of eating disorders (Joy, Kussman, & Nattiv, 2016).

It is well established that there is a high prevalence of eating disorders among rhythmic gymnastics athletes, and eating disorders are commonly related to body image disorders and body esteem, factors potentially enhanced by the competitive environment of high-performance sport (Joy et al., 2016). The internal and/or external pressure for an ideal physique

could lead to excessive training and restrictive dietary practices, yet a detailed description of the common dietary practices of these athletes is still not available (Vieira, Amorim, Vieira, Amorim, & Rocha, 2009) and it is still unclear how the risks of eating and body image disorders are related to dietary habits and food consumption (Fortes et al., 2015).

Notably, body image is pivotal for mental health and success for emale athletes engaged in aesthetic sports as has been demonstrated by different studies (Tan, Calitri, Bloodworth, & McNamee, 2016; Varnes et al., 2013). Athletes with healthy body image perceptions are less prone to excessively restrictive dietary practices, which may directly impact their sports performance (Logue et al., 2020; M. R. Silva & Paiva, 2015).

Most of the studies evaluating eating disorders risks in rhythmic gymnastics do not provide insightful details on how these risks influence dietary behavior in this population. As previously demonstrated (Jonnalagadda, Benardot, & Dill, 2000), monitoring dietary habits presents specific limitations, and underreporting dietary intake is a common practice in elite gymnasts, culminating in inadequate estimates of nutritional intake which consequently leads to increased health risks. It is important to emphasize that inadequate dietary intake is the etiological factor that determines the so-called Relative Energy Deficiency in Sport (RED-S; from the English "Relative Energy Deficiency in Sport"), which refers to impaired physiological function, including, but not limited to, metabolic rate, menstrual function, bone health, immunity, protein synthesis, cardiovascular health caused by relative energy deficiency (Mountjoy et al., 2018). Notably, adolescent athletes are at high risk of developing one or more of the components of the athlete's triad, consisting of eating disorders, amenorrhea, and osteoporosis (Mountjoy et al., 2014). This reinforces the need for nutritional counseling to prevent possible associated disorders (Mountjoy et al., 2018). Since dietary intake underreporting prevails in the context of eating disorders and in professional rhythmic gymnastics, it is important to investigate specific restrictive dietary practices and their relation to the presence of risks of eating disorders and body image distortion in this population.

As recently highlighted, rigorous studies examining the risks of eating and body image disorders and dietary intake among female athletes are scarce (Gastrich, Quick, Bachmann, & Moriarty, 2020). In addition, to further advance this field, it is imperative to combine different instruments to investigate the risks of eating and body image disorders. Moreover, using appropriate methods to ensure food intake data would provide insights in the influence of the risks of eating and body image disorders on dietary intake of macronutrients and micronutrients, which are important for sports performance. Thus, the objective of this study is twofold: to elucidate the relationship of risks of eating disorders and body image distortion with dietary practices of competitive rhythmic gymnasts, and to provide a detailed description of dietary practices of these athletes.

METHODS

This is an exploratory cross-sectional study, carried out with athletes from rhythmic gymnastics entities in the state of Rio Grande do Sul, South of Brazil. Eighteen female athletes aged between 12 and 19 were included. All participants (n = 18, mean age of 16.37, standard deviation of 4.0) had more than one year of practice in the modality and at least one participation in national-level competitions. The exclusion criteria included: previous diagnosis of an eating disorder, and/or any other psychological condition under treatment by a

psychologist or a psychiatrist. The sampling of the study was non-probabilistic and the recruitment was done by direct contact with the technicians responsible for the entities in the Rio Grande do Sul, throughout April and May in 2020. All participants and their legal guardians were informed about the nature and objectives of the study and provided signed informed consent forms for participation. This study was approved in March 2020 by the Methodist University Center Research Ethics Committee and registered in Plataforma Brasil (registration number 34217120.0.0000.5308).

The study was conducted via two video calls (due to pandemic-related restrictions) throughout May and June 2020. The athletes were undergoing their preparatory phase of training periodization and were training at home under their coach supervision to maintain their fitness levels. Two evaluations were performed: In the first evaluation, participants and their guardians received detailed information about the study procedures and provided informed consent. Afterward, the legal guardians left the video call and the athletes were asked to provide a 24-hour dietary recall for the evaluation of their nutritional status and eating habits. At least 48-hours after the first call, participants underwent a second video call evaluation, where they were asked to give a second 24-hour dietary recall and respond to three instruments: The Eating Attitudes Test (EAT-26) (Bighetti, Santos, Santos, & Ribeiro, 2004; Garner, Olmsted, Bohr, & Garfinkel, 1982), Body Esteem Scale Questionnaire (BES) (CAETANO, 2011), and the Body Shape Questionnaire (BSQ) to assess the distortion of body image.

Initially, the participants reported their height and body mass obtained in the last evaluation performed by the club (between February and March of 2020) for Body Mass Index calculations and classifications (Cavazzotto et al., 2014). To estimate the participants' reported food consumption, two 24-hour food recalls separated by two days were used and the mean intake from the two days were considered (Fisberg, Marchioni, & Colucci, 2009). Participants were first asked about how many meals they had on the previous day, followed by the meal composition (what they ate, if the meals included salt, oils, etc.) and then the portion sizes. To assist participants to estimate portion sizes, a photo album of homemade measuring tools was used during the calls from which they identified portion sizes (i.e. number and size of spoons, glasses, etc.) of each food or drink consumed (Monteiro, 2007). These were then converted to grams accordingly (PINHEIRO, 2013). The composition of energy, macronutrients (carbohydrates, proteins, and fats), and fibres (and other micronutrients) was obtained using food composition databases (Núcleo de Estudos e pesquisas em Alimentação, 2016) and specific labels when necessary.

Subsequently, the mean values of total energy consumption, carbohydrates, proteins, and fats obtained in the 24-hour food recalls were divided by body mass, and the mean value of total energy consumption (kcal) was compared with the estimated daily requirement using the Schofield formula (Carteri & Feldmann, 2019; Reale, Roberts, Lee, Bonsignore, & Anderson, 2020) to obtain energy adequacy (Energy consumed / Estimated Energy requirement x 100) multiplied by physical activity level obtained with a specific questionnaire (Guedes, Lopes, & Guedes, 2005). The values obtained for calories (kcal/kg); carbohydrates, proteins, and fats (g/kg); calcium, iron, sodium, total fibres, and cholesterol (g/day), were compared with nutritional recommendations (RDA) for the relevant age group (14- to 18-year-old) (Medicine, 2000; Padovani, Amaya-Farfán, Colugnati, & Domene, 2006). For assessments of underreporting, we calculated the ratio of estimated energy requirement and reported energy intake from the food recalls (Mirmiran, Esmaillzadeh, & Azizi, 2006).

The Brazilian validation of the Eating Attitudes Test - EAT26 was used to assess the risk of eating disorders (Bighetti et al., 2004; Garner et al., 1982). The EAT-26 is a self-report questionnaire composed of 26 objective questions, containing the following options: Always / Often / Sometimes / A few times / Almost never / Never, which score from 0 to 3. The total score can vary from 0 to 78 and the results are categorized as the presence (≥ 20) or absence (EAT <20) of risk of eating disorders (Scherer, Martins, Pelegrini, Matheus, & Petroski, 2010).

Body image distortion was assessed using the Brazilian validation of the Body Shape Questionnaire – BSQ, which consists of 34 questions with answers including: 1 - Never; 2 - Rarely; 3 - Sometimes; 4 - Frequently; 5 - Very often; 6 - Always. The total score can vary from 34 to 204 points and the higher the score, the greater the degree of body image distortion. A score of less than 80 is considered as the absence of body image distortion, 80 to 110 indicates mild distortion, 111 to 140 indicates moderate distortion, and a score higher than 140 indicates serious distortion" (Cordás TA, 1994).

Body esteem was assessed using the Brazilian validation of the Body Esteem Scale - BES, which considers different aspects of body image through 38 questions (CAETANO, 2011). The results are obtained by the sum of values attributed to answers, as follows: "I have a strong negative feeling (score = 1) / I have a medium negative feeling (score = 2) / I have neither negative nor positive feelings: I am neutral (score = 3) / I have a medium positive feeling (score = 4) / I have a strong positive feeling (score = 5)". The total score can vary from 38 to 190 points and the higher the score the greater the degree of body esteem.

Subject characteristics, food consumption, and BES score are presented as mean ± standard deviation. The data obtained from the EAT-26 and BSQ are presented using simple and relative frequencies. Distributions of all variables were assessed to verify normality, using the Shapiro-Wilk test. The Student's t-test was used to compare the energy consumption found in the 24-hour food recalls with estimated energy requirement. Dietary adequacies were identified using the one-sample t-test for each variable compared with the daily recommended intake for the 14-18 age group . Pearson's linear correlation was used to assess the correlation between different variables. The level of significance established for the analyses was p <0.05. All data were analyzed using the statistical program Statistical Package for Social Sciences (SPSS), version 26.0.

RESULTS

Rhythmic gymnastics athletes have normal body mass

The sample characterization data are shown in Table 1. Considering the nutritional status according to the classification of the body mass index in relation to age, most participants were in the "eutrophic" range (73.7% of the total), four were in the range considered "thin" (21.1% of the total), and one in the "overweight" range (10.5% of the total).

Rhythmic gymnastics athletes have inadequate nutritional intakes

The data on dietary intake are shown in Table 2. No differences were found between the estimated and the total energy intake. We found an estimated energy requirement to reported energy intake ratio of 0.94±0.25, indicating that the participants were under-reporters as evaluated by the food recalls as this was significantly different to the ratio between the estimated energy requirement and the usual energy intake (2.16±1.11, p = 0.002). The daily total energy intake was not different when compared to the estimated energy requirement. Several inadequacies were observed.

Table 1
Sample characterization data (n = 18).

	Mean ± S.D.
Age (years)	16.37 ± 4.0
Height (m)	1.64 ± 0.1
Body Mass (kg)	54.72 ± 10.0
Body Mass Index (kg /m^2)	20.27 ± 2.6
Estimated Resting Metabolic Rate (kcal/d)	1419.55 ± 110.1

S.D. = standard deviation; kcal/d = kilocalories per day

Table 2
Nutritional intake data (n = 18).

	Mean ± S.D.	Reference	Mean difference	*p value*
Relative energy intake (kcal/kg)	25.97 ± 8.0	-	-	-
Total energy intake (kcal/d)	1373.12 ± 338.0	-	-	-
Protein (g/kg)	1.61 ± 0.4	0.71[a]	0.90	0.001
Total protein (g/d)	85.94 ± 18.3	46.0[a]	39.94	0.001
Carbohydrates (g/kg)	0.8 ± 0.3	3.0[b]	-2.19	0.001
Carbohydrates (g/d)	165.14 ± 46.14	130.0[a]	35.14	0.004
Fats (g/d)	3.14 ± 1.2	1.0[b]	2.14	0.001
Cholesterol (g/d)	350.41 ± 151.7	200[a]	150.41	0.001
Total dietary fibres (g/d)	14.52 ± 6.0	26.0[a]	-11.48	0.001
Calcium (g/d)	641.78 ± 429.3	1300[a]	-668.21	0.001
Iron (g/d)	7.42 ± 1.9	15[a]	-7.57	0.001
Sodium (g/d)	1095.95 ± 526.4	1500[a]	-404.05	0.004

kcal/kg = kilocalories per kilogram; kcal/d = kilocalories per day; g/d = grams per day;
a = dietary intake from Institute of Medicine (Medicine, 2000)
b = minimum recommended intake for youth athletes (Bonci, 2010; Meyer, O'Connor, & Shirreffs, 2007)

Table 3
Risk of eating disorders, body image distortions, and body esteem.

.

Risk of eating disorders (EAT-26)	
Positive risk n(%)	8 (44.4)
Body image distortions (BSQ)	
Not Present	7 (38.9)
Mild distortion	6 (33.3)
Moderate distortion	5 (27.8)
Body esteem (BES)	
Total score (mean± Standard Deviation)	120.95 ± 20.72

Rhythmic gymnastics athletes are mostly at risk for eating disorders

The instruments used in the present study were all considered reliable (Cronbach´s alpha: 0.752 for the EAT-26; 0.866 for the BSE and 0.957 for the BSQ). The results of the questionnaires used are shown in Table 03. Some risk of eating disorders (EAT-26> 21) was found in 44.4% of the sample. Regarding body image, the majority presented some degree of body image distortion (61.1%): six participants presented mild distortion (33.3% of the total), five presented moderate distortion (27.8%) and seven participants (38.9%) did not present distortion of body image.

The risk for eating disorders correlates with body image distortion in rhythmic gymnastics athletes

When evaluating the correlations between the variables, we found an inverse correlation between energy intake per kilogram and the risk of eating disorders (-0.62; p = 0.004) and body image distortion (-0.70; p = 0.001). Inverse correlation were found between carbohydrate and lipid intake per kilogram with the risk of eating disorders (-0.69; p = 0.001, and -0.49; p = 0.03), and with body image distortion (-0.63; p = 0.004, and -0.63; p = 0.04). Positive correlations were found between body mass and body mass index with body image distortion (0.62; p = 0.002 and 0.51; p = 0.025, respectively). In addition, inverse correlations were found between body esteem and body image distortion (-0.69; p = 0.001) and body mass (-0.50; p = 0.029). Also, higher risk of eating disorders and higher body image distortion correlates with underreported energy intake in the food recalls (-0.65; p = 0.002 and -0.578; p = 0.010, respectively).

DISCUSION

The objective of this study was to verify the association of the risk of eating disorders with body image distortion and body esteem in rhythmic gymnastics athletes. Our study found a positive association between the risk of eating disorders, distortion of body image, and body mass index. Also, although most athletes presented adequate nutritional status (73.7% were in the “eutrophic” range), there were several nutritional inadequacies observed.

Maturation during adolescence is accompanied by physical and emotional problems that may result in psychological disorders or increased health risks due to inadequate dietary habits, smoking, consumption of alcoholic beverages and illegal drugs (Hart et al., 2020). Among female adolescents, this risk is greater due to the need to adapt to aesthetic standards imposed by society alongside the requirements of the sports practice itself (Joy et al., 2016; Trindade, Appolinario, Mattos, Treasure, & Nazar, 2019). Notably, the participating athletes showed adequate nutritional status related to height and weight adequacy, similar to several studies evaluating rhythmic gymnasts from Brazil (Bortoleto, Bellotto, & Gandolfi, 2014; Laffitte, Zap, Leandro, & Colleon, 2013; Viebig, Takara, Lopes, & Francisco, 2006), albeit these results contrasts with a study evaluating 20 international-level and 61 national-level rhythmic gymnasts aged between 13 to 20 who were classified as underweight with their BMI value17±1.8 kg/m^2 (Borrione et al., 2013). We believe that the competition level explains this difference, mainly due to higher training experience and training volumes, and body composition (less fat mass and higher muscle mass).

We observed several nutritional inadequacies when compared to the recommended values (Medicine, 2000; Padovani et al., 2006). In the present work, we performed the estimation of energy requirements according to the "Schofield" equation, considered accurate for this population (Carteri & Feldmann, 2019; Reale et al., 2020), and found that energy intake was adequate. However, the

distribution of macronutrients did not correspond to the reference values indicated by the recommendations, especially when considering young athletes. Through the dietary recalls, there was excessive consumption of protein and fats and total carbohydrates, alongside a low consumption of carbohydrates per kilogram. Similarly, a study that included 13 young Brazilian rhythmic gymnasts reported higher protein and fat intake while also higher intake of carbohydrates per kilogram when compared to the recommended values (Bortoleto et al., 2014). In addition to the difference in the carbohydrate per kilogram intake, the authors compared their results to the national guidelines for athletes, which are not specific to youth athletes or different age groups (Hernandez & Nahas, 2009). If we compare the mean protein intake by kilogram with the minimum recommended values from the American College of Sports Medicine of 1.2 to 1.6 grams per kilogram (Rodriguez, Di Marco, & Langley, 2009), considered appropriate for youth athletes, it would also be significantly different (mean difference of 0.41, p = 0.001) but within the recommended range. This reinforces the belief that young athletes usually consume more protein than recommended by RDA (Jeukendrup & Cronin, 2011). Also, although the total daily intake of carbohydrates seems appropriate when compared to the dietary recommendations of 130 grams per day (Medicine, 2000), the relative intake (grams per kilogram) are low when compared to the minimum recommendations for young athletes (Bonci, 2010; Meyer et al., 2007) or adults (Rodriguez et al., 2009). This is important when considering that the lower intake of carbohydrates and lipids per kilogram was associated with a higher risk of eating disorders. It indicates that these athletes are at risk of consuming less of these macronutrients. The increased popularity of low carbohydrate consumption (less than 45% of total energy intake) for weight management may have been responsible for the low intake of this nutrient by gymnasts, even if it can potentially impair their sports performance (Laffitte et al., 2013; Macedo, Santos, Tinsley, & Reischak-Oliveira, 2020). In addition, we found an inadequate consumption of calcium and iron. This is worrying, considering that this deficiency can contribute to the development of anemia and osteoporosis (Kerksick et al., 2018; Mountjoy et al., 2014). Also, the values of fibre and sodium were below the recommended values (26 and 1.5 grams per day, respectively) which may compromise sports performance (Kerksick et al., 2018; Mountjoy et al., 2018). These findings are similar to the study evaluating the presence of eating disorders in Olympic gymnastics athletes that reported inadequate intake of carbohydrates, proteins, and fats, alongside calcium, iron, and potassium (Morgani & Mendes, 2011).

Importantly, the prevalence of eating disorders is higher in Brazil compared to the rest of the world (Kolar, Rodriguez, Chams, & Hoek, 2016), and this risk may be higher in female adolescents, not necessarily linked to their nutritional status (Marthendal, Shimizu, & Azevedo, 2014). We found some risk of eating disorders in 44.4%, which is similar to a recent study in high-level Greek rhythmic gymnasts (Donti, Donti, Gaspari, Pleksida, & Psychountaki, 2021). However, our result is higher than the previous study in the same region with twenty-one Rhythmic Gymnastics athletes aged between 7 and 21 that reported an occurrence of 33.33% risk of eating disorders. This risk was higher in the categories of 9- and 10-year-olds and 15-year-olds or older (Marques , Gudolle, Lehnen, Lopes, & Becker Júnior, 2007). Accordingly, the level of aesthetic and physical demands within rhythmic gymnastics is important for the risk of eating disorders in this population, which can also be influenced by the state of mood and the influence of the media (Neves, Meireles, Carvalho, Almeida, & Ferreira,

2016). Reinforcing this assumption, a study evaluating 48 rhythmic gymnastics athletes from different categories\ comparing them with 48 elementary and high school students reported the risk of eating disorders in 82% of athletes aged 10 to 14 years and in 100% of athletes aged 15 to 18 years (Vieira et al., 2009). Although these values are higher than those reported in the present study, it should be noted that there is a difference in the competitive level. In the mentioned study all athletes had at least two years of competitive practice (Vieira et al., 2009).

The risk for eating disorders is linked to the distortion of body image and body esteem (Gonçalves & Kapczinski, 2008; Vitolo, Bortolini, & Horta, 2006). The risk of body image distortion was present in 57% of the study participants. Similarly to previous studies, it indicates higher body image distortion in female athlete adolescents, and shows that body image distortion influences the risk for eating disorders and dietary habits (de Bruin, Oudejans, & Bakker, 2007; Martins, Pelegrini, Matheus, & Petroski, 2010; Neves et al., 2016; Zaccagni, Rinaldo, & Gualdi-Russo). We expanded these results using interaction and mediation analysis, demonstrating that there is an effect of body image distortion in energy adequacy, which is mediated by body esteem. Additionally, body esteem presented correlation but no significant interaction with the eating attitude as evaluated by the EAT-26, and eating attitude was no mediator of the effects of body image distortion in the energy adequacy. Also, correlations were found between energy adequacy, nutritional status and the risk of eating disorders, and body image distortion. We confirmed previous studies in young students where dissatisfaction with thinness was associated with nutritional status only among women (Bosi, Luiz, Morgado, Costa, & Carvalho, 2006; L. P. R. d. Silva et al., 2019; Torstveit, Rosenvinge, & Sundgot-Borgen, 2008) and confirmed that body esteem may influence dietary habits, potentially leading to restrictions (de Bruin et al., 2007).

Some limitations of our study should be considered: The sampling method was non-probabilistic, and no prior power analysis was conducted. In addition, due to the pandemic restrictions to conduct anthropometric evaluation and the fact that some athletes changed cities (due to home training and limited access to training facilities at the time), we opted to use the reported height and weight of the last evaluation made by their club. This hindered our body composition analysis. It should be noted that we conducted a detailed analysis of the dietary intake, using a reliable method, and compared it to the established guidelines. This allowed us to expand our results to reinforce the necessary focus on the eating habits of these athletes. It must be considered that the definitive diagnosis in adolescents is often hindered by the stigma associated with eating disorders. Additionally, there is the possibility of manipulating responses, failing to mention specific symptoms and delaying treatment interventions. Since female adolescents are at higher risk for eating and body image disorders regardless of their engagement in sports, our results reinforce the need for nutritional education interventions in female adolescents and practitioners of rhythmic gymnastics and highlight the importance of a multidisciplinary approach with an aim to increase awareness and prevent possible eating disorders in this scenario.

CONCLUSION

Rhythmic gymnastics has its own specific requirements. The present study identified that 44.4% of the athletes were at risk of eating disorders and 61.1% had some degree of body image distortion. In addition, we showed that body image distortion and the risk of eating disorders are correlated with the energy consumption in this population. Also, the high intake of cholesterol, together with insufficient

intake of sodium, calcium, dietary fibres, and carbohydrate per kilogram could impact sports performance and health. Our results expand current literature, while at the same time reinforce the importance of a multidisciplinary approach with an aim to increase awareness and prevent possible eating disorders in this population.

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Article received: 13.7.2021
Article accepted: 19.12.2021

THE EFFECT OF SCORE COMPONENTS ON TOTAL SCORE IN THE INDIVIDUAL APPARATUS QUALIFICATION OF 1ST RHYTHMIC GYMNASTICS JUNIOR WORLD CHAMPIONSHIPS

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Original article *DOI:10.52165/sgj.14.1.97-105*

Abstract

The study aims to determine the effect of the total score components on the total score and the differences between the score components in the 1st Rhythmic Gymnastics Junior World Championship individual apparatus qualification held in Moscow, Russian Federation, in2019. In this study, 1708 scores of 138 gymnasts from 61 countries were analyzed in all routines. For all routines, the effects of difficulty subgroup scores (D_{1-2}, D_{3-4}) on difficulty total scores (DTS), execution subgroup deduction scores (E_{1-2}, $E_{3-4-5-6}$) on execution total scores (ETS), and the effects of DTS and ETS on total scores (TS) were examined. Descriptive statistics, linear regression, and one-way ANOVA analysis were used. In linear regression analysis results, it was observed that the effect of DTS on TS was higher than the effect of ETS on TS in rope, ball, clubs, and ribbon routines. Among all apparatus, the effects of DTS and ETS on TS were observed as the highest in the clubs routines and the lowest in the rope routines. The effect of D_{3-4} on TS was higher than D_{1-2}. The effect of deduction $E_{3-4-5-6}$ on TS was higher than E_{1-2} ($p<0.001$). Statistically significant differences were found only between the DTS mean scores of the apparatus ($p<0.000$) analyzed with one-way ANOVA. This has led to a conclusion that the balance in the effect of TS components on TS scores will contribute to the integrity and the artistic impact of routines and also lead to better results, therefore more time should be devoted to rope and ribbon routines in the early stages of physical preparation.

Keywords: Rhythmic gymnastics, Individual routines, Score analysis.

INTRODUCTION

Rhythmic gymnastics (RG) is a sports specialty of great technical demand and a high number of difficulties of extreme coordination and aesthetic complexity (Vernetta et al., 2017). Competition routines involve mastery of five manual apparatus (rope, hoop, ball, clubs, and ribbon) in combination with body elements involving various components for high performance: physical, technical, tactical, and psychological factors (Douda et al., 2007; Di Cagno et al., 2009). RG is one of the early specialized sports branches (Malina, 2010; Balyi, 2001; Law et al., 2007). Most of the skills necessary for successful competitive compositions take a gymnast a long time to learn and master (Jastrjembskaia, & Titov, 1999). And also, the harmony of these skills with music can increase the volume of the training.

In RG, The Code of Points (CoP) is taken into account in the preparations of the gymnasts and the evaluation of their performance. In RG, CoP is determined by the Internationale Gymnastics Federation (FIG) for RG rules and is updated every Olympic Cycle. For this reason, the CoP is considered a factor as important as it is fundamental to the inner logic of the sport or strategy (the gymnast's possibilities for interaction with space, time, apparatus, compatibility with other gymnasts, and criteria of success or failure) when creating competition routines and training plans (Ávila-Carvalho et al., 2012a; Leandro et al., 2017).

Competitive analysis (score or performance) in sports brings different new perspectives to coaches and training. There have been performance and score analysis studies on individual and group routines in the literature (Ávila-Carvalho et al., 2012b; Leandro et al., 2017; Batista et al., 2019; Kutlay, & Yardımcı, 2007; Agopyan, 2014; Örs, 2020; Ávila-Carvalho et al., 2011; Hökelmann et al., 2012). Batista et al., (2019) emphasize that quantitative information obtained from the analysis of elite routines is important. Because these data allow us to identify the main areas and categories of the elements used and to examine the relative importance of these elements, which can meet the current trends of RG, it provides a better training process (Batista et al., 2019).

Gymnasts practice increasingly intense routines in RG. In recent years, there has been a tendency to increase the points to be obtained per unit time in routines. It is important to design and present compositions that are unforgettable in the minds that are compatible with music, but there has been an increase in BD and AD scores, especially in AD (numbers and values). Although it is known that complex abilities should be included in routines to get high scores it is thought that the increase in AD numbers to increase the total score affects the balance of unity in routines. The analysis of the score components that affect the total result in RG routines can guide the decisions to be taken regarding the evaluation and guide the physical preparation of the gymnasts. The study aims to determine the effect of the total score components on the total score and the differences between the score components in the 1st Rhythmic Gymnastics Junior World Championship.

METHODS

138 elite gymnasts (thirteen-, fourteen-, and fifteen-year-old) from 61 countries participated in the individual apparatus qualifications of the 1st RG Junior World Championships (WCh), organized for the first time for the junior categoryin Moscow in 2019. 61 gymnasts competed in each apparatus. A total of 1708 scores were evaluated.

In all routines (rope, ball, clubs, ribbon), the effects of the score components on total scores (TS) and the differences between difficulty total score (DTS), execution total score (ETS), and TS were analyzed. The source of individual routines' official competition scores was the results book of 1st RG Junior WCh that is published on the International Gymnastics Federation (FIG) official web page (https://www.gymnastics.sport/site/events/searchresults.php, 2021).

The terms used in the RG judges panels were taken into account in the definitions ($D_{1\text{-}2}$, $D_{3\text{-}4}$, $E_{1\text{-}2}$, $E_{3\text{-}4\text{-}5\text{-}6}$) of the score components. $D_{1\text{-}2}$ and $D_{3\text{-}4}$ scores were added for each routine and DTS were determined. Execution artistic ($E_{1\text{-}2}$) and execution technique' ($E_{3\text{-}4\text{-}5\text{-}6}$) deduction scores were added and subtracted from 10.00 points and ETS was determined. Sum of DTS and ETS made variable total score (TS) .

SPSS 22.0 program (SPSS Inc., Chicago, IL) was used for statistical analysis of the study. Descriptive statistical

analyses were performed to determine the mean ± standard deviation values of the components and subcomponents for all routines (rope, ball, clubs, ribbon).

Differences in DTS, ETS, and TS mean scores among all apparatus were analyzed with one-way ANOVA. Differences between apparatus were analyzed with least significant difference (LSD) from post hoc tests.

Linear regression analysis was performed to determine the effects of routines' total score components on TS. For each routine, the effects of difficulty subgroup scores ($D_{1-2,}$ D_{3-4}) on DTS, the execution subgroup deduction scores ($E_{1-2,}$ $E_{3-4-5-6}$) on ETS, the effects of DTS, and ETS on TS were determined. The level of significance was accepted at $p<0.05$.

RESULTS

Descriptive statistical analyses of $D_{1-2,}$ $D_{3-4,}$ DTS, $E_{1-2,}$ $E_{3-4-5-6,}$ ETS, and TS of all routines are shown in Table 1.

The descriptive statistics analysis of the rope, ball, clubs, and ribbon apparatus scores showed that the highest total score was obtained in the clubs' apparatus routine (14.21 ± 3.07). The second highest TS results were in the ball (14.09 ± 2.88), followed by the rope (12.95 ± 2.73) and the ribbon (12.75 ± 2.67) apparatus routines, respectively. The highest score in DTS results was in the ball apparatus routine (7.72 ± 1.79) followed by clubs (7.69 ± 1.83), rope (6.72 ± 1.42), and ribbon (6.54 ± 1.59). The highest scores in the ETS results were again found in the clubs' apparatus routines (6.54 ± 1.33) followed by the ball (6.49 ± 1.22), rope (6.45 ± 0.91), and ribbon (6.22 ± 1.18) apparatus (Table 1).

The One-way ANOVA analysis results for all routines DTS, ETS, TS are shown in Table 2.

.

Table 1
Descriptive Statistics of All Routines.

Score Components	Rope x̄ and SD (N=61)	Ball x̄ and SD (N=61)	Clubs x̄ and SD (N=61)	Ribbon x̄ and SD (N=61)
D_{1-2}	3.47 ± 0.56	3.39 ± 0.72	3.54 ± 0.73	3.54 ± 0.84
D_{3-4}	3.26 ± 1.02	4.34 ± 1.23	4.15 ± 1.26	2.93 ± 1.02
DTS	6.72 ± 1.42	7.72 ± 1.79	7.69 ±1.83	6.54 ± 1.59
E_{1-2}	-1.79 ± 2.91	-1.40 ± 0.45	-1.42 ± 0.52	-2.38 ± 7.13
$E_{3-4-5-6}$	-2.12 ± 0.62	-2.11 ± 0.81	-2.04 ± 0.89	-2.29 ± 0.81
ETS	6.45 ± 0.91	6.49 ± 1.22	6.54 ± 1.33	6.22 ± 1.18
TS	12.95 ± 2.73	14.09 ± 2.88	14.21 ± 3.07	12.75 ± 2.67

N; Number of routines, x̄, and SD; Mean ± Standard Deviation, D_{1-2}; BD score, D_{3-4}; AD score, DTS; D total score, E_{1-2}; EA deduction score, $E_{3-4-5-6}$; ET deduction score, ETS; E total score, TS; Total score.

Table 2
The One-way ANOVA Analysis of DTS, ETS, and TS in All Routines.

Score Components		Rope (1) (N=61)	Ball (2) (N=61)	Clubs (3) (N=61)	Ribbon (4) (N=61)	F	p	Post Hoc
DTS	x̄ and SD	6.72 ± 1.42	7.72 ± 1.79	7.69 ± 1.83	6.54 ± 1.59	8.565	0.000*	1-2 1-3 2-4 3-4
	Minimum	3.70	3.50	3.40	2.90			
	Maximum	10.90	12.80	12.40	12.80			
ETS	x̄ and SD	6.45 ± 0.91	6.49 ± 1.22	6.54 ± 1.33	6.22 ± 1.18	0.874	0.455	-
	Minimum	3.95	3.70	1.55	2.30			
	Maximum	8.90	9.20	9.15	8.35			
TS	x̄ and SD	12.95 ± 2.73	14.09 ± 2.88	14.21 ± 3.07	12.75 ± 2.67	4.342	0.005	-
	Minimum	1.32	7.65	5.05	5.90			
	Maximum	19.80	22.00	21.55	18.25			

N; Number of routines, x̄, and SD; Mean ± Standard Deviation, DTS; D total score, ETS; E total score, TS; Total score, Post hoc; 1 (rope), 2 (ball), 3 (clubs), 4 (ribbon). *p<0.001.

Table 3
The Regression Analysis Results of the Rope and Ball Routines.

Score Components		Rope (N=61)				Ball (N=61)			
		B	t	F	R^2	B	t	F	R^2
D_{1-2}	→DTS	0.82*	11.08	122.80	0.68	0.87*	13.24	175.20	0.75
D_{3-4}	→DTS	0.95*	23.40	547.54	0.90	0.95*	24.98	624.17	0.91
DTS	→TS	0.82*	10.94	119.76	0.67	0.96*	25.66	658.34	0.92
E_{1-2}	→ETS	0.89*	14.97	224.04	0.79	0.94*	20.23	409.06	0.87
$E_{3-4-5-6}$	→ETS	0.97*	28.87	833.63	0.93	0.98*	112.33	1505.78	0.96
ETS	→TS	0.77*	9.25	85.62	0.59	0.94*	21.29	453.24	0.89

N; Number of routines, B; Beta, D1-2; BD score, D3-4; AD score, DTS; D total score, E1-2; EA deduction score, E3-4-5-6; ET deduction score, ETS; E total score, TS; Total score. *p<0.001.

Table 4
The Regression Analysis Results of the Clubs and Ribbon Routines.

Score Components		Clubs (N=61)				Ribbon (N=61)			
		B	t	F	R^2	B	t	F	R^2
D_{1-2}	→DTS	0.86*	13.03	169.76	0.74	0.61*	5.94	35.31	0.37
D_{3-4}	→DTS	0.96*	25.01	625.36	0.91	0.94*	21.87	478.33	0.89
DTS	→TS	0.98*	33.48	1120.91	0.95	0.97*	31.82	1012.17	0.95
E_{1-2}	→ETS	0.91*	17.10	292.50	0.83	0.91*	16.75	280.50	0.83
$E_{3-4-5-6}$	→ETS	0.97*	31.22	974.41	0.94	0.93*	19.13	366.02	0.86
ETS	→TS	0.96*	25.40	645.33	0.92	0.95*	22.98	528.07	0.90

N; Number of routines, B; Beta, D_{1-2}; BD score, D_{3-4}; AD score, DTS; D total score, E_{1-2}; EA deduction score, $E_{3-4-5-6}$; ET deduction score, ETS; E total score, TS; Total score. *p<0.001.

According to the ANOVA analysis results, statistically significant differences were found in the DTS results. According to the post hoc test analysis results, these significant differences were found between rope and ball, rope and clubs, ball and ribbon, and between clubs and ribbon. There was no significant difference between ETS and TS in any apparatus (Table 2).

Regression analyses of all routines' score components are shown in Table 3 and 4.

In the results of regression analysis, $D_{3\text{-}4}$ had the highest effect on DTS from all DTS components in all apparatus. Again, for all apparatus, the highest effect on TS from TS components were the DTS components. $E_{3\text{-}4\text{-}5\text{-}6}$ had the highest deduction effects of ETS components on ETS in all apparatus. In all apparatus, the highest effects of DTS and ETS on TS were observed in the clubs routines and the lowest in the rope routines (Table 3 and 4).

DISCUSSION

Rhythmic gymnastics is a sport that combines technical, aesthetic, and artistic parameters to reproduce an optimal execution model, both in the matter of form and execution (Díaz-Pereira et al., 2014). Performance is evaluated by the judges according to the rhythmic gymnastics Code of Points (RG-CoP) (FIG, 2017). Since the performance does not come out from an objective measure, but from a complex judging process, quite often RG is considered to be a subjective sport. The analysis of the competition results (subgroup scores that make up the result score) can guide the future decisions and the preparations of the gymnasts. In this study to determine the effect of the total score components on the total score and the differences of DTS, ETS and TS mean scores among all apparatuses were analyzed in 1st Rhythmic Gymnastics Junior WCh individual apparatus qualification.

According to the descriptive statistics of the routines of this study, in DTS, ETS, and TS of means, the ball and clubs routine had the highest results (Table 1). Soft apparatuses (rope and ribbon) can be a little more difficult to control in composition than other apparatus, mistakes made may reduce the execution and difficulty scores. 13, 14, and 15-year-old gymnasts competed in the same category in this competition, which may affect the mean and standard deviation values. In RG, time is needed to master the routines in each apparatus. Junior category' gymnasts are just at the beginning of their performance peak and their DTS, ETS, and TS scores may be lower than in the senior category. In RG, apparatuses have different handling characteristics (weight, dimension, and shape) and at these ages and levels, some apparatus may be more easy and sympathetic to the gymnasts.

In this study, according to the results of the one-way ANOVA analysis of the differences between the DTS, ETS, and TS components means of the apparatuses, significant results were obtained between the DTS components (Table 2) ($F=8.565$, $p=0.000$). Gymnasts perform increasingly intense routines in terms of apparatus and body difficulties to increase DTS. At the same time, it is known that many factors are affecting DTS. In general, the high mistake rate of gymnasts in routines, the level of technical preparation of the gymnast, the low values of AD and BD difficulties selected for the routines affect the DTS score. The structural features of the apparatuses can also make it difficult to control the apparatus during BD, AD, R, S. In addition the fact that trainers choose a different starting apparatus can also affect the apparatus experience time and apparatus skill between apparatuses. The reason why there is no significant difference between ETS averages maybe because trainers and athletes tend to increase DTS. Because as DTS increases, TS can also increase.

In this study, according to the Regression Analysis, the effect of D_{3-4} on TS was higher than D_{1-2} ($p<0.001$). This result shows that AD and R (Motion components of D_{3-4}) are the most effective movement groups in DTS in all routines, and gymnasts include more AD and R movement groups in their routines to increase their scores per unit time. The lack of a limit on the number of AD in RG-CoP (FIG, 2017) may have increased the number of AD in routines. In effect rates by apparatuses, the effect of D_{1-2} on DTS determined highest in the ball routines (87%) and the lowest in the ribbon routines (61%). Execution mistakes may be higher in ribbon routines than in ball routines, which may negatively affect the D_{1-2} scores. Because, according to the rules, difficulties are not counted in major execution mistakes. The effect of D_{3-4} on DTS was observed the most in the clubs (96%), while the values of the other apparatuses were close to each other. The effect of DTS on TS was observed the most in clubs (98%) and the lowest in rope routines (82%) (Table 3, 4) ($p<0.001$). In general, gymnasts perform apparatus difficulties more often in their clubs' routines, which can increase their D_{3-4} scores. In addition, some trainers may prefer rope apparatus as a starting apparatus to improve the gymnasts' skills on a difficult apparatus. This situation may vary depending on the physical readiness of the gymnast or the decisions taken by the technical committees in the countries. Naturally, gymnasts need to develop body techniques as well as apparatus techniques. For this, each trainer determines the body difficulties (with different characteristics and values) specified in the rules, according to the level of the gymnasts. The skillful interaction between gymnast and apparatus and the increasing difficulty components in routine composition as the development of RG (Lebre E, 2011). However, Ávila-Carvalho et al., (2012b) emphasized that the limited variety in the selection of difficult elements makes routine composition boring, and artistic value may be compromised (Ávila-Carvalho et al., 2012b). An increase in the number of ADs in routines can lower the EA score. Additionally, the increase of AD may be well tolerated (with variety and creativity) in good-level gymnasts, but the EA scores may be adversely affected in low-level gymnasts.

RG abilities and skills are quite complex and include physical fitness, elegant and artistic presentation as well as body movement techniques, so trainers should not limit RG training to technique only (Jastrjembskaia, & Titov, 1999). In our study, according to the regression analysis the effect of $E_{3-4-5-6}$ (deduction score) on TS was higher than E_{1-2} (deduction score) ($p<0.001$). In all routines, as stated in the RG-CoP (FIG, 2017), all deductions for mistakes of apparatus and body technique are higher in the evaluation of $E_{3-4-5-6}$ than deductions in evaluation of E_{1-2}. Therefore, $E_{3-4-5-6}$ deductions may have a high impact on TS. In effect rates by apparatuses, the effect of E_{1-2} (deduction score) on ETS was observed the most in the ball routines (94%) and the lowest in the rope routines (89%). It is thought that the harmony between the choreography and the chosen music (expressivity), as well as the apparatus experience, is better on the ball routines and therefore its effect may be higher. The effect of $E_{3-4-5-6}$ (deduction score) on ETS was greatest in the ball routines (98%) and the lowest in the ribbon routines (93%). In general, the deductions applied in the $E_{3-4-5-6}$ evaluation are more in the ribbon routines (the lack of clarity of the shapes created in the space affects both the execution score and the difficulty score), but there may be situations that develop for different reasons (loss of the apparatus, total loss of balance with fall) in the competition. Deduction scores for loss of the apparatus are highest in the RG CoP than in other deductions. The effect of ETS on TS was found the most in the clubs (96%) and the lowest in the rope routines

(77%) (Table 3, 4) ($p<0.001$). Because the clubs are double apparatus, it requires perfect coordination. For this reason, the movements performed with clubs are repeated a lot in training, this may have reduced the execution deductions and affected the TS.

In RG, apparatuses are divided into two as rigid (hoop, ball, and clubs), and soft (ribbon and rope) in terms of their structural features (Jastrjembskaia, & Titov, 1999). The rope's movement character of the routines is generally dynamic, energetic and the music choices are also of this feature. This dynamic structure can negatively affect the use of the rope apparatus and reduce the execution scores.

Bobo Arce, & Mendez Rial, (2013) emphasizes that to determine a higher performance in rhythmic gymnastics, research on all subjects related to the field, including studies involving dimensions related to technical aspects, should be increasingly continued (Bobo Arce, & Mendez Rial, 2013). Most of the published studies on the content of RG routines include analysis of the number and level of difficulty elements (Batista et al., 2019; Kutlay, & Yardımcı, 2007; Agopyan, 2014; Ávila-Carvalho et al., 2012b; Caburrasi, & Santana, 2003; Trifunov, & Dobrijević, 2013). The studies examining the number and types of difficulties, detailed score analysis studies for all competitions can be useful in terms of examining the effects of the rules.

There is a strong correlation between technical value points and final score Caburrasi, & Santana, 2003). In our study, the effect of DTS on TS in all routines was found to be higher than the effect of ETS on TS. This result also supports our hypothesis that RG can weaken the artistic and aesthetic emphasis by increasing the number of AD in routines to increase the scores to be obtained in unit time, especially in recent years. RG has static (balances) and dynamic moves/difficulties (jumps and rotations) at different values and difficulty levels. Even if it is of the same value, the execution of somebody's difficulties takes a longer time in composition and is not preferred by the gymnasts.

In recent years, the tendency to score more points per unit time can negatively affect the integrity of the composition and limit its variety. Some difficulties limit the use of apparatus techniques and gymnasts may not prefer to use these difficulties in order not to reduce the execution score. All these situations can partially limit apparatus and body techniques, movement connections, and creativity in RG routines. All these features and the skill level of the gymnast determine the design of the composition. A balanced distribution of apparatus and body difficulties is essential for an effective composition. Due to this dynamic structure and rapid development of RG, it is necessary to follow and update all these issues with such studies. FIG-RG-TC can make new adjustments to the CoP, taking into account the reasons for the increase or decrease in the score components.

Competition rule changes guide the preparations of gymnasts. The present study may contribute mainly to the coaching process, to identify the most effective performance indicators and trends in the development of RG, and also to the database formation. In the future, score analyses to be made large-participation competitions may be beneficial.

CONCLUSION

Each score component that determines the total score is important for a good performance. The balance between the scores of the total score components can positively affect the variety of movement in the composition. Otherwise, routines with different music but similar movements patterns may develop. In recent years, the tendency to score more points per unit time has increased the number of ADs in routines, weakening

their artistic and aesthetic impact and limiting diversity as it negatively affects the integrity of the composition. The balance created through the effect of TS components on TS scores will contribute to the integrity and artistic effect in routines. For this reason, we think that limiting the number of ADs in routines will strengthen the compositions artistically. Also, for better results, more time should be devoted to rope and ribbon routines in the early stages of physical preparation.

LIMITATIONS

In this study, only one competition score analysis was conducted. The score components and performance analyses of competitions in which many gymnasts and groups participate (every World and European Championships) could make important contributions to the decisions related to the preparations of athletes and their coaches.

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Article received: 1.10.2021
Article accepted: 2.12.2021

ARE THERE CONNECTIONS BETWEEN HANDEDNESS, COMPETITIVE RESULTS AND MOTIVATION IN WHEEL GYMNASTS?

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Original article *DOI:10.52165/sgj.14.1.107-117*

Abstract
Handedness is a performance-influencing factor in many competitive sports. In female team handball, psychological factors such as motivation have been connected to handedness. It should be researched whether this is also the case in wheel gymnastics and whether motivation is related to performance or handedness. For this purpose, 203 German wheel gymnasts were studied. There are significant differences in motivational aspects between gymnasts of different handedness within the straight line discipline. No differences were found in the all-around. There were not enough cases of gymnasts competing in spiral or vault only. When comparing the prevalence of different types of handedness in the general population to those among wheel gymnasts, no specific evaluation could be conducted for male gymnasts due to too few cases, although it should be noted that all 13 male participants were right-handed. When comparing the percentages of the left-handed and ambidextrous among female gymnasts to those in the general female population, it is evident that there is a higher percentage of ambidexters and left-handers among wheel gymnasts than in the general female population. There are differences in the percentages of female gymnasts of different handedness competing in straight line and all-around. There are correlations between percentage of handedness and competitive results when considering quintiles of competitive results (e. g. $r = 0.949$ and $p \leq 0.014$ for technical difficulty in left-handed athletes). Our results suggest that it might be necessary to consider handedness when it comes to individual coaching and selection.

Keywords: Handedness, Competitive results, Motivation, Disciplines, Performance.

INTRODUCTION

Wheel gymnastics originated in Germany in 1925 when Otto Feick built a two-rimmed wheel in which a person can stand while the wheel itself is moving (Sebesta, 2002). In current wheel gymnastics, there are four different disciplines: vault, straight line with/ without music, spiral and, more recently, cyr (Kauther, Rummel, Hussmann, Lendemans, Wedemeyer & Jaeger, 2015). In wheel gymnastics, points are awarded to the athlete for technical difficulty and

composition of a routine but deducted from the execution value if the athlete performs the movement technically correctly but inaccurately (Deutscher Turner-Bund (DTB), 2008). According to literature, the disciplines demand strength, endurance, and flexibility as well as core, explosive and jumping strength, coordination of movement, concentration, emotional control, perception, stress resistance and self-esteem as well as aesthetic expression (Hundrieser, 2012; Weyermann, 2016).

Sports performance is limited by physical aspects and psychological factors such as motivation: performance demands and psychological factors have been found to be related, for example, in netball (Grobbelaar & Eloff, 2011) and soccer (Hughes, Caudrelier, James, Redwood-Brown, Donnelly, Kirkbride et al., 2012). It should be researched whether motivation is also performance-relevant in wheel gymnastics. It is known that self-regulation practice enhances gymnastic skills (Wolko, Hrycaiko & Martin, 1993). Hume, Hopkins, Robinson, Robinson & Hollings (1993) found that motivation correlates with attainment in gymnastics, while D'Arripe-Longueville, Hars, Debois & Calmels (2009, p 1) showed that "*the main psychological characteristics developed by all the participants pertained to achievement motivation, performance enhancement cognitive skills (e.g., focusing, imagery), and affective and psychosomatic skills (e.g., ability to deal with anxiety; relaxation)*". Munkácsi, Kalmár, Hamar, Katona & Dancs (2012) claim that a strong motivational driving force is essential to perform high level gymnastic exercises and maintain daily practice.

In team sports, handedness can be a performance-influencing factor. In handball, right-handed players are often put on the left side of the court and left-handers on the right, since this leads to optimal angles when shooting at the goal (Oberbeck, 1989; Pohn, 2009). Amongst female German players, the percentages of handedness differed from the female population, and the percentages of handedness per position varied (Weber, 2018). In the same study, motivational differences according to handedness were found. Also, handedness has been found to be related to velocity in repeated sprints in male prepubertal youth players (Ziyagil, 2011) and reaction in female elite players (Al Awamleh, Mansi & Alkhaldi, 2013). These findings could perhaps be extended to individual sports.

Hand preference is connected to laterality (Pritzel, 2006). In the general population there are about 10% left-handed people (Pohn, 2009; Springer & Deutsch, 1998; Raymond, Pontier, Dufour & Moller, 1996). Among the female population, Coren (1993) found 90.9% right-handed, 6.8% left-handed and 2.4% ambidextrous. Among artistic gymnasts, Bessi (2016) found 84.4% to be right-handed. For different kinds of sports, the frequency of left-handedness in athletes differs from that in the general population, especially in interactive sports. In baseball, there seems to be an ideal relation regarding the staffing of positions with the right and the left-handed (Loffing & Hagemann, 2012). Human lateralities incorporate handedness, leggedness/footedness and a preferred direction of turn. Not only the executing organs but sensors and central nervous structures show lateral differences (Hermsdorf, 2009) while brain functions are also partially lateralized (for example logic/analysis, perception, kinaesthetic ability, visual and linguistic aspects; Bogen, 1969). Handedness as a lateral phenomenon is the disposition to perform fine coordinative movements faster and more precisely with the preferred hand (Stier, 1911). It is still unclear whether handedness is genetically determined or developed later (Hermsdorf, 2009; Springer & Deutsch, 1998), although it should be assumed that handedness can be shifted to a certain degree via training (Maeda, Souza & Teixeira, 2014). There

are several tests to diagnose handedness, one being the determination of the preferred hand while observing the preference during several tasks (Hermsdorf, 2009). If neither hand is preferred, ambidexterity can be assumed. No preference is related to benefits in both-handed tasks (Kourtis, De Saedeler & Vingerhoets, 2014). Another method of diagnosis is based on performance, where the better performing hand is identified (Oberbeck, 1989).

Left-handers are over-represented at elite-levels of interactive sports (Hagemann, 2009) and most often outperform right-handers (left-handers' advantage, Grouios, Tsorbatzoudis, Alexandris & Barkoukis, 2000; Loffing & Hagemann, 2012). The left-handers' advantage is based on shorter reaction times (Noroozian Shadloo, Shakiba & Panahi, 2012) as well as tactical advantages (Sattler, 2007) since opponents are not used to left-handers (Wood & Aggleton, 1989). In ice-hockey, ambidextrous players perform better (Porac & Coren, 1981). In handball, players are used to right-handed opponents and are thus unable to anticipate the left-handers' actions as well as those of the right-handed players (Schorer, Loffing, Hagemann & Baker, 2012). According to Sattler (2007), the left-handed do have tactical advantages due to the dominance of the right hemisphere of the brain.

When observing lateral phenomena occurring in gymnastics, there are differences regarding injuries on the balance beam in relation to the preferred leg used on take-off (Pajek, Hedbávný, Kalichová & Čuk, 2016). Handedness, footedness and probably brain hemisphere lateralisation are predictors of the twist direction regarding both global and local movements (Stochl & Croudace, 2013). Also, the twist direction might be related to lateral preference (Heinen, Vinken & Velentzas, 2010) as well as the hand put down first in round-offs and cartwheels, which implies a connection to handedness (Sands, 2000). There are differences in the twist direction according to the performance level and the performed element: lateral preference is linked to rotational preference in non-elite gymnasts, and vestibulospinal asymmetry is connected to rotational preference in elite gymnasts (Heinen, Jeraj, Vinken & Velentzas, 2012).

Despite the claimed relevance of laterality for motoric and sensor aspects, there are only few sports-related studies on this theme (Fischer, 1988). Certain psychological and cognitive abilities are said to occur together with left-handedness (Grouios et al., 2000; Holtzen, 2000; Noroozian et al., 2012) and could thus influence sports performance in wheel gymnastics. Cognitive advantages for left-handers in sports are also mentioned (Raymondet al., 1996), as well as characteristics concerning visuospatial and attentional factors (Springer & Deutsch, 1998; Bisiacchi, Ripoll, Stein, Simonet & Azémar, 1995) and hemispheric/visuomotoric factors (Annett, 1985; Azémar, Ripoll, Simonet & Stein, 1983; Gorynia & Egenter, 2000; Gursoy, 2009; Holtzen, 2000; McLean & Ciurczak, 1982). Goulet, Bard & Fleury (1989) mention visual perception (also: Hagemann, 2009; Loffing, Schorer, Hagemann & Baker, 2012; McMorris & Colenso, 1996; Schorer et al., 2012). Neuropsychological disposition is also mentioned (Boulinguez, 1999), next to differences regarding volition, motivation, and disposition for action (Weber, 2018).

The main question is if and how handedness influences performance in wheel gymnastics. To address this topic, the study aims to answer the following detailed questions:

1. Are there significant differences in motivational aspects between gymnasts of different handedness within the different disciplines?
2. Do gymnasts differ from the overall population regarding percentage of right-handers, left-handers and ambidexters?

3. Are gymnasts of different handedness competing in different gym wheel disciplines (vault, spiral, straight line, all-around)?
4. Are there correlations between percentage of handedness and competitive results when considering certain groups of gymnasts?

METHODS

Measurements included 203 voluntary participants of the German Gymnastics Federation (Deutscher Turner-Bund/ DTB) in the gym wheel section. Informed consent was obtained from all participants (female: N = 183, age average = 21.17 ± 11.91; male: N = 20, age average = 16.84 ± 4.90). The age ranged from 6 to 58 for female and from 7 to 27 for male gymnasts.

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

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

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

Oneway ANOVA was performed amongst gymnasts at both performance levels (Bundesklasse/ Landesklasse) and within two disciplines (Straight line/ All-around), once for all gymnasts and once for female gymnasts only as there was an insufficient number of male participants. The criterion level for significance was set at $p<0.05$ and the trend significance at $p<0.10$. The effect size was evaluated with η^2 (Eta partial squared), where $0.01<\eta^2<0.06$ constitutes a small effect, $0.06<\eta^2<0.14$ constitutes a medium effect and $\eta^2>0.14$ constitutes a large effect (Cohen, 1988). Correlations between performance and motivation were calculated via Pearson and Spearman`s Rho with correlation levels >0.1 (weak), >0.3 (moderate) and >0.5 (strong) for Pearson`s correlation coefficient. Statistical analysis was performed in SPSS, version 26 (SPSS, Inc., Chicago, IL).

RESULTS

There are significant differences in motivational aspects between gymnasts of different handedness within the straight line discipline. No differences were found in the all-around. There were not enough cases of gymnasts competing in spiral or vault only.

Table 1
Differences according to handedness between female gymnasts competing in straight line (Oneway ANOVA and Scheffé post hoc test).

Differences	N	$X \pm SD$	p	η^2
Fear of failure	44	10.48 ± 7.97	0.045	0.141
Overall performance motive	44	44.77 ± 9.44	0.020	0.173
Fear of failure				
Right-handed vs. ambidextrous	36 vs. 6	10.19 ± 7.40 vs. 7.83 ± 9.00	0.065	-
Left-handed vs. ambidextrous	2 vs. 6	23.50 ± 4.95 vs. 10.48 ± 7.67	0.050	-
Overall performance motive				
Right-handed vs. ambidextrous	36 vs. 6	44.08 ± 8.52 vs. 43.00 ± 11.18	0.023	-
Left-handed vs. ambidextrous	2 vs. 6	62.5 ± 2.12 vs. 43.00 ± 11.18	0.034	-

Table 2
Percentages of handedness within disciplines and at competitive levels (female athletes).

Discipline/ competitive level	Right-handed [%]	Left-handed [%]	Ambidextrous [%]
Straight line: N = 49	79,6	8,2	12,2
All-around: N = 29	89,7	10,3	0
Bundesklasse: N = 24	95,8	4,2	0
Landesklasse: N = 36	72,2	11,1	6,7

Estimated failure at confidence interval 0.95 = 5.2 %.

Table 3
Correlations between percentages of handedness within performance quintiles and arithmetic mean of performance related parameters.

Correlations		Overall merit	Difficulty value	Execution value
Right-handed	r	-,918	-,827	*,783*
	p	,028	,084	*,118*
	N	5	5	*5*
Left-handed	r	,855	,949	-,832
	p	,065	,014	,080
	N	5	5	5

Not significant

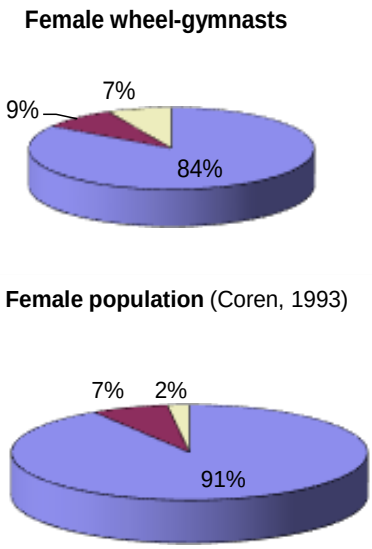

Figure 1. Percentages of handedness among female wheel gymnasts and the female population; blue = right-handed, magenta = left-handed, yellow = ambidextrous; estimated failure = 5.2% for confidence interval 0.95.

When comparing the prevalences of different types of handedness in the general population to those among wheel gymnasts, no dedicated evaluation could be conducted for male gymnasts as there were too few cases, although it should be noted that all 13 male participants were right-handed. When comparing the percentages of left-handedness and ambidexterity among female gymnasts to those in the general female population, it is evident that there is a higher percentage of ambidexters and the left-handed among wheel gymnasts than in the general female population.

There are differences in the percentages of female gymnasts of different handedness competing in straight line and all-around. Spiral and vault could not be evaluated due to too few cases. Interestingly, no ambidexters are competing at the Bundesklasse level and the percentage of the left-handed is very low.

When testing for different types of handedness among wheel gymnasts, statistics could not be evaluated in subgroups for male gymnasts as there were not enough cases.

There are correlations between the percentage of handedness and competitive results when considering quintiles of competitive results in the straight line discipline. The percentage of the left-handed in quintiles correlated positively with the arithmetic mean of the overall merit and difficulty value within quintiles, while for the right-handed the correlations were negative. The more left-handed in a quintile, the better the arithmetic mean for overall merit and difficulty, while the more right-handed correlated with a lower arithmetic mean for overall merit and difficulty. When considering the execution merit, there was a negative correlation between the percentage of the left-handed and the execution merit. The higher the percentage of the left-handed, the lower was the arithmetic mean of the execution value in that quintile. No significant correlations were found regarding ambidexters.

DISCUSSION

There are significant differences in motivational aspects between gymnasts of different handedness within the straight line discipline. The left-handed displayed a significantly higher fear of failure compared to the right-handed and the ambidexters, while the latter had a higher fear of failure compared to the right-handed. It should be noted that all ambidexters were 33 years old or older and competing at the Landesklasse level. This could mean that they were expecting to fail because of their already decreased performance quality, which could have negatively affected their fear of failure. The left-handers' higher fear of failure will be discussed below. The overall performance motivation was the highest in the left-handed followed by the ambidexters and the right-handed. This could be due to the left-handers` increased fear of failure.

When comparing the percentages of the left-handed and ambidexters among female gymnasts to those in the general female population, it is evident that there is a higher percentage of left-handers (9%) and ambidexters (7%) among wheel gymnasts than in the general female population (7 and 2%). Even when calculating estimated failure of 5.2%, the percentage of ambidexters is much higher. At the same time, the results match those of Bessi (2016), who found 84.4% right-handers in artistic gymnasts of both genders. This suggests a coordinational advantage (probably similar to the left-handers' advantage in interactive sports as discussed in the introduction) for gymnastics, which could be linked to the findings of Kourtis et al. (2014). Ambidexters might benefit from a better coordination regarding both-handed movements and the ability to flexibly choose rotation directions (which might be linked to handedness as discussed in the introduction) for different elements.

There are differences in the percentages of female gymnasts of different handedness competing in straight line and all-around. This suggests that there might be a connection to the observed difference in twist direction between gymnasts at the elite and the lower level (Heinen et al., 2012). Interestingly, no ambidexters are competing at the Bundesklasse level and the percentage of the left-handed is very low. The higher age of the ambidexters explains their high prevalence of 12.2% in the lower class; all-around has not been introduced until some years ago in Landesklasse and therefore none of the older ambidexters are performing well enough to compete in this discipline. Still, it is notable that there are no ambidexters and fewer left-handed gymnasts at the Bundesklasse level. When considering the results of Bessi (2016), none of the groups of the current study matches Bessi's (2016) percentages. However, in regard to the connection between turning direction and handedness in artistic gymnastics (Heinen et al., 2012; Bessi, 2016), it is probable that the direction of turn in the spiral discipline might influence the performance and learning curve of the left-handed and/ or ambidexters in that discipline. The direction of turn in German clubs is mostly predetermined according to the preference of the coaches in the clubs. This might put gymnasts with different types of handedness in different positions regarding motor learning and competitive results.

There are correlations between the percentage of handedness and competitive results when considering quintiles of competitive results in the straight line discipline. The percentage of the left-handed in quintiles correlated positively with the arithmetic mean of the overall merit and difficulty value within quintiles, while the correlations for the right-handed were negative. The more left-handed in a quintile, the better the arithmetic mean for overall merit and difficulty, whereas the more right-handed correlated with a lower

arithmetic mean for overall merit and difficulty. When considering the execution merit, there was a negative correlation between the percentage of the left-handed and the execution merit. The higher the percentage of the left-handed, the lower the arithmetic mean of the execution value in that quintile was. This could mean that the left-handed perform well at difficulty while right-handers are able to display good execution. Perhaps repeating a task accurately is not as motivating for the left-handed, as they have a higher activity in the right ("creative") hemisphere (e. g. Gorynia & Egenter, 2000).

CONCLUSION

It is evident that the topic needs further consideration, especially when regarding coordinational differences and differences in task motivation between gymnasts of different handedness and rotation direction in the spiral discipline. It is yet to be determined which handedness-related factors influence performance in wheel gymnastics, probably at a neural or vestibulospinal level. However, it can be concluded that gymnasts of different handedness need coaching according to their individual needs. A special coaching or selection for left-handers and ambidexters, especially in the spiral discipline, could be indicated.

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Article received: 11.2.2021
Article accepted: 19.10.2021

DEMANDS PROFILE IN WHEEL GYMNASTICS: DIFFERENCES BETWEEN ATHLETES AT DIFFERENT PERFORMANCE LEVELS, BETWEEN GENDERS AND IN DIFFERENT DISCIPLINES

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Original article *DOI:10.52165/sgj.14.1.119-130*

Abstract

Performance in many competitive sports is limited by motivation as well as constitutional factors. In this paper the question is addressed whether motivation is related to performance in wheel gymnastics and whether the manifestation of motivation is related to gender, performance level or competitive discipline. To this end, 203 German wheel gymnasts of varying performance level were studied. Different levels of motivation, competitive results and percentages of body fat were found in different groups of gymnasts: gymnasts performing in all-around/ straight line male and female athletes and in gymnasts competing at different performance levels. Also, female and male gymnasts differed significantly in body fat percentage, age and overall merit. Differences between performance levels underline the importance of individual coaching regarding, e. g., hope for success ($p \leq 0.003$, $\eta^2 = 0.108$) and other performance limiting factors. Further, individual coaching for athletes competing in different disciplines seems necessary, as shown by differences in the overall performance motive ($p \leq 0.033$, $\eta^2 = 0.042$). Therefore, each group of athletes should receive coaching tailored to their needs during training and performance that considers their individual background and circumstances, in order to optimize performance.

Keywords: *Body fat percentage, Disciplines, Performance, Gender, Motivation.*

INTRODUCTION

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

movement, concentration, emotional control, perception, stress resistance and self-esteem, along with aesthetic expression (Hundrieser, 2012; Weyermann, 2016).

Sports performance is limited by physical aspects and psychological factors such as motivation: performance demands and psychological factors have been found to be related, for example, in netball (Grobbelaar & Eloff, 2011) and soccer (Hughes, Caudrelier, James, Redwood-Brown, Donnelly, Kirkbride et al., 2012). It should be researched whether motivation is also performance-relevant in wheel gymnastics. It is known that self-regulation practice enhances gymnastics skill (Wolko, Hrycaiko & Martin, 1993). Hume, Hopkins, Robinson, Robinson & Hollings (1993) found that motivation correlates with attainment in gymnastics, while D'Arripe-Longueville, Hars, Debois & Calmels (2009, p 424) showed that "*the main psychological characteristics developed by all the participants pertained to achievement motivation, performance enhancement cognitive skills (e.g., focusing, imagery), and affective and psychosomatic skills (e.g., ability to deal with anxiety; relaxation)*". Munkácsi, Kalmár, Hamar, Katona & Dancs (2012) claim that a strong motivational driving force is essential to perform high level gymnastic exercises and maintain daily practice.

When selecting athletes for wheel gymnastics, the current discussion on talent selection must be kept in mind. While Samuelsen (2003) claims that anthropometric factors are irrelevant for performance in wheel gymnastics because the wheels come in different sizes, Rummel (2016) names BMI as relevant and claims that in this respect wheel gymnastics is comparable to ski-jumping (Muller, Groschl, Muller & Sudi, 2006). Female gymnasts show a lower BMI than males and female wheel gymnasts lie in the lowest percentile within the German population (Kromeyer-Hauschild, Wabitsch, Kunze, Geller, Geiß, Hesse et al., 2001). Some gymnasts are below the z-scores recommended by the World Health Organization (Onis, Onyango, Borghi, Syiam, Nishida & Siekmann, 2007). Low BMI is mostly prevalent in amateur wheel gymnasts according to Rummel (2016).

Atiković, Kalinski & Čuk (2017) found that due to static strength, e. g.,which can only be developed over time, differences in the age of gymnasts in different disciplines is performance relevant on the rings. This is the reason why the average age is higher on this apparatus, while gymnasts competing on the floor have a higher training load and are usually younger. The floor exercise, while being very complex, is linked to strength, flexibility, muscular anaerobic endurance (Nunomura, 2002) and reactive force at take-offs and landings (Karacsony, Čuk, Tihanyi, Fink, Jošt & Čoh, 2005).

Conditional and constitutional factors are viewed as controversial in talent selection (Gonçalves, Rama & Figueiredo, 2012), so mental skills might be of better use (Baron-Thiene & Alfermann, 2015). According to Moesch, Hauge, Wikman & Elbe (2013). Skills such as volition and probably motivation might be a better predictor than other performance factors in selecting for team sports. Wagner, Finkenzeller, Würth and v. Duvillard (2014) state that mental skills are highly relevant for success in handball. This might also be true for individual sports and thus wheel gymnastics, perhaps even with differences regarding gender or different disciplines. However, so far, only a few studies have researched the gender- or discipline-specific demand profiles in wheel gymnastics. Koumpoula, Tsopani, Flessas and Chairopoulou (2011) found high motivation as relevant in rhythmic gymnasts. Also, motivation and training time can be seen as predictors of attainment in gymnastics (Hume, Hopkins, Robinson, Robinson & Hollings, 1993), and motivation is related to gymnastics performance (Munkácsi, Kalmár, Hamar,

Katona & Dancs, 2012). It should be clarified whether motivation is performance relevant for wheel gymnasts of different gender and/or in different disciplines.

Without a corresponding study, Mies (1994) states that wheel gymnastics can be counted among the aesthetic sports, where, according to Potter, Lavery and Bell (1996), athletes are required to look slim. In aesthetic sports such as artistic and rhythmic gymnastics, performance is related to slenderness in terms of body proportions, BMI or body fat percentage. Various examples can be found in literature (e. g. Claessens, Lefevre, Beunen & Malina, 1999; Bacciotti, Baxter-Jones, Gaya & Maia, 2017) for female athletes, and low percentages of body fat can be found in male athletes as well (Gurd & Klentrou, 2003). Compared to other aesthetic sports, wheel gymnasts display a rather low body fat percentage and earn lower scores from the judges for their performance if they don't meet this requirement (Weber, 2020). It should be clarified whether there are specifics demands regarding body fat percentage at different competitive levels and within different disciplines.

To facilitate individualized training for different groups of gymnasts, the study aims to answer the following questions:

1. Are there differences in percentages of body fat, competitive results or psychological performance factors in female gymnasts performing in different disciplines or at different performance levels that can be shown via a) ANOVA or b) specific demands regarding the aforementioned factors that can be shown via testing for correlations?
2. Are there differences between male and female athletes for the different variables?

METHODS

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

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

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

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

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

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

To assess differences regarding motivational factors and body fat percentages between disciplines and performance levels, Oneway ANOVA was performed in each of the following subgroups: female gymnasts at both performance levels (Bundesklasse/ Landesklasse) and in two disciplines (Straight line/ All-around) as there was an insufficient number of male participants. Also, Oneway ANOVA was performed to test for differences between genders. The criterion level for significance was set at $p<0.05$ and the trend significance at $p<0.10$. The effect size was evaluated with η^2 (Eta partial squared), where $0.01<\eta^2<0.06$ constitutes a small effect, $0.06<\eta^2<0.14$ constitutes a medium effect and $\eta^2>0.14$ constitutes a large effect (Cohen, 1988). To test for specific demands, correlations were calculated via Pearson and Spearman`s Rho with correlation levels >0.1 (weak), >0.3 (moderate) and >0.5 (strong). Different types of correlation coefficients were used due to varying sample sizes as well as outliers and lack of homogeneity within subgroups (David 1938; Mukaka, 2012). Statistical analysis was performed in SPSS, version 25 (SPSS, Inc., Chicago, IL).

RESULTS

There are different body fat percentages, competitive results in straight line and psychological performance factors in female gymnasts performing in all-around/ straight line and in gymnasts competing at different performance levels (Tab. 1).

There seem to be specific demands for female athletes competing in different disciplines or at different performance levels (Tab. 3). Athletes at the Bundesklasse level could not be evaluated according to discipline as there were too few cases.

Table 1
Differences between female gymnasts competing in different disciplines and at different performance levels.

Differences	N	$\bar{X} \pm SD$	p	η^2
Straight line vs. all-around (all performance levels)				
Overall merit*	74 vs. 26	5.50 ± 1.45 vs. 7.80 ± 1.83	0.000	0.302
Difficulty in competition	69 vs. 26	2.50 ± 1.12 vs. 4.50 ± 1.29	0.000	0.639
Difficulty in training	53 vs. 25	2.75 ± 1.30 vs. 4.45 ± 1.23	0.000	0.284
Age	78 vs. 36	23.92 ± 14.83 vs. 19.53 ± 6.70	0.092	0.025
Composition in competition	57 vs. 26	0.83 ± 0.31 vs. 1.00 ± 0.00	0.007	0.085
Hope for success	73 vs. 35	33.56 ± 7.66 vs. 36.91 ± 5.26	0.021	0.049
Overall performance motive	72 vs. 35	43.56 ± 9.03 vs. 47.63 ± 9.42	0.033	0.042
Straight Line vs. all-around (Landesklasse**)				
Overall merit	42 vs. 6	5.45 ± 1.53 vs. 6.85 ± 1.20	0.038	0.090
Difficulty in competition	39 vs. 6	2.42 ± 1.11 vs. 3.73 ± 1.11	0.010	0.144
Net hope	41 vs. 6	22.76 ± 11.54 vs. 31.67 ± 11.81	0.085	0.065
Bundesklasse vs. Landesklasse				
Age	33 vs. 49	15.88 ± 5.74 vs. 28.96 ± 15.05	0.000	0.221
Body fat percentage	33 vs. 48	12.67 ± 2.64 vs. 15.74 ± 3.83	0.000	0.168
Hope for success	31 vs. 48	37.90 ± 5.30 vs. 33.29 ± 7.25	0.003	0.108
Overall performance motive	31 vs. 47	48.35 ± 8.83 vs. 43.00 ± 9.68	0.016	0.074

*All values for straight line. **Dividing into disciplines in Bundesklasse was not possible due to too few cases.

Table 2
Performance relevance of certain factors measured as correlations between performance variables within subgroups for female gymnasts.

Subgroup	Correlations	Pearson's r	*p*	N
Landesklasse	Age vs. Difficulty	- 0.263	0.085	38
	vs. Execution	0.448	0.005	38
Bundesklasse	Age vs. Difficulty	0.412	0.051	23
	vs. Composition	0.438	0.032	24
	vs. Deduction off planned difficulty	0.406	0.061	22
	vs. Hope for Success	- 0.401	0.025	31
	vs. Fear of Failure	0.491	0.005	31
	vs. Net hope	- 0.545	0.002	31
	Fear of Failure vs. Execution	- 0.579	0.004	23
	vs. Deduction off planned difficulty	0.592	0.005	21
	Net Hope vs. Execution	0.470	0.024	23
	vs. Deduction off planned difficulty	- 0.457	0.037	21
	OPM** vs. Execution	- 0.577	0.004	23
	vs. Deduction off planned difficulty	0.639	0.002	21
Straight Line	Age vs. OPM	- 0.263	0.027	71
	vs. Execution	0.321	0.014	58
	vs. Body fat percentage	0.334	0.003	76
	Fear of Failure vs. Difficulty	0.369	0.003	65
	vs. Composition	0.303	0.026	54
	vs. Overall merit	0.295	0.014	68
	Net Hope vs. Difficulty	- 0.260	0.037	65
	vs. Composition	- 0.234	0.089	54
	vs. Overall merit	- 0.229	0.060	68
	OPM vs. Difficulty	0.261	0.036	65
All Around	Age vs. Body fat percentage	0.482	0.003	36
	vs. Difficulty**	- 0.499	0.009	26
	Fear of Failure vs. Execution	- 0.382	0.059	25
	Net Hope vs. Execution	0.414	0.040	25
	OPM vs. Deduction off planned difficulty	0.353	0.098	23
Landesklasse Straight Line	Age vs. Execution	0.446	0.010	32
	vs. Body fat percentage	0.363	0.020	41
	Fear of Failure vs. Difficulty	0.351	0.033	37
	vs. Overall merit	0.293	0.066	40
Landesklasse All Around	Age vs. Difficulty*	- 0.905	0.013	6

*Overall performance motive **Difficulty value in the straight line discipline

Table 3
Differences between gymnasts of different gender.

Differences (female vs. male)	N	$\bar{X} \pm SD$	p	η^2
Body fat percentage	113 vs. 16	14.62 ± 3.75 vs. 8.32 ± 3.51	0.000	0.259
Age	114 vs. 15	22.54 ± 5.11 vs. 16.07 ± 12.98	0.059	0.028
Overall merit	100 vs. 15	6.10 ± 1.84 vs. 6.97 ± 1.97	0.092	0.025

Further, there are differences between male and female athletes in percentages of body fat, age and overall merit (tab. 2). No gender-related differences were found when considering other performance measures or motivational aspects.

DISCUSSION

For athletes competing in different disciplines, it is evident that gymnasts in the all-around had higher values in all competitive values compared to athletes competing only in straight line. This could be due to better coordination, a higher level of training, and more weekly training time as this might help them develop their skills more thoroughly. Also, gymnasts competing in straight line only were significantly older than gymnasts competing in the all-around while displaying lower values in the composition of their routines. This might be caused by more training time for younger competitors due to fewer demands in their daily lives. Gymnasts competing in the all-around had a higher hope of success and overall performance motive.

When considering results for gymnasts at the Landesklasse level, athletes competing in the all-around had a higher overall merit and difficulty, also higher net hope, probably due to having had success in the past, or, again, due to more time spent training.

This matches results for motivational factors at the Bundesklasse level, where hope of success and overall performance motive are significantly higher than at Landesklasse. This might be caused by higher self-esteem. Additionally, athletes at the Bundesklasse level were significantly younger than at the Landesklasse level, this is probably due to a mixture of more training time and also better constitution and physical fitness at a younger age. This matches the results of Atiković et al. (2017) who found age-related differences between gymnasts competing on different kinds of apparatus. It is evident that the body fat percentage of the older gymnasts at the Landesklasse level is significantly higher than that at Bundesklasse, which is not in accordance with findings by Rummel (2016), but matches the results of a literature research conducted by Weber (2020). The body fat percentage seems to be a performance limiting factor, although it might also be that the aesthetic aspect might have influenced the judging (Weber, 2020).

When comparing male and female wheel gymnasts, it appears that males display a lower body fat percentage, as indicated in the abovementioned literature research regarding previous studies on gymnasts from various disciplines (Weber, 2020). Also, male wheel gymnasts displayed a significantly lower age than females, probably due to early drop-out due to social pressure from peers during puberty. Males had a higher overall merit than females. Due to the low number of male participants, it was not possible to attribute the higher overall merit to any cause, e. g., higher difficulty, execution, or composition values.

When comparing gymnasts from Bundesklasse and Landesklasse, correlations occur at the Landesklasse

level between age and difficulty (negative correlation) as well as execution (positive correlation), while at the Bundesklasse level, positive correlations are present between age and difficulty, age and composition, age and deductions off planned difficulty, age and fear of failure as well as fear of failure and deduction off planned difficulty, net hope and execution and overall performance motive and deduction off planned difficulty. Negative correlations can be found between age and hope of success, age and net hope, fear of failure and execution, net hope and deduction off planned difficulty, and overall performance motive and execution. This could mean that a high difficulty routine cannot be performed at a higher age and/ or with less training time. Also, the execution seems to improve with age despite training time per week, but rather concurrent with time spent in training over a lifetime. BK athletes seem to have a higher composition with rising age, but also a lower difficulty. Their motivation decreases, perhaps due to growing more nervous over time or having less success in line with a decrease in physical fitness. Fear of failure seems to have a negative effect on execution, probably due to being nervous in competition and making more minor mistakes.

A comparison of straight line versus all-around shows that the overall performance motive decreases with increasing age, perhaps due to less success or disappointments accumulated over time. It must be mentioned that there is a higher number of Landesklasse athletes performing in straight line, probably due to not having enough time to train more than one discipline. The concept of competing in the all-around was only introduced for Landesklasse gymnasts a few years ago. Execution value and body fat percentage increase with age in gymnast competing in straight line, just as the execution value did in gymnasts competing at the Landesklasse level. For straight line competitors, fear of failure is linked positively to difficulty value, composition value and overall merit, probably due to athletes being motivated to take a higher risk to win. This also shows in net hope as it is negatively linked to the three aforementioned factors and the overall performance motive is positively linked to the difficulty value in straight line. In the all-around, age correlates positively with body fat percentage and negatively with difficulty in the straight line routine. Interestingly, fear of failure correlates negatively with execution, which has not been the case in straight line. Net hope is linked positively to the execution value, underlining the positive effect of hope of success in the accuracy of movements. For all-around competitors, the overall performance motive is connected to deduction off planned difficulty which might be caused by increased pressure during competition.

Considering differences between competitors in straight line and all-around for Landesklasse athletes only, execution and body fat percentage are connected positively with age in the straight line discipline. This underlines the hypothesis that accuracy in the execution of movement improves over the lifespan. Also, fear of failure correlates positively with difficulty and overall merit, probably due to a high level of ambition and thus high pressure to compose routines with a high difficulty. For Landesklasse gymnasts competing in the all-around, there is a high negative correlation between age and difficulty, probably also showing a decline in physical ability for the older gymnasts who are predominantly competing at the Landesklasse level.

CONCLUSION

Athletes at different performance levels need to be coached individually, as are athletes competing in different disciplines. Gender, on the other hand, does not have a strong effect when it comes to differences between gymnasts. Also, a strong aging effect is measurable.

More attention should be paid by coaches to the triad of physical decline - age - training time. It seems that older athletes mostly do not have the possibility to train properly despite needing more training to keep fit and achieve good results due to demands placed on them by daily life. This might affect hope of success and thus self-esteem, resulting in poor performance. Also, aspects of mental health must be taken into account. There might be connections between success and dropout rates for older athletes, even though they could still be competing at the Landesklasse level for some time: instead, there is a loss of role models, possibilities to learn from experiences and rivalry for the younger athletes as well as costs to the health care system. Especially ageing athletes should be encouraged to keep fit.

In summary, psychological factors seem to be performance relevant in wheel gymnastics as also shown in studies of other gymnastics disciplines (Calmels et al., 2009; D'Arripe-Longueville et al., 2009; Hume et al., 1993; Munkácsi et al., 2012; Wolko et al., 1993). Some factors can be considered performance relevant in general and within the different disciplines, including hope of success, fear of failure, net hope, overall performance motive and, to a certain degree, body fat percentage. While fear of failure may pose a hindrance to some gymnasts, others need it to drive their performance. These findings should be considered and gymnasts should be coached accordingly.

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Article received: 19.2.2021
Article accepted: 26.9.2021

SHORT HISTORICAL NOTES XXIII

Anton Gajdoš, Bratislava, Slovakia
Michal Bábela, Faculty of Physical Education and Sports, Bratislava, Slovakia

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

Szilveszter CSOLLÁNY (April, 13, 1970 Sopron – January, 24, 2022 Budapest, Hungary)

Szilveszter Csollany was known for his extraordinary strength from his childhood. He had not a typical body of a gymnast as his curved legs did not match the aesthetic requirements of gymnastics. He knew that, but reckoned he would still have a chance to became succesfull gymnast if he managed to execute his routines reliably and without mistakes. It is usual that the talented men are autonomus and have their own ways. He was one of those gymnasts who can be difficult to work with. He was helped by several coaches both in his club and on the national selected team during his career, notably by Nándor Szólás in Győr. (from book Rings by Ivan Čuk and István Karácsony).

He lived in Budapest with Szilvia and daugther Szimona.

The first gymnastics competition was at 1983 and soon showed his great potential, especially on rings. The first international debut was in Korea in 1988, where he placed 3rd on rings. Same year at Junior European Championship in Avignon he took bronze medal on rings.

As senior his achievements are:

European Championship

1990 Lausanne (SUI)	Rings 3.
1992 Budapest (HUN)	Rings 3.
1994 Prague (CZE)	Rings 3.
1998 St.Petersburg (RUS)	Rings 1.
2000 Bremen (GER)	Rings 2.
2002 Patras (GRE	Rings 3.

World Cup

1997 Zurich (SUI)	Rings 1.
1998 Sabae (JPN)	Rings 1.
2000 Glasgow (UK)	Rings 1.

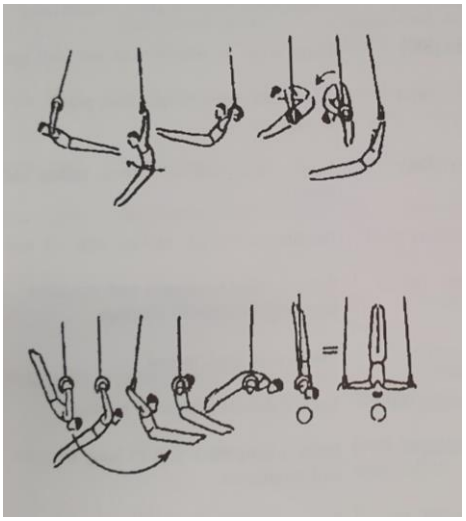
World Championships

1992 Paris (FRA)	Rings 2.
1994 Brisbane (AUS)	Rings 7.
1996 San Juan (PUR)	Rings 2.
1997 Lausanne (SUI)	Rings 2.
1999 Tianjin (CHN)	Rings 2.
2001 Ghent (BEL)	Rings 2.
2002 Debrecen (HUN)	Rings 1.

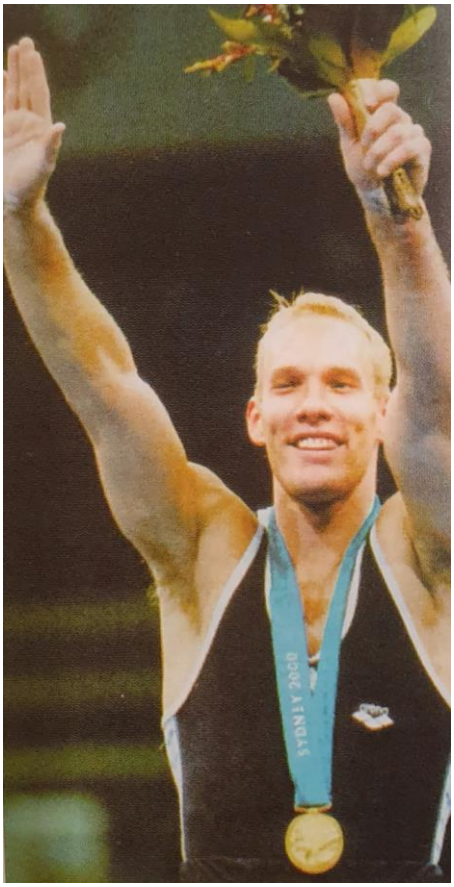
Olympic Games

1992 Barcelona (ESO)	Rings 6.
1996 Atlanta (USA)	Rings 2.
2000 Sydney (AUS)	Rings 1.

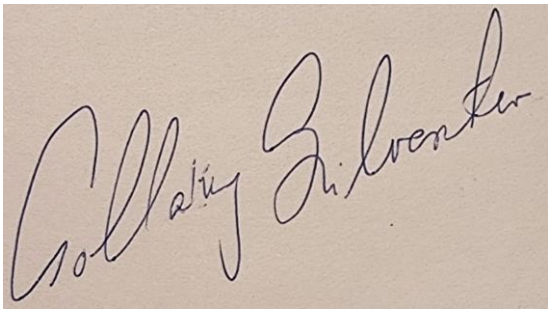
Long he was in shadow of another excellent gymnast on rings Yuri Chechi (ITA), but he managed to overcome it and won European, World and Olympic title.

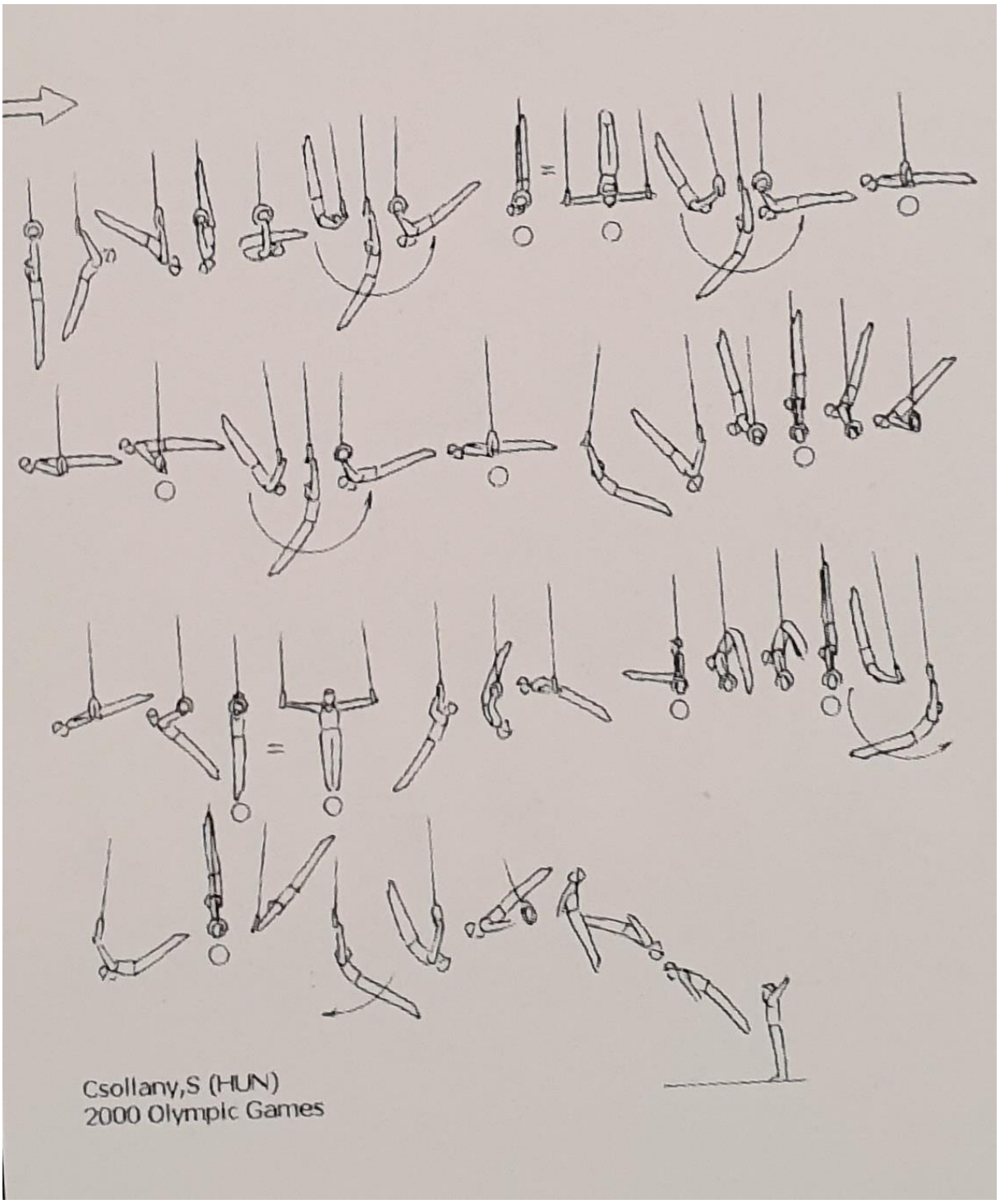


His excellency and creativity is also in FIG Code of Points, where he has his name under two elements (Figure right)



The happiest moment at competitions – Sydney OG 2000 (from the book István Karácsony A Magyar Tornasport Kronikaja, 2002).





Exercise from OG 2000 (from the book István Karácsony A Magyar Tornasport Kronikaja, 2002).

Slovenski izvlečki / Slovene Abstracts

Tony Froissart, Thierry Terret

ZAPUŠČINA OLIMPIJSKEGA PRVAKA LETA 1924, TELOVADCA LEONA ŠTUKLJA

Olimpijski prvak v orodni telovadbi Leon Štukelj je na 8. olimpijadi leta 1924 nastopil izjemno. Članek razčleni telovadbo Štuklja, ki je bila za tiste čase povsem drugačna od ostalih telovadcev, zato je potrebno oceniti njegov vpliv na razvoj orodne telovadbe. Štukelj je s svojim nastopom utrl pot do velikih sprememb v orodni telovadbi, predvsem na krogih, kjer je blestel. Zdi se, da so se nekateri tehnični predpisi mednarodne orodne telovadbe še posebej zgledovali po prvinah, ki jih je izvajal leta 1924. Štukelj je veljal tudi za vzorčno osebnost vzgojne metode, ki so jo razvili jugoslovanski Sokoli. Posledično je bil zelo močan tudi njegov odtis kot simbol moralne in telesne vadbe. Članek je postavljen na področje zgodovine kulture. Njegov namen je preučiti razvoj Štukljevega nastopa in zapuščine. Poleg zgodovinopisja olimpijskih iger leta 1924 uporablja različne temeljne vire: francoski dnevni tisk, objavljen ob olimpijskih igrah 1924, arhiv Olimpijskega študijskega centra v Lozani, arhiv mesta Colombes, uradno poročilo z olimpijskih iger 1924, 1928 in 1936, arhiv Mednarodne telovadne zveze in Štukljev lastni življenjepis (1989).

Ključne besede: Štukelj, olimpijske igre, telovadba, pomen, Sokol.

Mateus Henrique de Oliveira, Leticia Bartholomeu de Queiroz Lima, Andrize Ramires Costa

ZNAČILNOSTI SESTAV TELOVADK NA GREDI IN PARTERJU NA OI 2016 V RIU

Orodna telovadba je šport, ki obsega različne gibe, ki se izvajajo na orodjih, ki jih povezuje umetnost gibanja. Pravilnik za ocenjevanje je dokument, ki združuje vsa pravila tega športa; usmerja delo vaditeljev in telovadcev ter pomaga pri sestavljanju sestav, predstavljenih na tekmovanjih. Ta raziskava se osredotoča na žensko orodno telovadbo in izvajanje njenih pravil, ki jih določa Pravilnik za ocenjevanje 2013-2016. Namen je razčleniti sestave na prvine, ki so jih predstavile telovadke na olimpijskih igrah v Riu 2016 in odkriti možne tehnične odnose med sestavo na gredi in sestavami na parterju. Razčlenjenih je bilo 82 sestav na gredi in 82 sestav na parterju, skupaj 164 vaj, ki so jih izvedle telovadke v predtekmovanju. Opazili smo, da je Pravilnik za ocenjevanje še malo raziskan, telovadke pa uporabljajo le nekaj prvin, ki so na voljo. V tem smislu bi morala Mednarodna telovadna zveza natančneje določiti pravila za ocenjevanje, ki ureja šport, oblikovati strategije za boljšo uporabo prvin, ki so na voljo v okviru pravil.

Ključne besede: kompozicija, pravilnik za ocenjevanje, olimpijske igre.

Takashi Sano, Shohei Kokudo

PREGLED GIBALNIH VZORCEV, KI ODRAŽAJO STOPNJO ZNANJA OSNOVNOŠOLCEV RAZNOŠKE ČEZ SKRINJO VZDOLŽ

Namen pričujoče študije je bil preučiti gibalne vzorce, ki odražajo znanje raznožke čez skrinjo vzdolž pri osnovnošolcih, in razjasniti razlike v tehniki gibanja glede na spol, razred in višino skrinje. Preiskovanih je bilo 453 otrok (220 fantov, 233 deklet) od 3. do 6. razreda. Njihova gibanja pri preskoku so zabeležili z leve in sprednje strani ter jih ocenili po opazovalnem ocenjevalnem kriteriju. Razčlenitev raznožke je bila uporabljena za izločitev vzorcev gibanja posameznega značilnega dela raznožke. Verjetnost pripadnosti vsakemu vzorcu gibanja je bila razvrščena po spolu, razredu in višini orodja. Da bi raziskali značilnosti gibanj glede na spol, razred in višino orodja, smo izvedli $\chi 2$ test in analizo variance. Kot rezultat določitve vzorcev gibanja, je postalo jasno, da lahko preskoke osnovnošolcev razvrstimo v pet skupin: neuspešni skoki, preskoki odvisni od opore rok, preskoki s slabim doskokom, dobri preskoki in preskoki z močnimi potiski in odrivi v opori. Med dečki in dekleti ni bilo razlike v pojavnosti gibalnih vzorcev ($\chi 2=7,707$, $p>0,05$). Čeprav je obstajala pomembna razlika v stopnji pojavljanja vzorcev med ocenami ($\chi 2=42,615$, $p<0,01$), se gibi z visoko kakovostjo niso nagibali k povečanju, ko so ocene naraščale. Pet gibalnih vzorcev, pojasnjenih v tej študiji, naj bi vodilo do podrobnega vrednotenja preskokov in izboljšanju pouka glede na njihovo znanje.

Ključne besede: telesna vzgoja , uspešnost, preskok, osnovna šola, razvrščanje.

Vasiliki Kaioglou, Konstantinos Karteroliotis, Maria Koutsouba, Fotini Venetsanou

TELESNO KULTURNA PISMENOST NEVRHUNSKIH TELOVADK

Otroci, zlasti dekleta, ne kažejo ravni telesne aktivnosti (TA) in telesne pismenosti (TP), ki bi bila povezana z zadostnimi zdravstvenimi koristmi. Telovadba naj bi bila primerno področje za krepitev PL otrok in sorodnih prvin, kot je PA. Namen te študije je bil oceniti raven TP nevrhunskih telovadk, da bi odkrili področja zadostnega in nezadostnega razvoja v njihovi TP. Preiskovano je bilo 101 dekle, staro 8-12 let (Mstarost=10,1±1,4), ki se je vsaj eno leto udeleževalo telovadbe za razvedrilo (Mleta=3,7±2,0), ocenilo kanadsko oceno telesne pismenosti (CAPL). -2). Za vse udeleženke so bile izračunane povprečne ocene (M±SD) za celotno TP in z njo povezane elemente. V skladu s tem je bila vsaka od njih razvrščena v eno od štirih razlagalnih kategorij CAPL-2, kar je navedlo, ali je bila na ne priporočeni (»začetek«, »napredovanje«) ali priporočeni (»doseči«, odlično«). Regresijska analiza je preučila povezavo skupnega TP rezultata s starostjo udeležencev in leti udeležbe pri telovadbi. Čeprav telovadke, podobno kot enako stari otroci po vsem svetu, niso izkazale ustrezne ravni PL, je bila njihova telesna pripravljenost dovolj razvita in so bile pretirano motivirane/samozavestne za TA. Nasprotno pa so bili druge prvine elementi TP, to je njihova gibalna pristojnost, znanje TA, sodelovanje TA, pod priporočenimi ravnmi, kar kaže na pomanjkljivosti v njihovem razvoju TP. Starost je bila povezana s skupnim TP (b=.440, p=.0001), leta udeležbe v telovadbi pa ne (b=.090, p=.325). Sodelovanje pri telovadbi je pomembno za krepitev več delov TP telovadk; za razvoj celotne palete prvin TP pa je treba dati prednost izvajanju večih delov telovadnih programov.

Ključne besede: gibalna pristojnost, telesna pripravljenost, telesna dejavnost, zdravstveno znanje, motivacija.

George Dallas, Costas Dallas, Vasiliki Kolovou, Panagiotis Pappas, Vasilis Mellos, Giorgos Paradisis

TRENUTNI UČINKI ENO IN DVOSTRANKEGA TRESENJA CELEGA TELESA NA SKAKALNE SPOSOBNOSTI, DVOSTRANSKO NESKLADNOST IN POMANJKANJE MOČI PRI BIVŠIH TELOVADCIH

Tresenje celega telesa (WBV) se uporabljajo za izboljšanje skakalne sposobnosti, mišične moči, moči in zmogljivosti v različnih športih. Dvostranski primanjkljaj (BLD) je opredeljen kot razlika v velikosti največje sile med enonožnim ali sonožnim odrivom. Ta raziskava je proučila učinek enostranskih in dvostranskih tresenj celega telesa (WBV) na skakalne sposobnosti, neskladnost in BLD na nekdanje telovadce. Osemindvajset telovadcev se je prostovoljno prijavilo za sodelovanje v tej študiji. Udeleženci so izvedli 4 poskusne načine v ne zaporednih dneh v naključnem vrstnem redu. Vsak način je vključeval 3-minutno ogrevanje na tekalni stezi pri 2,22 ms^{-1}, čemur je sledil 2-minutni počitek. Načini tresenja so bili: a) WBV z nogami [dvonožno] (WBVB), b) WBV z eno nogo [enostransko] (WBVU), c) WBVB z izklopom naprave (NWBVB) in d) WBVU z napravo izklop (NWBVU). Odvisni spremenljivki sta bili vskok iz čepa (SJ) in vskok iz stoje na stegnjenih nogah (CMJ) sonožno in enonožno. Rezultati so pokazali pomemben učinek vplivov med stanjem in časom na SJ tako pri stanju (sonožno/enonožno) kot pri CMJ, medtem ko je bil pomemben glavni učinek ugotovljen za stanje in čas na SJ. Končno, WBV bistveno izboljša simetrijo spodnjih okončin med izvajanjem SJ. Poleg tega je bil dvostranski WBV (WBV B) najučinkovitejši pogoj za dvostransko in enostransko delovanje SJ in CMJ.

Ključne besede: dvostranski primanjkljaj; vskok z ene noge; neskladnost.

Ivanova Vesela Ivanova

ŠPORTNE ZNAČILNOSTI VRHUNSKIH RITMIČARK

Vrhunski športniki so osebe, ki v sebi združujejo izjemno nadarjenost, dolgoletno trdo delo in izrazite osebnostne lastnosti. Vrhunske ritmičarke se od tega določila ne razlikujejo, saj njihove športne značilnosti vključujejo vse te značilnosti. Namen raziskave je razviti metodologijo za oblikovanje športnih značilnosti vrhunskih ritmičark na podlagi trenutnih ritmičark iz ZDA, Singapurja in Tajvana ter primerjati dobljene rezultate. To bi nam lahko pomagalo oceniti trenutne navade teh ritmičark, pozitiven ali negativen vpliv navad na njihovo uspešnost in potrebne spremembe, ki jih je treba narediti za izboljšanje vadbe. Rezultati in statistična obdelava podatkov iz opravljenega poskusa so pokazali, da so tri preučevane srste vrhunskih ritmičark (skupaj 63) izkazale močno zavzetost in vključenost v vadbo. Na splošno so imeli singapurske in tajvanske ritmičarke težave pri sporazumevanju s svojim vaditelji in zaostajali v razvoju tehničnih lastnosti in miselnih sposobnosti za učinkovito prilagajanje v primerjavi z vrstnicami iz ZDA. Hkrati pa so pokazali višjo stopnjo samozavedanja za izboljšave. Po drugi strani pa so ritmičarke iz ZDA pokazali pomanjkljivosti v doslednosti pri vadbi. Številčne vrednosti so tudi pokazale, da so nekatere ameriške športnice izkazale omejitve pri razvoju telesnih lastnosti in sposobnosti, ki bi lahko vplivale na njihov poklicni športni razvoj v prihodnosti.

Ključne besede: ritmika, šport, značilnosti.

Maria Letícia Jardim, Ana Clara Justino Valencio, Lizia Nardi Menegassi, Ricardo Azevedo Da Silva, Randhall Bruce Carteri

TVEGANJE ZA MOTNJE PREHRANE IN SAMOPODOBE PRI MLADIH RITMIČARKAH JE POVEZANO Z NEPRIMERNIM VNOSOM ENERGIJE IN HRANIL

Ritmika je lepi šport s posebnimi zahtevami, ki lahko pospešijo razvoj motenj hranjenja, kar vodi do pomembnih prehranskih pomanjkljivosti, ki lahko ogrožajo športno uspešnost in zdravje. Tako je cilj tega dela razčleniti povezave med tveganjem za motnje hranjenja in zaznavanjem telesne podobe in prehranjevalnih navad pri brazilskih ritmičarkah. Osemnajst športnic, starih med 12 in 19 let, se je odzvalo na dva 24-urna odpoklica hrane, na standardizirano meritev prehranjevalnega odnosa (EAT-26), na lestvico spoštovanja telesa (BES) in na vprašalnik o obliki telesa (BSQ). Obstajala je povezava med tveganjem za motnje hranjenja, popačenjem telesne podobe in indeksom telesne mase (0,51; p = 0,025 in -0,50; p = 0,029). Ugotovljene so bile negativne povezave med vnosom ogljikovih hidratov in lipidov na kilogram s tveganjem za motnje hranjenja (-0,69; p = 0,001 in -0,49; p = 0,03) in s popačenjem telesne slike (-0,63; p = 0,004 in -0,63; p = 0,04). Ugotovljene so bile tudi negativne povezave med energijskim vnosom na kilogram in tveganjem za motnje hranjenja (-0,62; p = 0,004) ter popačenjem telesne podobe (-0,70; p = 0,001). Naši rezultati poudarjajo pomen večdisciplinarnega pristopa za povečanje ozaveščenosti in preprečevanje morebitnih motenj hranjenja pri teh športnicah.

Ključne besede: prehranjevalne navade, duševno zdravje, psihologija športa.

Pınar Tatlıbal, Emine Kutlay, Onur Oral

UČINEK POSAMEZNIH DELOV OCENE NA KONČNO OCENE NA PRVEM MLADINSKEM SVETOVNEM PRVENSTVU RITMIČARK

Namen je bil ugotoviti učinek delov skupnega rezultata na skupni rezultat in razlike med deli točkovanja na 1. mladinskem svetovnem prvenstvu v ritmiki v predtekmovanju, ki je potekalo v Moskvi, Ruska federacija, leta 2019. Razčlenjenih je bilo 1708 rezultatov 138 ritmičark iz 61 držav v vseh sestavah. Za vse sestave so učinki rezultatov težavnostnih podskupin (D1-2, D3-4) na skupne ocene težavnosti (DTS), rezultati odbitkov podskupine izvedbe (E1-2, E3-4-5-6) na skupne rezultate izvedbe (ETS), in preučili so učinke DTS in ETS na skupne rezultate (TS). Uporabljena je bila opisna statistika, prema regresija in enosmerna ANOVA. V rezultatih regresije je bilo ugotovljeno, da je bil učinek DTS na TS večji od učinka ETS na TS pri sestavah s kolebnico, žogo, kiji in trakom. Med vsemi orodji so bili učinki DTS in ETS na TS najvišji pri sestavah s kiji in najnižji pri sestavah s kiji. Učinek D3-4 na TS je bil večji kot D1-2. Učinek odbitka E3-4-5-6 na TS je bil višji kot E1-2 ($p<0,001$). Statistično pomembne razlike so bile ugotovljene le med srednjimi ocenami DTS orodja ($p<0,000$), razčlenjene z enosmerno ANOVA. To je pripeljalo do zaključka, da bo ravnovesje v učinku delov TS na rezultate TS prispevalo k celovitosti in umetniškemu učinku sestav ter vodilo tudi do boljših rezultatov, zato je treba več časa posvetiti sestavam s kolebnico in trakom v zgodnjem obdobju telesne priprave.

Ključne besede: ritmika, sestave, posameznice, ocena rezultatov.

Johanna Weber

POVEZAVE MED ROČNOSTJO, TEKMOVALNO USPEŠNOSTJO IN MOTIVACIJO NA TELOVADNEM NA KOLESU

Ročnost je dejavnik, ki vpliva na uspešnost v številnih tekmovalnih športih. V ženskem rokometu so psihološki dejavniki, kot je motivacija, povezani z ročnostjo. Tudi pri telovadbi je potrebno raziskati, ali je tako tudi pri telovadnem kolesu in ali je motivacija povezana z zmogljivostjo ali roko. V ta namen se je preučilo 203 nemške telovadce na kolesu. Obstajajo pomembne razlike v motivacijskih vidikih med telovadci s prevladujočo roko v disciplini ravne črte. V mnogoboju ni bilo ugotovljenih razlik. Primerov, da bi telovadci tekmovali samo v spirali ali preskoku, je bilo premalo. Če primerjamo razširjenost različnih vrst ročnosti v splošni populaciji s tistimi med telovadci na kolesih, za moške telovadce zaradi premajhnega števila primerov ni bilo mogoče izvesti posebne ocene, čeprav je treba opozoriti, da je bilo vseh 13 moških udeležencev desničarjev. Če primerjamo odstotke levičark in soročnosti med telovadkami in tistimi v splošni ženski populaciji, je razvidno, da je med telovadkami na kolesih višji odstotek soročnosti in levičarjev kot v splošni populaciji. Obstajajo razlike v odstotkih telovadk različnih rok, ki tekmujejo v ravni liniji in v mnogoboju. Obstajajo povezave med odstotkom ročnosti in tekmovalnimi rezultati, če upoštevamo range tekmovalnih rezultatov (npr. $r = 0,949$ in $p \leq 0,014$ za tehnične težave pri levičarjih). Naši rezultati kažejo, da bi bilo treba pri vadbi posameznika in izboru upoštevati ročnost.

Ključne besede: ročnost, tekmovalni rezultati, motivacija, discipline, uspešnost.

Johanna Weber

ZAHTEVE PRI TELOVDNEM KOLESU: RAZLIKE MED TELOVADCI NA RAZLIČNIH STOPNJAH KAKOVOSTI, SPOLU IN DISCIPLINAH

Uspešnost v številnih tekmovalnih športih je omejena tako z motivacijo kot tudi s telesnimi dejavniki. V prispevku se obravnava vprašanje, ali je motivacija povezana z uspešnostjo pri telovadnem kolesu in ali je prikaz motivacije povezan s spolom, stopnjo uspešnosti ali tekmovalno disciplino. V ta namen se je preučilo 203 nemške telovadke na kolu različnih stopenj uspešnosti. Različne ravni motivacije, tekmovalnih rezultatov in odstotkov telesne maščobe so bile ugotovljene pri različnih skupinah telovadcev: telovadci, ki so nastopali v mnogobojih/posameznih disciplinah. Telovadci in telovadke so se bistveno razlikovali v odstotku telesne maščobe, starosti in splošnih značilnostih. Razlike med ravnmi uspešnosti poudarjajo pomen vadbe posameznika glede, npr. npr. upanje na uspeh ($p \leq 0,003$, $\eta 2 = 0,108$) in druge dejavnike, ki omejujejo uspešnost. Nadalje se zdi potrebno vadbo prilagoditi posamezniku, ki tekmuje v različnih disciplinah, kar kažejo razlike v celotnem motivu uspešnosti ($p \leq 0,033$, $\eta 2 = 0,042$). Zato bi morala vsaka skupina športnikov med vadbo in nastopom prejemati vadbo, prilagojeno njihovim potrebam, ki upošteva njihovo lastno ozadje in okoliščine, da bi uspešnost povišali.

Ključne besede: odstotek telesne maščobe, discipline, uspešnost, spol, motivacija

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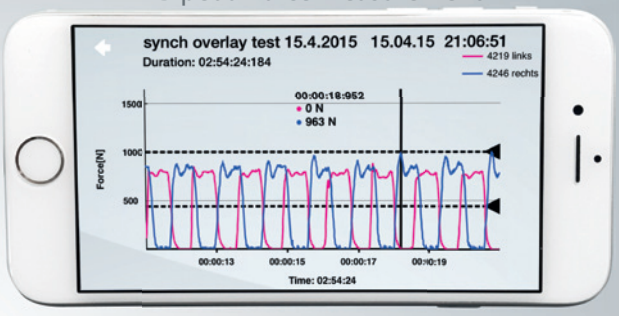

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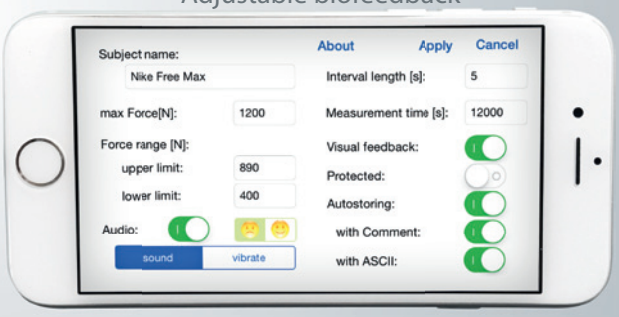

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