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XVII Freiburg International Gymnastics Congress:
On left Flavio Bessi, spiritus agens of XVII Freiburg International Gymnastics Congress and on right Eric Bucharin, expert, olympic coach from France represents his speach at scientific congress part (photo Jonas Rohleder).

EDITORIAL

Dear friends,

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

Please note that our address is

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

We are still working as volunteers and splitting our duties with our younger coworkers. You may have noticed that the administrator has become very strict when articles are not prepared according to the guidelines. To avoid any prolonged delays in getting your article approved, please read the guidelines carefully and make sure to follow them. We are still experiencing problems with our reviewers as, unfortunately, many of them have no time to review our submissions. I would like to appeal to you to please help us out. As a specialized journal, we have access to only a limited number of researchers. Let's all make an effort to be a part of the prominent scientific community on the Web of Science and SCOPUS!

This issue covers a diverse range of content, the authors are coming from Slovakia, Spain, Turkiye, Slovenia, Japan, Greece, Iran, Singapure, Brazil, USA and Finland. For 10 articles are included researchers from 11 countries.

Anton Gajdoš prepared his 28th short historical note introducing the first World Championship in 1903 in Antwerpen.

At the end of the issue are three letters to editor. The first one from Hardy Fink who writes about new rules on World Championship participations and their impact on future attendances. The second one is a report from Freiburg Congress from Flavio Bessi and the last one is invitation to participate in research from Johanna Weber.

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

XVII Freiburg International Gymnastics Congress, expert part in gymhall (photo Jonas Rohleder)

THE HISTORY OF GYMNASTICS IN THE TERRITORY OF SLOVAKIA FROM 1918 TO 1980

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Original article *DOI: 10.52165/sgj.15.3.299-321*

Abstract
Gymnastics has been practised in the territory of Slovakia for over a century. During this period, Slovak gymnasts have achieved significant sports successes. This manuscript focuses on the emergence and development of gymnastics in the territory of Slovakia from the beginning of the 20th century to the early 1980s, looking at the main reasons and factors that influenced the emergence, development and direction of gymnastics in the territory of Slovakia during this period. The article also features the most successful gymnasts born on the territory of Slovakia who achieved significant sports success at the international level between 1918 and 1980. The basic criterion for including Slovak gymnasts among successful athletes was their representative participation in top international gymnastics competitions, with final placements in all-around and individual gymnastics events, up to a maximum of 10th place. Information detailing the significant achievements of Slovak gymnasts can be found in the attached tables, which list the greatest sports accomplishments of Slovak gymnasts at the Olympic Games, World Championships, and European Championships.
Regarding the methodology employed in this manuscript, we adhered to standard historical research methods. Our primary focus was on collecting materials related to the subject matter. We diligently searched for primary sources, including diaries, newspapers, books, speeches, historical records, and electronic data. We then categorized these facts and examined their relationships using the comparative method as our foundation. Based on our analysis of this information, we prepared the manuscript.

Keywords: *history, Slovakia, apparatus gymnastics, artistic gymnastics, sports results.*

BEGINNINGS OF GYMNASTICS IN THE TERRITORY OF SLOVAKIA

Gymnastics, known as the "Mother of Sports", started in Slovakia based on the principles of the Sokol movement (Gajdoš, Novák & Račko, 2003). The Sokol movement, known as the Sokol, was founded by Dr. Miroslav Tyrš and Dr. Jindřich Fügner in Bohemia (today Czech Republic) in Prague on February 16, 1862 (Sak, 2012). The first Sokol Slovak branch was founded on November 14, 1918, in Uhorská Skalica (today Skalica, western Slovakia). This can be considered the very first organizational structure of gymnastics in the territory of Slovakia (Gajdoš, Novák & Račko, 2003).

In the early days, apparatus gymnastics held a prominent position within the Sokol movement. Apparatus gymnastics made its way into Slovak schools, particularly in the first Slovak grammar schools. The Revúca grammar school (1862-1874) distinguished itself by maintaining an excellent standard of physical education and gymnastics, with the notable presence of Dr. Ivan Branislav Zoch, a prominent Slovak educator. In 1873, Dr. I. B. Zoch authored a work titled "Krátky návod k vyučovaniu telocviku hlavne pre národnie školy" ("A Short Guide to Teaching Physical Education, Primarily for National Schools"), wherein he meticulously described and provided graphical illustrations of 140 fundamental physical exercises, including basic gymnastic routines. Dr. Zoch also introduced his own terminology for gymnastic exercises, employing words such as "prieč" for the horizontal bar and "máre" for parallel bars. Furthermore, he innovatively designed various gymnastic apparatuses, which he comprehensively documented and illustrated in the aforementioned work. In addition to apparatus gymnastics, the publication incorporated progressive exercises in running, jumping, and folk dances, marking a significant contribution to physical education (Semáková et al., 2019).

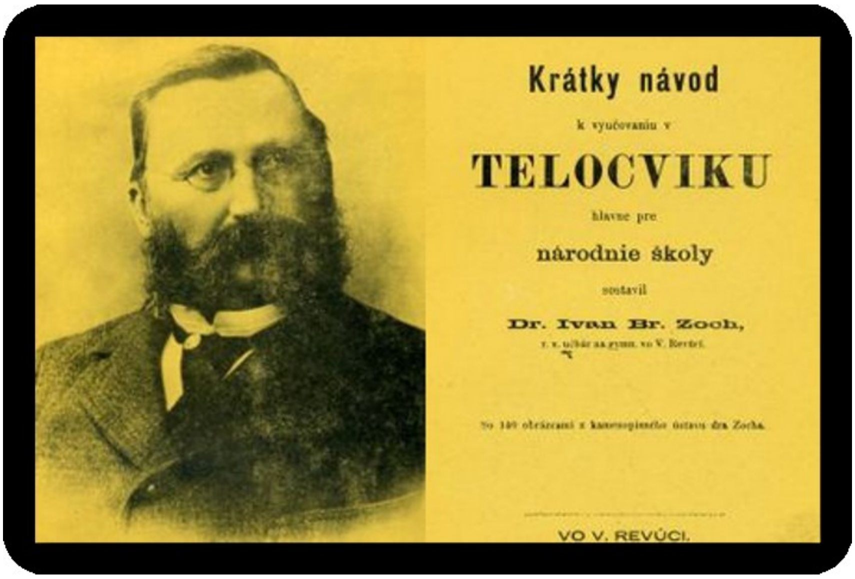

Figure 1. Ivan Branislav Zoch and his work *"Short Guide to Teaching Physical Education, Primarily for National Schools"* (Internet: www.sportency.sk).

Gymnastics gained widespread popularity in Slovakia during the latter half of the 20th century, particularly within the school environment. However, before 1914, Slovak gymnasts only sporadically participated in top-level competitions. A notable exception occurred at the the 5th Olympic Games held in Stockholm in 1912 when the sole athlete from Slovakia, Ľudovít Kmeťko (March 22, 1884 – †1952), hailing from Košice in eastern Slovakia, competed as part of the 16-member gymnastics team representing Hungary. In the team all-around exercises, he secured a silver medal, emerging as the most valuable gymnast within the Hungarian gymnastics delegation (Souček, 2010). The Hungarian team amassed a total score of 227.25 points at these Olympic Games. In addition to Kmeťko, the Hungarian silver-winning team comprised non-Slovak gymnasts such as Berkes-Bittenbinder, Erdődy, Fóti, Gellért, Halmos-Haberfeld, Helmich, Herczeg, Keresztessy, Karponai-Krizmanich, Pászty, Pétery, Réti-Rittich, Szűcs, Téry, and Tuli (Gajdoš, Novák & Račko, 2003). Ľ. Kmeťko was an ardent advocate of the Swedish gymnastics school and the author of the work "Boj telovýchovných systémov" ("The Battle of Physical Education Systems") (Souček, 2010).

The significant development of apparatus gymnastics as the first form of gymnastics in Slovakia occurred after the end of World War I, i.e., after 1918, mainly due to the merit and support of the Sokol movement. Among the important personalities who contributed to the development of the Sokol movement and thus also the development of gymnastics in the territory of Slovakia were Vavro Šrobár[1], Pavel Blaho[2], Samuel Zoch[3], and Kornel Stodola[4] (Sportency.sk, 2010). With their significant support, Sokol units began to emerge gradually in other Slovak cities, such as Holíč, Predmier, Stupava, Trenčianske Teplice, Ružomberok, Nitra, Nové Mesto nad Váhom, Liptovský Svätý Mikuláš, Žilina, and Turčiansky Svätý Martin. On February 16, 1919, the first independent Sokol organization, Sokolská župa Masarykova (The Sokol District of Masaryk), was established, with headquarters in Bratislava and managed by Vavro Šrobár (Perútka, 1980).

From the perspective of gymnastics, apparatus gymnastics was predominantly favored within these Sokol units. Moreover, apparatus gymnastics found its place in various other organizations across Slovakia, including Orol[5], Robotnícka telocvičná jednota (The Workers' Gymnastics Union)[6], Federácia robotníckych telocvičných jednôt (The Federation of Workers' Gymnastics Unions)[7], Deutscher Turnverband (The German Physical Education Association) in Czechoslovakia, the Hungarian Physical Education Association in Czechoslovakia, and Maccabi (the Jewish Physical Education Association) in Czechoslovakia (Gajdoš & Jašek, 1980).

The first official men's gymnastics competition took place in 1921 in Levice in western Slovakia. Female gymnasts entered the competitive scene a bit later, in 1923 (Sportency.sk, 2010). Initially, women's gymnastics encompassed a range of disciplines, including rings, parallel bars, horse vaulting with pommel handles, and long horse jumping.

[1] Vavro Šrobár (1867 - 1950) was a Slovak physician, politician, educator, and editor. He played a prominent role in interwar Slovak politics in Czechoslovakia, first as the Minister Plenipotentiary for the Administration of Slovakia, and later as a professor at Comenius University in Bratislava, from 1935 onward. He advocated for the national unity of Czechs and Slovaks (Maťovčík et al., 1999).

[2] Pavel Blaho (1867 - 1927) was a Slovak physician, journalist, builder, politician, and national activist (Maťovčík et al., 1999).

[3] Samuel Zoch (1882 - 1928) was a Slovak Lutheran pastor, public figure, politician, church dignitary, and writer (Maťovčík et al., 1999).

[4] Kornel Stodola was a Slovak politician, secretary of a hospital in Vienna, and a prominent figure in Slovak economy (Maťovčík et al., 1999).

[5] Orol was a Catholic sports club founded in 1909. The first Orol unit was established in 1919 in Malacky. This sports club favoured the practice of compulsory floor exercises, apparatus gymnastics and physical games (Vejvar, 2014).

[6] Robotnícka telocvičná jednota (T*he Workers' Gymnastics Union*) was founded on August 22, 1897, in Prague (territory of Bohemia). The first *Workers' Gymnastics Union* in Slovakia was established on February 22 in Ružomberok. In 1903, the organization merged and transformed into the Zväz robotníckej telocvičnej jednoty (Association of *Workers' Gymnastics Union*). From a sports perspective, the philosophy of this organization was based on the Sokol movement and the Tyrš' system of gymnastics was prefered (Perútka et al., 1980).

[7] Federácia robotníckych telocvičných jednôt *(The Federation of Workers' Gymnastics Unions* J) was founded on 8 May, 1921. In Slovakia, this organization had the most significant activity in Vrútky, Trnava, Banská Bystrica, and Košice. In 1926, the FRTJ merged with revolutionary workers' sports and tourist organizations to form the Federation of Proletarian Physical Education. This organization focused on public performances (Worker's Spartakiads) combined with gymnastics, sports games, athletics and scouting (Perútka et al., 1980).

Between 1928 and 1948, women's gymnastics competitions were characterized by compulsory routines that constituted the core of the program. These routines were kept secret, meaning that gymnasts were provided with a list of assigned routines before the competition, and each female gymnast had the opportunity to practice her designated routine twice. The program for female gymnasts also featured floor exercises and apparatus gymnastics, with restrictions on acrobatic elements. These competitions primarily revolved around assessing general physical fitness, with the inclusion of free gymnastics routines only emerging toward the end of the 1930s (Gajdoš & Jašek, 1988).

Figure 2. Example of an exercise from I.B. Zoch's work *"The Short Guide to Teaching Physical Education, Primarily for National Schools"* (Internet: www.podvihorlatskenoviny.sk).

Figure 3. 7th All-Sokol Slet in 1920 in Prague (Bohemia, today Czech Republic). Mass gymnastics exercise of men (Internet: http://www.smirice.eu/spolky/sokol1/sokol.htm).

In the 1920s, the Sokol movement was relatively less widespread in Slovakia. In 1920, the number of members in Slovak Sokol units was 18 494, while in Czech Sokol units, there were 562 651 members. (Perútka et al., 1980). The level of training in Slovak Sokol units was generally lower than in the Sokol movement in Bohemia, which is why Czech athletes achieved better results in competitions. (Sportency.sk, 2010). Slovak gymnasts from the Sokol movement participated for the first time in the *VII. All-Sokol Slet in 1920*[8]. In the competition, the most successful performances were achieved by Sokol members from Liptovský Mikuláš (northern Slovakia). Among the female gymnasts, the most successful were *Grubová*, who took 3rd place and *Cimráková*, who took 14th place. In the following decade, Slovak athletes did not achieve significant success in gymnastics events due to the smaller representation of Slovaks in the Sokol movement. Overall, in 1929, only 0.6 percent of the Slovak population was organized in the Sokol movement, and its influence was minimal (Gajdoš & Jašek, 1988).

Slovak gymnasts achieved more notable success in gymnastics at the 9th All-Sokol Slet in 1932. In the team competition of the middle division, the squad representing Zvolen, situated in central Slovakia, secured a commendable 7th place. This accomplished team consisted of gymnasts Vychodil, Štancel, Pížl, Muránsky, Devečka, Trnka, and Laska. Alongside these male gymnasts, the 1930s also witnessed the emergence of other outstanding gymnasts in Slovakia, including Chovan, Výboch, Severíny, Šotkovský, Gonda, Štedrucker, Jurek, and Urban, who contributed significantly to the gymnastics scene in Slovakia (Gajdoš & Jašek, 1988).

The most accomplished female gymnast from Slovakia prior to World War II was Matilda Pálfyová, born on March 3, 1912, in Kostoľany nad Hornádom in eastern Slovakia. She was a member of Sokol Košice and had risen to become one of the world's top athletes by 1935. At the Olympic Games held in Berlin in 1936, representing Czechoslovakia, she achieved an impressive 2nd place in the combined team exercises (team all-around). The Czechoslovak female gymnastics team, which included Pálfyová, secured a total score of 503.60 points. This silver medal-winning Olympic team also featured Foltová, Děkanová, Veřmiřovská, Hřebřinová, Dobešová, Větrovská, and Bajerová. The German athletes claimed the Olympic championship, which was significantly influenced by the atmosphere of Nazi Germany.

Matilda Pálfyová continued to shine at the World Championships in Prague (Czech Republic) in 1938, where she achieved 1st place in the team all-around and earned the title of World Champion alongside her fellow gymnasts. The Czechoslovak female gymnastics team garnered a total score of 552.76 points, with Pálfyová's contributions being pivotal. Her teammates in this victorious effort included Nežerková, Děkanová, Dobešová, Foltová,

[8] The Sokol Slets were public events including gymnastics, competitions of males and females, parades, and the arts, that lasted several days (Sokolomuseum.org). Over 100 000 gymnasts participated at VII. All-Sokol Slet (slet.sokol.eu, n.d.). The program of the VII. All-Sokol Slet also included rhythmic gymnastics, performances by teenage girls, and competitions for women and teenage girls (Strachová, 2020). The Sokol Slet – this technical name of the mass gymnastics exercise literally means in the Czech language "The falcons have flown to a certain place", therefore "Sokol Slet" ("Falcon Flight"). This metaphor is difficult to translate into any language (own note).

Hendrychová, Skálová, and Veřmiřovská (Gajdoš, Novák & Račko, 2003).

During this period, female gymnasts did not compete in individual apparatus disciplines officially. However, Matilda Pálfyová unofficially achieved the highest scores on the rings and the vault. In the individual all-around competition, she secured the 3rd place with a total score of 81.98 points. Pálfyová is historically the first woman from Slovakia to have participated in the Olympic Games and, at the same time, she is the very first Slovak Olympic medalist.In her honor, the Slovak Olympic and Sports Committee annually presents the Matilda Pálfyová Award, recognizing women for their outstanding sports achievements, contributions to sports, and dedication to the Olympic movement (Souček, 2010).

Figure 4. Matilda Pálfyová, the first Slovak Olympic medallist from the Summer Olympics in Berlin in 1936 (Slovak Gymnastics Federation).

SLOVAK GYMNASTICS IN THE YEARS 1939-1945

The World War II period (1939-1945) significantly influenced further development of gymnastics in Slovakia. While Slovakia gained independence as an autonomous state, it fell under the influence of a totalitarian regime that had a detrimental impact on physical education in the country. All physical education associations and organizations, including Sokol, were disbanded in Slovakia and integrated into the Hlinkova garda. (Hlinka's Guard)[9] (Bučka, 2007). As for gymnastics, during the years of the wartime Slovak State (1939-1945), gymnastics was a part of physical education organizations, especially the Hlinka's Guard Physical Education Organization. Seman does not mention any national sports association related to gymnastics within the governing body of sports (Slovak Central Sports Council) (Seman, 2018).

Apart from Matilda Pálfyová (see the previous page for her detailed sports results), Gejza Romančík from Žilina (northwest Slovakia) achieved significant gymnastics success during these years. He

[9] The Hlinka's Guard (HG) operated as a semi-military organization of the Hlinka Slovak People's Party (HSĽS) from 1938 to 1945. The Emergency Units of the Hlinka Guard (POHG) played a special role within its framework and were deployed at the end of World War II in police and military operations alongside the German armed forces against military and civilian targets in the territory of the Slovak Republic (Ústav pamäti národa, 2017).

was included in the training team for the 12th Olympic Games in Tokyo in 1940, which did not take place due to the ongoing World War II. However, Romančík continued to train and became the Slovak gymnastics champion in 1941. It was an elimination competition where competitors competed in free routines on parallel bars, horizontal bar, rings, vault, and pommel horse jumping (Perútka et al., 1980). In 1942, he became the leader of the Slovak gymnastics team, which participated in inter-state gymnastics competition with Germany. The Slovak national team was represented by Faga, Severíny, Búrka, Štoder, Janečka, Muránsky, Murček, Romančík, Gonda. The Slovak gymnastics team lost to Germany gaining 489 points vs. 550.5 points won by Germany, i.e., by a difference of 61.5 points. The best Slovak gymnast was Romančík, who scored 73.8 points out of possible 80. (Maar, 1942).

During World War II, Pavel Mudroch (August 31, 1910 – †1944) from Sotina (today Senica, western Slovakia) was also one of the pioneers of Slovak male gymnastics (Senica.sk, 2017). He was the deputy commander of the Oddiel armádnych pretekárov (the Army Athletes Unit)[10], where he trained several gymnasts. His coaching ambitions were interrupted by his joining the Slovak National Uprising in 1944, where he perished (Gajdoš & Jašek, 1988).

From the conclusion of World War II in 1945 until February 1948, sports gymnastics in Slovakia did not exist as an independent sport. Instead, it functioned as an extension of apparatus gymnastics, primarily practiced within Sokol, RTJ, and Orel. Numerous sports officials and coaches either relocated to the Czech Republic or ceased their active involvement in the field. Some sports clubs even contended that apparatus gymnastics had detrimental effects on health and advocated for its exclusion from physical education. (Gajdoš & Jašek, 1988).

Figure 5. Official poster of an international gymnastics competition including Slovak State and Germany, in Žilina in 1942 (Slovak Gymnastics Federation).

[10] Oddiel armádnych pretekárov (OAP) was established in 1941. This military-sports organization during the time of the Slovak State (1939 -1945) gathered skilled soldiers, athletes (Perútka, 1967).

SLOVAK GYMNASTICS IN THE 1950s, 1960s AND 1970s

In 1951, a shift in terminology occurred, replacing the conventional term "apparatus gymnastics" with the designation "sports gymnastics." Gymnastics classes were introduced in accordance with a unified sports classification system (Krejčoves, 2006). Up until 1951, Slovakia had only one division dedicated to sports gymnastics, situated in Kremnica, which is located in central Slovakia (Gajdoš, Novák & Račko, 2003).

The resurgence of sports gymnastics development took place subsequent to the consolidation of physical education. From 1951 onward, Slovak gymnasts actively participated in national competitions. During the 1950s, several coaches and officials played pivotal roles in advancing gymnastics in Slovakia. Noteworthy contributions came from Štancel and Pížl in Bratislava, Buksan in Košice, the Dajč brothers, Zavadin in Prešov, Burko and Severíny in Zvolen, and the elder Novák in Trnava (Gajdoš & Jašek, 1988).

The enactment of the law governing the organization of physical education and sports in 1952 had a profound impact on the development of physical education and sports, including sport gymnastics, in Slovakia. This legislation elevated sport gymnastics to one of the eight primary sports, garnering increased attention and fostering a high-quality sports training environment for athletes (Gajdoš, Novák & Račko, 2003).

Another pivotal moment for sport gymnastics in Slovakia occurred with the establishment of the Sports Youth Games (SYG), the Sports Youth Schools (SYS), and the Sports Juveniles Schools (SJS) in 1952 (Gajdoš & Jašek, 1988). The Sports Youth Schools system comprised five sports gymnastics divisions in Bratislava, Košice, Žilina, Prešov, and Banská Bystrica. Additionally, the system recorded 23 club sections in the Sports Juveniles Schools, with the most prominent clubs located in Bratislava, Žilina, Prešov, Trnava, Michalovce, Topoľčany, Komárno, and Zvolen. The cumulative membership of gymnasts in these units (SYS, SJS) in 1952 reached a total of 847 individuals (Gajdoš, Novák & Račko, 2003). Consequently, it is evident that the establishment of the Sports Youth Schools and Sports Juveniles Schools made a substantial contribution to the promotion of sports gymnastics in Slovakia and played a pivotal role in expanding the pool of young athletes for the gymnastics program in Slovakia.

The catalyst for the development of gymnastics in Slovakia was the establishment of the Gymnastics Sports Section within the Slovak Committee for Physical Education and Sport in 1953. The first chairman was an enthusiastic promoter of gymnastics, a distinguished coach, a gymnastics judge, and an associate professor, Július Štancel (Gajdoš & Jašek, 1988). In 1953, the sports gymnastics section of the Slovak Committee of Physical Education and Sports organized the first Slovak championships in the city of Svit, which took place from December 19 to 20. There were over 140 athletes from almost all Slovak regions, including men, women, and youth gymnastics competitions. The best gymnasts in the women's competition were Černohlávková-Čížiková (1st place) from Bratislava, Xénia Rovná (2nd place), Škrabáková (3rd place), while in men's gymnastics the best gymnasts were Kolár (1st place), Kaštánek (2nd place) and David (3rd place). Among the best youth competitors were Pavel

Gajdoš from Michalovce (1st place), J. Juras (2nd place) from Bratislava and T. Svitok (3rd place) from Nitra. The best young female gymnasts were Ružicková (1st place), Odstrčilová (2nd place) and Schmidtová (3rd place) (Sportency.sk, 2010)

Pavel Gajdoš (1.8.1936 - †2022), hailing from Veľké Berezné, which was then part of Czechoslovakia (now within the territory of Ukraine), stood out as one of the most accomplished gymnasts during the 1950s and 1960s. His notable achievements at the World Championships and the Olympic Games are as follows:

During the World Championships in Moscow in 1958 (Union of Soviet Socialist Republics), he secured the 3rd position in the team all-around and ranked 28th in the individual all-around.

At the Olympic Games in Rome in 1960 (Italy), his national team achieved a commendable 4th place in the all-around team competition, amassing a score of 557.15 points. In the individual all-around, he secured the 28th position (Ondík & Dobrovodský, 1961).

In the European Championship held in Luxembourg in 1961 (Luxembourg), he secured the 15th position in the individual all-around.

His most outstanding sports performance came at the World Championships in Prague in 1962 (Czechoslovakia), where his national team clinched the 3rd place in the team all-around, and he reached the 25th position in the individual all-around (Gajdoš, Novák & Račko, 2003).

At the Games of the Olympic Games in Tokyo in 1964 (Japan), his team achieved the 6th position in the team all-around, earning a total score of 558.15 points, while he secured the 106th position in the individual all-around (Bureš & Žurman, 1965).

Subsequent to his retirement from competitive gymnastics, P. Gajdoš, a two-time Olympian, embarked on a career as a professional gymnastics coach and an international gymnastics judge (Gajdoš & Jašek, 1988). In recognition of his remarkable sporting accomplishments, he was honored with the Bronze Rings Award by the Slovak Olympic Committee in 2007 (Gajdoš, A., 2010).

Figure 6. Pavel Gajdoš on the parallel bars (Internet: www.sportency.sk).

Among the successful gymnasts was also Ferdinand Daniš (January 1, 1929) from Opatová I in western Slovakia (Gajdoš, A., 2010). At the Olympic Games in Helsinki in 1952 (Finland), he attained 7th place in the team all-around. The Czechoslovak team scored a total of 555.55 points. In the individual all-around, Daniš placed 13th, and in the final on the pommel horse he placed 6th with a score of 19.30 points. He achieved another sports success at the Olympic Games in Melbourne in 1956 (Australia), where he placed fourth in the team all-around. The Czechoslovak team scored 554.10 points. In the individual all-around, Daniš placed 13th, and in the floor exercise, he placed 6th with a final score of 18.80 points (Novotný & Žurman, 1957). At the Olympic Games in Rome in 1960 (Italy), he achieved the 6th position in the team all-around. The Czechoslovak team, which included another Slovak, Pavel Gajdoš, achieved a final score of 557.15 points. In the individual all-around, Daniš achieved the 15th position (Ondík & Dobrovodský, 1961).

During the World Championships in Rome in 1954 (Italy), he secured the 5th position in the team all-around, with the Czechoslovak team accumulating a total score of 661.40 points. In the individual all-around, he attained the 29th position.

However, Daniš's most remarkable success materialized at the World Championships in Moscow in 1958 (Union of Soviet Socialist Republics), where he claimed the 3rd place in the team all-around, with the Czechoslovak team garnering a score of 549.30 points. In the individual all-around, he secured the 12th position.

Furthermore, he was successful at the European Championships in Copenhagen in 1959 (Denmark), where he achieved the 4th place in the individual all-around. On the pommel horse, he delivered an impressive performance, clinching the 2nd place with a score of 18.95 points. Additionally, he secured the 5th position on the rings and the 5th position on the horizontal bar (Gajdoš, Novák & Račko, 2003).

Based on his remarkable sports achievements, it is evident that Ferdinand Daniš was the most distinguished Slovak and Czechoslovak gymnast of the 1950s.

Figure 7. Ferdinand Daniš on the rings (Internet: www.sportency.sk).

Anna Marejková, born on October 24, 1933, in Turzovka, northern Slovakia, stood as a prominent figure in Czechoslovak gymnastics during the 1950s. Her notable achievements are as follows:

At the Games of the XVI. Olympiad in Melbourne in 1956 (Australia), she secured the 5th position in the team all-around, with the Czechoslovak team accumulating a total score of 435.36 points. In the individual all-around, she attained the 11th position. On the balance beam, she delivered an impressive performance, clinching the 4th place with a score of 18.55 points (Novotný, Brdíčková & Matlochová, 1959).

During the World Championships in Rome in 1954 (Italy), she achieved the 3rd place in the team all-around, with the Czechoslovak team scoring 211.75 points. In the individual all-around, she secured the 22nd position.

However, her most outstanding sporting achievement materialized at the World Championships in Moscow in 1958 (Union of Soviet Socialist Republics), where she claimed the 2nd place in the team all-around, with the Czechoslovak team amassing a total score of 371.855 points. In the individual all-around, she secured the 14th position (Gajdoš, Novák & Račko, 2003).

The concept of sports in Slovakia, including gymnastics, changed in 1957 with the establishment of the Czechoslovakian Union of Physical Education (ČSZTV)[11]. This resulted in the dissolution of Sports Juveniles Schools (SJS). However, in 1961, five gymnastics sports schools were established in Bratislava, Martin, Žilina, Košice and Prešov. Here, gymnastics experts nurtured Slovakian gymnastic talents, and nearly 300 gymnasts attended these schools (Gajdoš, Novák & Račko, 2003). The quality of sports gymnastics was further improved by the creation of jobs for the first professional gymnastics coaches in 1957, with Ladislav Kornoš becoming the professional coach for male gymnasts and Ján Čížik for female gymnasts (Sportency.sk, 2010).

As a part of college sports, the Independent Section of Sport Gymnastics was established in 1962. This development occurred following the establishment of the Physical Education Unity Slávia at Comenius University in Bratislava, and the aforementioned section dedicated to sports gymnastics was also founded as a part of this organization (Section of Sport and Artistic Gymnastics TJ Slavia UK). In 1967, two separate divisions were formed from this section, one for sports gymnastics and one for artistic gymnastics (later modern gymnastics) (Bobrík & Seman, 2012). In the mid-1960s, there were 133 clubs of sports gymnastics in Slovakia with a base of 6,179 members, including 135 professional trainers and 135 qualified judges (Gajdoš, Novák & Račko, 2003).

In the early 1970s, the development of sports gymnastics was significantly influenced by the new structure of the sports system. Centers of elite sports for adults and youth, training centers for youth, and residential sports schools were established. The federal state arrangement enabled the formation of Slovak representative teams in gymnastics. *Anton Gajdoš* led the men's national gymnastics team, and Já*n Čižík* led the women's national gymnastics team. The

[11] The Czechoslovak Association of Physical Education (ČSZTV) was founded on March 4, 1957. On April 2 and 3, 1957, the Slovak founding convention of ČSZTV was held in Bratislava, which became the highest authority responsible for the development of basic physical education, sports and tourism in Slovakia (Perútka, 1980, p. 176).

most significant gymnastics centres were situated in Bratislava, Prievidza, Detva, Trnava, Banská Bystrica, and Košice (Gajdoš, Novák & Račko, 2003). These favourable conditions in the organization and structure of gymnastics naturally led to sporting success for Slovak gymnasts at major gymnastics events.

The best results in women's gymnastics during the 1960s were achieved by Mariana Krajčírová (June 1, 1948) from Košice (Eastern Slovakia). At the Olympic Games in Tokyo in 1964 (Japan), she placed 2nd in the team all-around. The Czechoslovak team attained a total score of 379.989 points. She finished 22nd in the individual all-around (Bureš & Žurman, 1965). Krajčírová won her second silver Olympic medal at the Olympic Games in Mexico City in 1968, where the Czechoslovak female gymnasts placed 2nd in the team all-around with a score of 382.20 points. She finished 9th in the individual all-around and 4th on the vault (Červinka & Pacina, 1968). Together with M. Krajčírová, the phenomenal Czech gymnast Věra Čáslavská represented Czechoslovakia team at the Olympic Games in Mexico, where she won silver medal in the team all-around, silver medal on the balance beam and four gold medals in the individual all-around, in the floor exercise, vault, and on uneven bars. With four Olympic gold medals and two silver Olympic medals, she became the best female athlete at the Olympic Games in Mexico in 1968 (Reinhardt, 2008). At the Olympic Games in Munich in 1972, Krajčírová secured the 5th position in the team all-around. The Czechoslovak team achieved a score of 365.00 points. In the individual all-around, she finished 11th (Hornáček, 1973).

Krajčírová achieved significant success at the World Championships in Dortmund, Germany, in 1966, where she clinched the first place in the team all-around. The Czechoslovak female gymnasts garnered an overall score of 383.625 points. In the individual all-around, she attained the seventh position and also placed seventh in the vault final.

At the World Championships in Ljubljana, Slovenia, in 1970, she secured the third position in the team all-around. The Czechoslovak team achieved an overall score of 371.900 points. She finished 4th in the uneven bars final.

Krajčírová achieved her sports success at the European Championships in Amsterdam in 1967 (Netherlands), where she earned the 3rd place in the individual all-around with a final score of 38.199 points. She also claimed the 3rd position in the uneven bars final, 4th in the floor exercise final, 4th in the vault final, and 5th in the beam final (Gajdoš, Novák & Račko, 2003).

In the poll for the Slovak Gymnast of the 20th Century, M. Krajčírová took the first place (Gajdoš, 2010). By securing two silver Olympic medals in 1964 and 1968, a gold medal in 1966 from the World Championship, a bronze medal in 1970 from the World Championships, and another bronze medal from the 1967 European Championships, Mariana Krajčírová established herself as the most successful female gymnast in the history of Slovak gymnastics. To this day, no other Slovak female gymnast has achieved such sporting success.

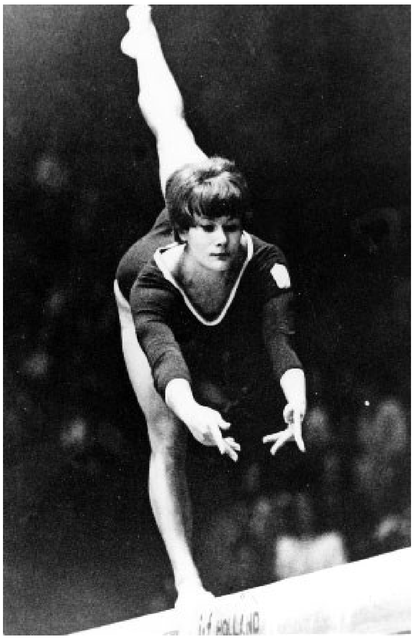

Figure 8. Mariana Krajčírová on the beam. The best Slovak female gymnast is a two-time Olympic silver medallist from the Olympic Games in 1964 and 1968 and she is a gold medallist from the World Championships in 1966 (Internet: www.sportency.sk).

Among the best Slovak male gymnasts in the 1960s were Karol Feč, Anton Gajdoš, Stanislav Fiala, Karol Tomaškovič, Milan Barborík, and František Bočko (Sportency.sk, 2010). František Bočko (born on July 7, 1941) from Šenkvice in western Slovakia achieved the most significant sports accomplishments among these male gymnasts. Bočko participated in the Olympic Games in Tokyo in 1964 as a substitute in the Czechoslovak team (Gajdoš, Novák & Račko, 2003). He achieved a notable success at the Olympic Games in Mexico City in 1968, finishing in 4th place in the team all-around with a score of 557.10 points. In the individual all-around, he secured the 22nd place (Červinka & Pacina, 1968). At the World Championships in Dortmund in 1966, he achieved the 4th place in the team all-around with a score of 551.20 points. In the individual all-around, he finished in the 50th place (Gajdoš, Novák & Račko, 2003).

In the 1970s, outstanding achievements were recorded by Slovak female gymnast Ľubica Krásna (born on March 21, 1953) from Bratislava. She secured the 3rd place in the team all-around at the World Championships in Ljubljana in 1970 (Olympic.sk, 2017).

Another accomplished Slovak gymnast, Zdenka Bujnáčková (born on April 25, 1955, in Bratislava), played a pivotal role in helping the Czechoslovak team achieve the 5th position in the team all-around at the Games of the XX. Olympiad in Munich in 1972. At the World Championships in Varna, Bulgaria, in 1974, she secured the 5th place in the team all-around. In the individual all-around, she finished in the 33rd position.

Bujnáčková etched her name in the annals of world gymnastics through her originality in the floor exercise, as she became the first gymnast in the world to incorporate a back handspring with a 720-degree turn and two sideways somersaults on the balance beam into her routines (Gajdoš, Novák & Račko, 2003).

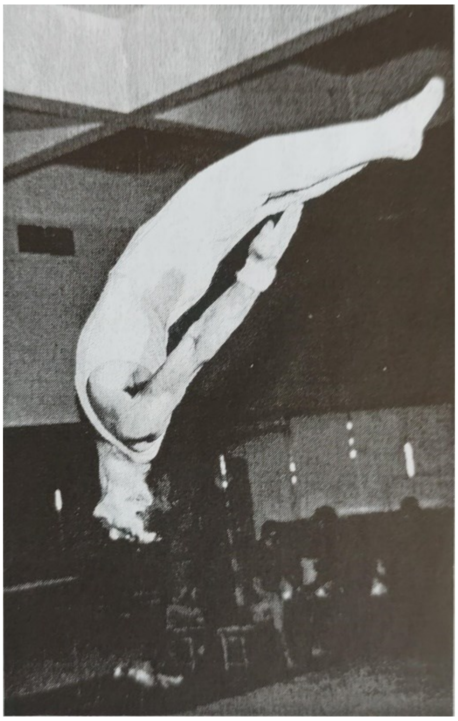

Figure 9. František Bočko during gymnastics exercise (Internet: www.sportency.sk).

Figure 10. Zdenka Bujnáčková during gymnastics exercise. She was the first gymnast in the world to incorporate a back handspring with a 720-degree turn and two sideways somersaults on the balance beam into her routines (Internet: www.sportency.sk).

Slovak female gymnast *Ingrid Holkovičová (December 12, 1959) from Bratislava* successfully represented Czechoslovakia at the *Olympic Games in Montreal, Canada, in 1976* (Olympic.sk, n.d.). She contributed to the Czechoslovak team's 5th-place finish in the team all-around and achieved the 16th position in the individual all-around (Dobrovodský, 1977).

In addition to her Olympic achievements, she also garnered remarkable success at the European Championships in Prague in 1977. In the individual all-around, she secured the 8th place and earned a position in the finals on three gymnastics apparatuses. She finished 5th in both the uneven bars and balance beam events, and she clinched the 4th position in the floor exercise (Gajdoš, Novák & Račko, 2003).

The most remarkable sports achievements in Slovak men's gymnastics during the 1970s were reached by Jozef Konečný, born on December 2, 1953, from Bratislava (Gajdoš, 2010).

At the Olympic Games in Moscow in 1980, he secured the 6th place in the team all-around. The Czechoslovak team garnered a score of 569.80 points. In the individual all-around, he finished in the 43rd position (Dobrovodský, 1981).

During the World Championships in Strasbourg, France, in 1978, he achieved the 9th place in the team all-around and finished 61st in the individual all-around. Similarly, at the World Championships in Fort Worth, USA, in 1979, he secured the 10th place in the team all-around and the 31st position in the individual all-around.

However, his most significant sports success materialized at the European Championships in Essen, Germany, in 1979, where he clinched a silver medal (2nd place) on the vault, earning a score of 19.475 points. In the individual all-around, he finished in the 24th position.

In 1981, he further solidified his standing in gymnastics by becoming the absolute champion of Czechoslovakia in the individual all-around (Gajdoš, Novák & Račko, 2003).

Figure 11. Jozef Konečný on the rings (Internet: www.sportency.sk).

At the Olympic Games in Moscow in 1980, another Slovak male gymnast, Rudolf Babiak, (April 12, 1956, †2020) from Banská Bystrica in central Slovakia, successfully represented the Czechoslovak team. Babiak, along with J. Konečný, finished 6th in the team all-around, 10th on the rings and 21st in the individual all-around (Dobrovodský, 1981).

In women's gymnastics competitions in the 1970s, Czechoslovakia was successfully represented by Eva Marečková

(May 28, 1964) from Detva in Central Slovakia (Gajdoš, Novák & Račko, 2003). She achieved significant success at *the Olympic Games in Moscow in 1980* where she secured the 4th place in the team all-around. The Czechoslovak team achieved a final score of 388.80 points (Schubert et al., 1981). In the individual all-around, she placed 12th. She placed 7th on the uneven bars and 7th on the vault (Olympic.sk, n.d.). At *the World Championships in Strasbourg in 1978*, she finished 6th in the team all-around. The Czechoslovak team scored 388.75 points. In the individual all-around, she placed 16th. At the World Championships in Fort Worth in 1979, she attained the 5th place in the team all-around. The Czechoslovak team achieved a score of 382.300 points. In the individual all-around, she placed 10th, and in the individual apparatus final on the balance beam she came 4th. At the European Championships in Copenhagen, Denmark, in 1979, she secured the 6th place in the individual all-around and attained notable success by advancing to the finals on three gymnastics apparatuses. Specifically, she finished 5th on the uneven bars, 7th on the balance beam, and 6th in the floor exercise.

She also achieved significant successes at the World Cup in Sao Paulo in 1978 (Brazil), where she placed 5th in the individual competition on the balance beam, and at the World Cup in Tokyo in 1979 (Japan), where she secured the 5th position in the individual competition in the floor exercise.

Marečková emerged as the most prominent Slovak female gymnast of the 1970s, as evidenced by her ranking in the "World Gymnastics" poll for the best gymnast globally, where she achieved the 4th position (Gajdoš, Novák & Račko, 2003).

At the Olympic Games in Moscow in 1980, Slovakia was represented in the Czechoslovak team by Jana Labáková (born on January 26, 1966) from Detva. In addition to the 4th place in the team all-around competition, she secured the 11th position in the individual all-around, finished 7th on the vault, and achieved the 6th place in the floor exercise final (Grexa & Souček, 2007).

Labáková achieved significant success at the World Cup in Toronto in 1980, where she earned the 2nd place on the vault and placed 4th in the individual all-around. Another notable accomplishment came at the European Championships in Gothenburg, Sweden, in 1983, where she secured the 8th place in the individual all-around, finished 8th on the balance beam, and claimed the 3rd position on the uneven bars (Gajdoš, Novák & Račko, 2003).

The last successful Slovak female gymnast to reach sporting success in the 1980s was Katarína Šarišská, born on September 28, 1965, from Košice in eastern Slovakia. At the Olympics in Moscow in 1980, she, alongside Marečková and Labáková, secured the 4th place in the team all-around and finished 19th in the individual all-around (Dobrovodský, 1981). At the World Championships in Fort Worth in 1979, she secured the 5th place in the team all-around and the 33rd position in the individual all-around (Gajdoš, Novák & Račko, 2003).

CONCLUSION

Following the establishment of the Czechoslovak Republic in 1918, the development of gymnastics in Slovakia was notably influenced by the Sokol movement, which originated in the Czech Republic (Bohemia). Within the Sokol units established in Slovakia, apparatus gymnastics took precedence. A significant contribution to the development of gymnastics in Slovakia came from the Slovak figure Ivan Branislav Zoch, who summarized and innovated gymnastic exercises in his work titled "The Short Guide to Teaching Gymnastics Mainly for National Schools."

During that era, the first male gymnast from the territory of Slovakia who successfully represented Austria-Hungary was Ľudovít Kmeťko. Kmeťko earned a silver medal at the Games of the V. Olympiad in Stockholm in 1912, marking the first historical medal won by a Slovak athlete at a top-level men's gymnastics competition.

The first successful female gymnast representing independent Slovakia (Slovak State) was Matilda Pálfyová, who won a silver Olympic medal at the Olympic *Games* of the XI. Olympiad in Berlin in 1936 and became the first Slovak Olympic medallist in history.

A pivotal moment in the development of gymnastics in Slovakia occurred with the approval of the Law on the organization of physical education and sports in 1952. This law elevated artistic gymnastics to one of the eight main sports in Slovakia, resulting in increased attention, enhanced athlete support, and high-quality sports training. These changes were clearly reflected in the representation of Slovak male and female gymnasts on the international stage.

In the same year, Slovakia established the Sports Games of Youth and Sports Schools of Youth, further highlighting the growing interest in gymnastics. The system of Sports Schools of Youth included five sections for sports gymnastics (located in Bratislava, Košice, Žilina, Prešov, and Banská Bystrica), with 23 gymnastics sections registered in the Sports Schools of Adolescents, underscoring the sport's rising popularity.

A significant shift in the approach to sports in Slovakia, including gymnastics, occurred in 1957 with the establishment of the Czechoslovak Union of Physical Education (ČSZTV). In 1961, five gymnastic sports camps were established in Bratislava, Martin, Žilina, Košice, and Prešov, where gymnastics experts nurtured the talents of Slovak gymnasts. These camps attracted nearly 300 gymnasts. By 1961, the gymnastics community had expanded to 102 sections with 4,267 members.

The early 1970s witnessed a major influence on the development of gymnastics with the introduction of the so-called socialist system of sports. This led to the creation of centres of excellence for both adult and youth sports, training centres for youth, and residential sports schools. These institutions served as focal points where future successful Slovak gymnastics representatives concentrated under the guidance of professional Slovak coaches.

Despite more complicated socio-political periods such as World War I, World War II, and the totalitarian communist regime, Slovak gymnasts were able to deliver excellent sports results at the top international gymnastic competitions even during these challenging times. The most successful Slovak gymnasts include Matilda Pálfyová, Anna Marejková, Mariana Krajčírová, Ľubica Krásna, Zdena Bujnáčková, Jana Gajdošová, Eva Marečková, Ingrid Holkovičová, Jana Labáková and Katarína Šarišská. Successful Slovak male gymnasts include Ľudovít Kmeťko Ferdinand Daniš, Pavel Gajdoš, František Bočko, Jozef Konečný and Rudolf Babiak.

Table 1
Successful Slovak sportsmen in the years 1912-1980 – Artistic Gymnastics – Male – Olympic Games.

Name and surname	Olympic Games	Category/Discipline	Final result
Ľudovít Kmeťko	Olympic Games in Stockholm (Sweden) in 1912	Combined Team exercises (Team All-Around)	2nd
Ferdinand Daniš	Olympic Games in Helsinki (Finland) in 1952	Team All-Around Individual All-Around/ Pommel horse	7th 6th
Ferdinand Daniš	Olympic Games in Melbourne (Australia) in 1956	Team All-Around Individual All-Around/ Pommel horse	4th 6th
Ferdinand Daniš	Olympic Games in Rome (Italy)in 1960	Team All-Around	4th
Pavel Gajdoš	Olympic Games in Rome (Italy) in 1960	Team All-Around	4th
Pavel Gajdoš	Olympic Games in Tokyo (Japan) in 1964	Team All-Around	6th
František Bočko	Olympic Games in Mexico City (Mexico) in 1968	Team All-Around	4th
Jozef Konečný	Olympic Games in Moscow (Union of Soviet Socialist Republics) in 1980	Team All-Around	6th
Rudolf Babiak	Olympic Games in Moscow (Union of Soviet Socialist Republics) in 1980	Team All-Around Individual All-Around Individual/Rings	6th 21st 10th

Table 2
Successful Slovak sportsmen in the years 1912-1980 – Artistic Gymnastics – Female – Olympic Games.

Name and surname	Olympic Games	Category/Discipline	Final result
Matilda Pálfyová	Olympic Games in Berlin (Germany) in 1936	Combined Team exercises (Team All-Around)	2nd
Anna Marejková	Olympic Games Olympiad in Melbourne (Australia) in 1956	Team All-Around Individual All-Around Individual/Balance beam	5th 11th 4th
Mariana Krajčírová	Olympic Games in Tokyo (Japan) in 1964	Team All-Around Individual All-Around	2nd 22nd
Mariana Krajčírová	Olympic Games in Mexico City (Mexico) in 1968	Team All-Around Individual All-Around Individual/Vault	2nd 9th 4th
Mariana Krajčírová	Olympic Games in Munich (Germany) in 1972	Team All-Around Individual All-Around	5th 11th
Eva Marečková	Olympic Games in Moscow (Union of Soviet Socialist Republics) in 1980	Team All-Around Individual All-Around	4th 14th
Jana Labáková	Olympic Games in Moscow (Union of Soviet Socialist Republics) in 1980	Team All-Around Individual All-Around Individual/Floor exercise Individual/Vault	4th 11th 6th 7th
Katarína Šarišská	Olympic Games in Moscow (Union of Soviet Socialist Republics) in 1980	Team All-Around Individual All-Around	4th 19th

Table 3
Successful Slovak sportsmen in the years 1912-1980 – Artistic Gymnastics – Male – World Championships.

Name and surname	World Championship	Category/Discipline	Final result
Ferdinand Daniš	Rome 1954 (Italy)	Team All-Around	5th
		Individual All-Around	29th
Ferdinand Daniš	Moscow 1958 (Union of Soviet Socialist Republics)	Team All-Around	3rd
		Individual All-Around	12th
Pavel Gajdoš	Moscow 1958 (Union of Soviet Socialist Republics)	Team All-Around	3rd
		Individual All-Around	28th
Pavel Gajdoš	Prague 1962 (Czechoslovak Republic)	Team All-Around	3rd
		Individual All-Around	25th
František Bočko	Dortmund 1966 (Germany)	Team All-Around	4th
Jozef Konečný	Strasbourg 1978 (France)	Team All-Around	9th
		Individual All-Around	61st
Rudolf Babiak	Strasbourg 1978 (France)	Team All-Around	9th
		Individual All-Around	71st
Jozef Konečný	Fort Worth 1979 (USA)	Team All-Around	10th
		Individual All-Around	31st
Rudolf Babiak	Fort Worth 1979 (USA)	Team All-Around	10th
		Individual All-Around	71st

Table 4
Successful Slovak sportsmen in the years 1912-1980 – Artistic Gymnastics – Female – World Championships.

Name and surname	World Championship	Category/Discipline	Final result
Matilda Pálfyová	Prague 1938 (Czechoslovak Republic)	Team All-Around	1st
		Individual All-Around	3rd
Anna Marejková	Rome 1954 (Italy)	Team All-Around	3rd
		Individual All-Around	22nd
Anna Marejková	Moskva 1958 (ZSSR)	Team All-Around	2nd
		Individual All-Around	14th
Mariana Krajčírová	Dortmund 1966 (Germany)	Team All-Around	1st
		Individual All-Around	7th
		Individual/Vault	7th
Mariana Krajčírová	Ljubljana 1970 (Slovenia)	Team All-Around	4th
		Individual All-Around	20th
		Individual/Uneven bars	4th
Ľubica Krásna	Ljubljana 1970 (Slovenia)	Team All-Around	4th
		Individual All-Around	25th
Zdenka Bujnáčková	Varna 1974 (Bulgaria)	Team All-Around	5th
		Individual All-Around	33rd
Eva Marečková	Strasbourg 1978 (France)	Team All-Around	6th
		Individual All-Around	16th
Jana Gajdošová	Strasbourg 1978 (France))	Team All-Around	6th
		Individual All-Around	39th
Eva Marečková	Fort Worth 1979 (USA)	Team All-Around	5th
		Individual All-Around	10th
		Individual/Beam	4th
Katarína Šarišská	Fort Worth 1979 (USA)	Team All-Around	5th
		Individual All-Around	33rd

Table 5
Successful Slovak sportsmen in the years 1912-1980 – Artistic Gymnastics – Male – European Championships.

Name and surname	European Championship	Category/Discipline	Final result
Ferdinand Daniš	Copenhagen 1959 (Denmark)	Individual All-Around	4th
		Individual/Rings	5th
		Individual/Parallel bars	2nd
		Individual/Horizontal bar	5th
Pavel Gajdoš	Luxembourg 1961 (Luxembourg)	Individual All-Around	15th
Jozef Konečný	Essen 1979 (Germany)	Individual All-Around	24th
		Individual/Vault	2nd
Rudolf Babiak	Rome 1981 (Italy)	Individual All-Around	16th

Table 6
Successful Slovak sportsmen in the years 1912-1980 – Artistic Gymnastics – Female – European Championship.

Name and surname	European Championship	Category/Discipline	Final result
Mariana Krajčírová	Amsterdam 1967 (Netherlands)	Individual All-Around	3rd
		Individual – Uneven bars	3rd
		Individual – Vault	4th
		Individual – Beam	5th
		Individual – Floor exercise	4th
Ingrid Holkovičová	Prague 1977 (Czechoslovak Republic)	Individual All-Around	8th
		Individual – Uneven bars	5th
		Individual – Beam	5th
		Individual – Floor exercise	4th
Eva Marečková	Copenhagen 1979 (Denmark)	Individual All-Around	6th
		Individual – Uneven bars	5th
		Individual – Beam	7th
		Individual – Floor exercise	6th

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BODY COMPOSITION AND ITS RELATIONSHIP TO SPORTS INJURIES IN YOUNG FEMALE ACROBATIC GYMNASTS

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Abstract
The risk of injury is associated with elite sport. There is evidence that body composition may affect injury risk. The aim of this study was to analyze the incidence of injuries, and to determine the relationship of body composition with the incidence, typology and severity of injuries in female acrobatic gymnasts.
The sample included 92 female acrobatic gymnasts aged between 9 and 20 years (13.66 ± 2.66 years), 33 tops (11.06 and 1.41 age) and 59 bases (15.11 and 2.00 age). Body measurements (fat percentage, muscle percentage and the sum of 6 skinfolds), and body mass index (BMI) and their categorization into underweight, normal weight and overweight, were measured. Data about injuries were collected through a self-completed questionnaire at the end of the season, where it was recorded whether they had suffered injuries, the type of injury (joint, ligament, tendon or bone) and its severity (minor, moderate or severe). A descriptive, comparative and relational analysis of the studied variables and between groups was carried out.
The results obtained in this study indicate a higher percentage of uninjured gymnasts, but also a high percentage of injured gymnasts, with ligament injuries being the most frequent. As for the relationship with body composition and BMI, no significant relationships were observed in the incidence, typology or severity of injuries suffered by these athletes. It only seems to affect tendon injuries in the bases, with the injured gymnasts having a higher BMI, fat percentage and the sum of six skinfolds.

Keywords: *gymnastics; anthropometry; body composition; injuries; acrobatic gymnastics.*

INTRODUCTION

In any sport, and especially in competition at highest levels, injuries are an unavoidable inconvenience, therefore their prevention is essential to optimize sports performance. The importance of recording injuries associated with their causal factors can therefore be an excellent method for determining their influence on sport performance (Kolt & Kirby, 1999).

Numerous studies have investigated the incidence and prevalence of injuries in the gymnastic disciplines that have been incorporated into the FIG for the longest time, such as men's and women's artistic gymnastics and rhythmic gymnastics (Abalo et al., 2013). Recent reviews indicate a relatively high incidence of injury in artistic gymnastics (Cambell et al., 2019; Thomas & Thomas, 2019). One of these reviews includes 12 studies with 843 women evaluated for the type and frequency of injuries; it showed that the lower extremities were the most affected, followed by the upper extremities, spine and neck. (Thomas & Thomas, 2019). As a limitation of these studies, we found that they varied widely according to their demographic data and the type of injuries recorded, since there were no individual gymnasts' data. Likewise, only four of these studies reflected injury data in elite gymnasts. However, the data were collected either from the athletes'medical history, or from coaches' or physiotherapists' reports. In most studies on amateur athletes, the mean number of hours of training per year was not collected. This type of studies can help sports medicine specialists identify the most common injuries so that appropriate preventive actions can be taken. However, studies in acrobatic gymnastics (AG) are still somewhat limited. (Grapton et al., 2013; Purnell et al., 2010; Vernetta et al., 2018; Vernetta-Santana et al., 2022). It is noteworthy that of the 73 gymnasts in the study by Purnell et al. (2010), 50.7% have suffered some type of injury during training in the last 12 months, from contractures to bone fractures or muscle tears. These authors found that being over 13 years old and training ≥ 8 hours per week at 11 years of age were potential risk factors.

Currently the International Gymnastics Federation (FIG) comprises eight disciplines, including artistic gymnastics and rhythmic gymnastics. More studies on their anthropometric profiles have been conducted in these disciplines as we pointed out in relation to injuries. Body composition is considered a determinant of performance in these disciplines, especially at a high competitive level. The systematic review by Bacciotti et al. (2017) of seven articles in women's artistic gymnastics shows that a lower percentage of body fat is associated with better performance in competition. In other sports, increased body mass index (BMI) has been associated with an increased incidence of injuries, e.g., in women's soccer, and at lower age categories of soccer. (Brumitt et al., 2020; Sugimoto et al., 2018). Similarly, in the study by Ezzat et al. (2016) with a sample of 12,407 adolescents aged 12-19 years, no significant association was found between sports injuries and being overweight, but a secondary analysis revealed that overweight youth with the highest activity level were more likely to suffer sports injuries. A recent study of women's artistic gymnastics analyzed body composition (mean BMI =21.5 and % body fat = 21.9), training volume and injuries in 17 high-performance gymnasts, and found that the most injured areas were ankles and lower back, followed by knees, which mostly affected the gymnasts' training volume. (Jakše et al., 2021).

AG is characterized as a cooperative sport with two distinct roles, bases and tops. The difference between the roles is evident both in their function and in their physical characteristics. The base is the holder and supports the top. The top performs on the base, executing elements of flexibility and balance. (Vernetta et al., 2007). The constant inclusion in the Scoring Code of elements of great difficulty requires gymnasts to perform technically demanding elements and display a high technical level which could lead to an increased risk of injury (Vernetta et al., 2018), as hypothesized by Anwajler et al. (2005). These same authors point out that in a sample of 40 women in AG, the number of injuries in training is higher than those occurring in competition with statistically significant differences, as occurs in studies of AG (Purnell et al., 2010; Vernetta-Santana et al., 2022) and other gymnastic disciplines (Abalo et al., 2013a; 2013b; Vernetta et al., 2016).

Anthropometric studies on this gymnastic discipline have established that the bases show larger body dimensions than the tops, showing significant differences in the mean values of BMI ($p<0.01$) (bases: 20.28 kg/m2 and tops: 16.4 kg/m2) as well as in other somatotype variables analyzed, except for mesomorphy ($p=0.7$). The endomorphic component was higher in the bases (3.17) than in the tops (2.45), whereas the ectomorphic component was higher in the tops (3.27) compared to the bases (2.82). (Taboada-Iglesias et al., 2016). The study by Vernetta et al, (2018) finds a higher percentage of injuries in female bases than in tops, as does the study by Vernetta-Santana et al (2022), where this percentage affects both men and women. AG routines involve dynamic and static group performance skills, therefore the competition groups are configured and maintained according to the individual morphology of each gymnast. Hence, when an injury occurs in one of its components, it is not easy to replace it, which means in most cases the withdrawal of the entire team from the competition (Purnell et al., 2010). It should be noted that in this study 58.8% of the injuries occurred during the performance of a group skill, with the bases suffering more than half of all chronic injuries (52.9%), although no significant correlation was found between BMI and the occurrence of injuries. The identification of the incidence of injuries and the factors associated with their occurrence in AG is a fundamental issue for training, which will facilitate a safer and more effective practice, as well as enable the development of preventive programs. (Cai et al., 2018).

Given the limited evidence, the aim of this study was to analyze the incidence, typology and severity of injuries in female AG athletes and their relationship with different variables of body composition in one season.

METHODS

Participation was voluntary in all the procedures, and the participants could terminate participation at any time. Given that the majority were minors, it was the parents or legal guardians who gave their consent. All measurement procedures were approved by the Autonomous Committee on Research Ethics of the Xunta de Galicia (Spain) (reference number 2015/672) in compliance with the Declaration of Helsinki.

The present study included a sample of 92 women participating in national AG competitions (33 tops and 59 bases), in all age categories, and belonging to seven clubs from all over Spain. Gymnasts between 9 and 20 years old were analyzed. Younger gymnasts were left out due to the difficulty in filling out self-reports. The mean age (X) was 13.66 years with a standard deviation (SD) of 2.66 (tops 11.06 (1.41) age; bases 15.11(2.00) age).

A series of direct measurements were taken to calculate body composition variables following the procedures of the International Society for the Advancement of Kineanthropometry (ISAK). (Marfell-Jones et al., 2006).

The measurements included: weight (kg), taken with a Tanita digital scale with 100g sensitivity, and height (m), using a portable stadiometer. Six skinfolds (triceps, subscapular, supraspinal, abdominal, thigh and medial calf) (mm) were measured with a 0.2 mm precision plicometer. Two bone diameters were also measured in cm (bistiloid diameter of the wrist and femoral bicondylar diameter) with a Holtain caliper of 1mm precision.

The variables that were calculated were BMI, percentage of body fat, percentage of muscle, and skinfold sum.

BMI was calculated using the formula BMI = weight/height^2 (kg/m^2). This variable was taken into consideration as a continuous numerical and categorical variable for its division into underweight, normal weight and overweight. For this interpretation, the percentiles established by the World Health Organization were used as a reference (WHO, 2007) for girls aged 5 to 19 years, marking overweight at the 85th percentile. For the categorization of underweight, the international cut-off point for thinness grade 1 was adopted, proposed by Cole et al. (2007) for the classification of thinness based on BMI in children. For the 20-year-old participants, the standard WHO classifications for adult subjects were taken into consideration. For body composition, the percentage of body fat was calculated using the formula by Slaughter et al. (1988) indicated for girls and proposed by the consensus of the Spanish Group of Cineanthropometry (GREC). (Alvero et al., 2010).

- *Slaughter (1988): % body fat =0.610 x (Sk triceps + Sk* medial calf*) + 5.1*

The De Rose and Guimarães (1980) strategy, based on the four-component method proposed by Matiekga (1921), was used to calculate the percentage of muscle mass.

- *Muscle weight = total weight - (fat weight + bone weight + residual weight).*

Finally, the sum of six skinfolds was calculated:

- *Σ6 skinfolds (mm) = Sk triceps + Sk subscapular + Sk supraspinal + Sk abdominal + Sk* thigh + *Sk* medial calf

The data related to the injury profile of this study were collected by using a self-completed questionnaire. This questionnaire is an adaptation of the one developed by Navarro (2003) and validated in Aerobic Gymnastics (Abalo Nuñez et al., 2013b) for the purposes of AG (Taboada-Iglesias & Gutiérrez-Sánchez, 2015; Vernetta et al., 2018; Vernetta et al., 2021;). For this work, the following variables were considered:

- injured or not during the season;
- type of injury: injuries were classified as joint, muscle, ligament, tendon, bone or various types of injuries;
- severity of injury: grade I or minor (1 to 7 days of recovery), grade II or moderate (8 to 21 days of recovery) and grade III or severe (22 days or more or permanent disability depending on the time of functional impairment).

Data collection (questionnaire and measurements) was carried out at the end of the season, at the training place of each participating club, in small groups, and always in the presence of one of the authors. First, the injury questionnaire was filled out in paper format, lasting approximately 5 minutes. This resolved any doubts about the questions and helped the younger gymnasts to complete the survey. The questionnaire consisted of questions about the participant's characteristics (role, club, competition level and age) and whether he/she suffered injuries during the season (yes or no, number of injuries, type of injury and severity of the injury). In the case of suffering more than one injury, they were recorded with the value of various types of injury, or various types of severity if applicable. Finally, the anthropometric tests were performed according to the protocol and recommendations established by the ISAK.

A descriptive and comparative analysis of the variables was performed, selecting the mean (X) as the measure of central tendency and the standard deviation (SD) for numerical variables, and frequencies and percentages (%) for categorical variables as measures of dispersion. A comparative analysis between groups was also performed. To check the normality of the groups, the data were subjected to the Shapiro-Wilk test and the homogeneity of variance with Levene's statistic. The Student's t-test was performed to evaluate the differences in body composition measurements between the gymnasts who did or did not suffer an injury, and between the body composition of gymnasts who did or did not suffer each type of injury. The comparison of numerical variables between 3 or more groups or categories was performed using one-factor Anova or Kruskall-Wallis for the comparison of non-normal variables to analyse the differences in body composition between the different injury typologies and the relationship between the body composition and injury severity. The Chi-square test was used to analyze the relationship between categorical variables, as in the analysis of BMI categorization between the injured and the non-injured gymnasts. The data were analyzed using the SPSS 22.0 statistical program, with a significance level of $p<0.05$ for all tests.

RESULTS

The results will be explained starting with the descriptive analysis of the injury profile and then the comparative relationship between the different variables of body composition, with the incidence, type and severity of injuries.

Table 1 shows the frequencies and percentages of gymnasts who suffered or not injuries during the season. At the same time, the type of injuries and their severity are indicated. Regarding the type and severity of the injuries, the percentages are established with respect to the number of gymnasts injured and with respect to the total, since they are included in the comparative analysis.

Table 1
Frequencies and percentages of gymnasts with and without injury during the season, typology and severity of the injuries.

		Full sample			Tops (n=33)		Bases (n=59)	
		Frequency (n)	**Percentage (%)**		**n**	**%**	**n**	**%**
Injuries during the season	**YES**	33	35.9		13	39.4	20	33.9
	NO	59	64.1		20	60.6	39	66.1
	Total	92	100.0		33	100.0	59	100.0
			Regarding injured (n= 33)	Regarding total cases	Regarding injured (n=13)		Regarding injured (n=20)	
Type of injury	**Joint injury**	3	9.1	3.3	0	0	3	15.0
	Muscle injury	5	15.2	7.6	1	7.7	4	20.0
	Ligament injury	8	24.2	12.0	3	23.1	5	25.0
	Tendon injury	6	18.2	8.7	3	23.1	4	15.0
	Bone injuries	6	18.2	9.8	5	38.5	1	5.0
	Various	5	15.2		1	7.7	4	20.0
	Total	33	100.0		13	100.0	20	100.0
Severity of injury	**Grade 1 or minor**	15	45.5	16.3	3	23.1	12	60.0
	Grade 2 or moderate	11	33.3	13.0	6	46.2	5	25.0
	Grade 3 or severe	7	21.2	7.6	4	30.8	3	15.0
	Total	33	100.0		13	100.0	20	100.0

There are 64.1% of gymnasts who did not suffer any injury during the season, compared to 35.9% of those who did. Within this group of gymnasts who suffered injuries, there were 24.2% ligament injuries, while the least frequent injury was joint injury (9.1%). Finally, 45.5% of injuries that occurred were grade 1 or minor, followed by grade 2 or moderate injuries (33.3%), and grade 3 or severe (21.2%), that caused a limitation for more than 22 days. The separate analysis of the tops and the bases shows a very similar distribution in terms of the incidence of injuries. However, in terms of typology, female bases have a greater number of joint, muscle, tendon and ligament injuries, while in the tops group, bone injuries predominate. Finally, in terms of severity, female bases suffer more minor and moderate injuries, while in the tops, moderate and severe injuries dominate.

Relationship between body composition and injury incidence

In the analysis between the variables of body composition and the incidence of injuries occurring during the season, it is observed that there are no significant differences ($p<0.05$) between the groups that suffered injuries and those that did not, in any of the variables studied (Table 2).

The relationship between BMI categorization into underweight, normal weight and overweight, and the groups of injured and non-injured gymnasts was also not significant ($p=0.431$) for the total sample, neither for top ($p=0.528$) nor for bases ($p=0.435$) individually.

Table 3 shows how the gymnasts are distributed according to the BMI categories with respect to having suffered or not injuries. Across the board, it is much less frequent to suffer injuries than not.

Table 2.
Comparison of BMI, % body fat, % muscle mass and sum of 6 skinfolds between gymnasts who suffered injuries and those who did not.

	Full sample				**Tops**				**Bases**			
	Injuries during the season	**X**	**SD**	**Sig. (bila-teral)**	**Injuries during the season**	**X**	**SD**	**Sig. (bila-teral)**	**Injuries during the season**	**X**	**SD**	**Sig. (bila-teral)**
BMI	Yes (n=33)	18.59	2.57		Yes (n=13)	16.57	1.79		Yes (n=20)	19.90	2.14	
	No (n=59)	19.03	2.91	.464	No (n=20)	16.56	1.62	.754	No (n=39)	20.30	2.59	.630
% body fat	Yes (n=33)	17.99	3.22		Yes (n=13)	16.01	2.11		Yes (n=20)	19.28	3.19	
	No (n=59)	18.59	4.88	.485	No (n=20)	15.05	3.06	.364	No (n=39)	20.40	4.66	.059
% muscle mass	Yes (n=33)	45.82	1.51		Yes (n=13)	45.47	1.18		Yes (n=20)	46.04	1.68	
	No (n=59)	45.75	2.29	.870	No (n=20)	46.50	1.96	.244	No (n=39)	45.37	2.38	.090
∑6Sk (mm)	Yes (n=33)	61.90	15.58		Yes (n=13)	51.58	10.45		Yes (n=20)	68.62	14.8	
	No (n=59)	64.86	23.14	.468	No (n=20)	47.70	15.50	.410	No (n=39)	73.66	21.5	.065

[Mean (X); Standard Deviation (SD); Body Mass Index (BMI); *Sum of 6 skinfolds* (∑6Pl)] *p<0.05

Table 1
Incidence of injuries according to BMI categories (underweight, normal weight and overweight).

			Full sample			**Tops**			**Bases**		
			Injuries during the season			**Injuries during the season**			**Injuries during the season**		
			YES (n=33)	**NO (n=59)**	**Total (n=92)**	**YES (n=13)**	**NO (n=20)**	**Total (n=33)**	**YES (n=20)**	**NO (n=39)**	**Total (n=59)**
BMI (Categories)	**Underweight (n=12; 13,0%)**	**Recount % within BMI (Categories)**	4	8	12	2	5	7	2	3	5
			50.0%	50.0%	100.0%	15.4%	25%	100.0%	10.0%	7.7%	100.0%
	Normal weight (n=74; 80,4%)		27	47	74	9	14	23	18	33	51
			32.9%	67.1%	100.0%	69.2%	70.0%	100.0%	90%	84.6%	100.0%
	Overweight (n=6; 6,5%)		2	4	6	2	1	3	0	3	3
			33.3%	66.7%	100.0%	15.4%	5.0%	100.0%	0%	7.7%	100.0%

Body Mass Index (BMI)

Relationship between body composition and injury typology.

The relationship between body composition and the type of injury suffered was analyzed from two perspectives. First, the total sample was analyzed by dividing the groups that had or had not suffered each type of injury independently. The analysis indicated that there were no significant differences between the groups. Therefore, it is understood that in the complete sample, there are no significant differences in body composition between gymnasts who had joint injuries and those who did not, as well as in muscular, ligament, tendon and bone injuries (Table 4).

Table 5 shows that there were no significant differences in the tops. However, Table 6 shows that in the group of female gymnasts with differences in BMI, percentage of fat and the sum of skinfolds, higher values were presented by those gymnasts who suffered tendon injuries.

On the other hand, a comparison was conducted among all the injury groups in order to analyze if there were anthropometric differences among them. The statistical analysis indicated that there were no significant differences in BMI (p=0.197), body fat percentage (p=0.448), muscle mass percentage (0.396), or in the sum of 6 skinfolds (p=0.218). The behavior of the groups in these variables in the complete sample can be seen in Figure 4. Although no significant differences were found, it should be noted that joint injuries were the highest across the board.

Our analysis of the tops group did not show significant differences for BMI (p=0.533), fat percentage (p=0.203), muscle percentage (0.437), or the sum of 6 skinfolds (p=0.273). The same applies to the bases (BMI (p=0.357), fat percentage (p=0.332), muscle percentage (0.371), the sum of 6 skinfolds (p=0.181)).

Table 4
Comparison of BMI, % body fat, % muscle mass and sum of folds between gymnasts who did or did not suffer each type of injury.

		X	SD	Sig. (bilateral)		X	SD	Sig. (bilateral)
	Joint injuries				**Muscle injuries**			
BMI	No (n=89)	18.77	2.77		No (n=85)	18.88	2.81	
	Yes (n=3)	21.96	1.40	.051	Yes (n=7)	18.82	2.74	.960
% body fat	No (n=89)	18.28	4.38		No (n=85)	18.46	4.37	
	Yes (n=3)	21.14	2.34	.264	Yes (n=7)	17.31	4.25	.504
% muscle mass	No (n=89)	45.75	2.03		No (n=85)	45.79	2.02	
	Yes (n=3)	46.50	2.52	.532	Yes (n=7)	45.52	2.37	.737
∑6Sk(mm)	No (n=89)	63.16	20.63		No (n=85)	63.99	20.99	
	Yes (n=3)	82.93	14.35	.104	Yes (n=7)	61.43	18.07	.754
	Ligament injuries				**Tendon injuries**			
BMI	No (n=81)	18.86	2.79		No (n=84)	18.92	2.85	
	Yes (n=11)	19.00	2.87	.875	Yes (n=8)	18.35	2.03	.583
% body fat	No (n=81)	18.42	4.44		No (n=84)	18.48	4.48	
	Yes (n=11)	18.02	3.77	.774	Yes (n=8)	17.28	2.42	.247
% muscle mass	No (n=81)	45.72	2.08		No (n=84)	45.73	2.12	
	Yes (n=11)	46.17	1.71	.491	Yes (n=8)	46.20	.73	.190
∑6Sk(mm)	No (n=81)	64.06	21.33		No (n=84)	64.55	21.25	
	Yes (n=11)	61.87	16.03	.744	Yes (n=8)	55.95	11.92	.264
	Bone injuries							
BMI	No (n=83)	19.01	2.82					
	Yes (n=9)	17.56	2.16	.139				
% body fat	No (n=83)	18.44	4.51					
	Yes (n=9)	17.77	2.48	.667				
% muscle mass	No (n=83)	45.79	2.12					
	Yes (n=9)	45.60	1.02	.791				
∑6Sk(mm)	No (n=83)	64.30	21.50					
	Yes (n=9)	59.21	10.57	.247				

[Mean (X); Standard Deviation (SD); Body Mass Index (BMI); Sum of 6 skinfolds (∑6Sk)] *p<0.05

Table 5

Comparison of BMI, % body fat, % muscle mass, and sum of folds between gymnasts who did or did not suffer each type of injury as tops

		X	SD	Sig. (bilateral)		X	SD	Sig. (bilateral)
	Joint injuries				**Muscle injuries**			
BMI	No (n=32)	16.56	1.69		No (n=31)	16.54	1.71	
	Yes (n=1)	16.67		.950	Yes (n=2)	16.96	.37	.735
% body fat	No (n=32)	15.38	2.75		No (n=31)	15.61	2.72	
	Yes (n=1)	17.12		.538	Yes (n=2)	12.69	.22	.146
% muscle mass	No (n=32)	46.11	1.78		No (n=31)	46.12	1.80	
	Yes (n=1)	45.48		.729	Yes (n=2)	45.65	.53	.717
∑6Sk(mm)	No (n=32)	49.12	13.89		No (n=31)	49.82	13.92	
	Yes (n=1)	52.70		.801	Yes (n=2)	40.05	.92	.336
	Ligament injuries				**Tendon injuries**			
BMI	No (n=31)	16.65	1.68		No (n=32)	16.60	1.68	
	Yes (n=2)	15.24	.34	.525	Yes (n=1)	15.57		.552
% body fat	No (n=31)	15.52	2.66		No (n=32)	15.43	2.77	
	Yes (n=2)	14.01	4.66	.455	Yes (n=1)	15.35		.976
% muscle mass	No (n=31)	46.08	1.77		No (n=32)	46.09	1.78	
	Yes (n=2)	46.21	1.89	.926	Yes (n=1)	46.11		.991
∑6Sk(mm)	No (n=31)	49.90	13.6.		No (n=32)	49.37	13.88	
	Yes (n=2)	38.85	14.21	.275	Yes (n=1)	44.60		.737
	Bone injuries							
BMI	No (n=31)	16.56	1.71					
	Yes (n=2)	16.59	1.02	.983				
% body fat	No (n=31)	15.54	2.77					
	Yes (n=2)	13.67	1.08	.355				
% muscle mass	No (n=31)	46.08	1.81					
	Yes (n=2)	46.25	.20	.897				
∑6Sk(mm)	No (n=31)	49.83	13.4					
	Yes (n=2)	39.85	7.71	.325				

[Mean (X); Standard Deviation (SD); Body Mass Index (BMI); Sum of 6 skinfolds (∑6Sk)] *p<0.05

Table 6

Comparison of BMI, % body fat, % muscle mass, and sum of folds between gymnasts who did or did not suffer each type of injury as bases

		X	SD	Sig. (bilateral)		X	SD	Sig. (bilateral)
	Joint injuries				**Muscle injuries**			
BMI	No (n=59)	20.16	2.43		No (n=54)	20.19	2.39	
	Yes (n=0)				Yes (n=5)	19.86	3.14	.772
% body fat	No (n=59)	20.02	4.23		No (n=54)	20.05	4.16	
	Yes (n=0)				Yes (n=5)	19.70	5.40	.864
% muscle mass	No (n=59)	45.60	2.17		No (n=54)	45.62	2.21	
	Yes (n=0)				Yes (n=5)	45.34	1.94	.784
∑6Sk(mm)	No (n=59)	71.95	19.51		No (n=54)	71.99	18.90	
	Yes (n=0)				Yes (n=5)	71.48	28.06	.956
	Ligament injuries				**Tendon injuries**			
BMI	No (n=48)	20.06	2.51		No (n=55)	19.92	2.24	
	Yes (n=11)	20.61	2.13	.503	Yes (n=4)	23.45	3.04	**.004***
% body fat	No (n=48)	19.89	4.39		No (n=55)	19.68	4.05	
	Yes (n=11)	20.58	3.55	.631	Yes (n=4)	24.71	4.30	**.020***
% muscle mass	No (n=48)	45.58	2.25		No (n=55)	45.57	1.95	
	Yes (n=11)	45.66	1.89	.921	Yes (n=4)	45.99	4.77	.713
∑6Sk(mm)	No (n=48)	71.22	2.53		No (n=55)	69.62	16.95	
	Yes (n=11)	75.13	14.60	.554	Yes (n=4)	104.03	26.78	**.000***
	Bone injuries							
BMI	No (n=58)	20.21	2,43					
	Yes (n=1)	17.36		.249				
% body fat	No (n=58)	20.11	4,21					
	Yes (n=1)	14.86		.221				
% muscle mass	No (n=58)	45.58	2,19					
	Yes (n=1)	46.79		.585				
∑6Sk(mm)	No (n=58)	72.42	19,35					
	Yes (n=1)	44.90		.164				

[Mean (X); Standard Deviation (SD); Body Mass Index (BMI); Sum of 6 skinfolds (∑6Sk)] *p<0.05

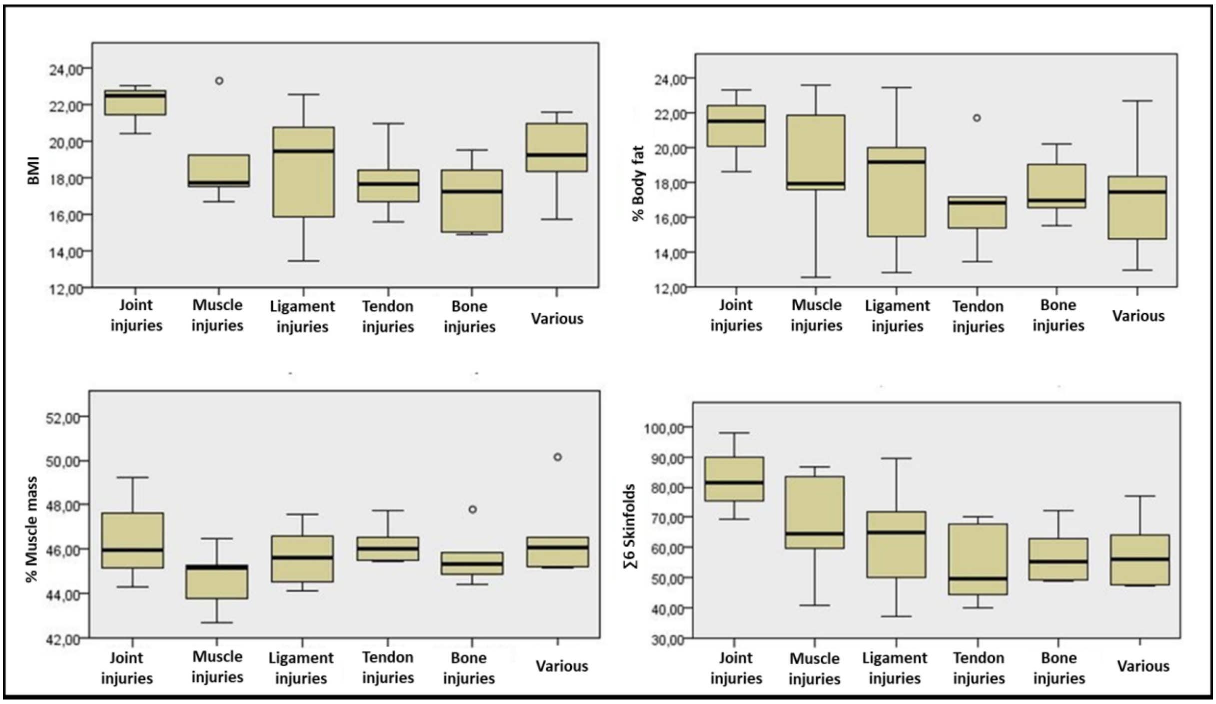

Figure 1 BMI, % body fat, % muscle mass and the sum of 6 skinfolds in different types of injuries.

Relationship between body composition and severity of injuries

The relationship between the body composition and injury severity indicated that there were also no significant differences in BMI (p=0.508), body fat percentage (p=0.518), muscle mass percentage (0.879), or in the sum of 6 skinfolds (p=0.598). Figure 5 shows the behavior of the groups of gymnasts in the complete sample, with grade 1, grade 2 or grade 3 injuries within the different body composition variables. It shows the anthropometric homogeneity in the three groups.

In the tops group, no significant differences were obtained for BMI (p=0.467), the body fat percentage (p=0.121), the muscle percentage (0.964) and in the sum of 6 skinfolds (p=0.172). The same applies to the group of bases for BMI (p=0.315), the body fat percentage (p=0.378), the muscle percentage (0.651) and the sum of 6 skinfolds (p=0.217).

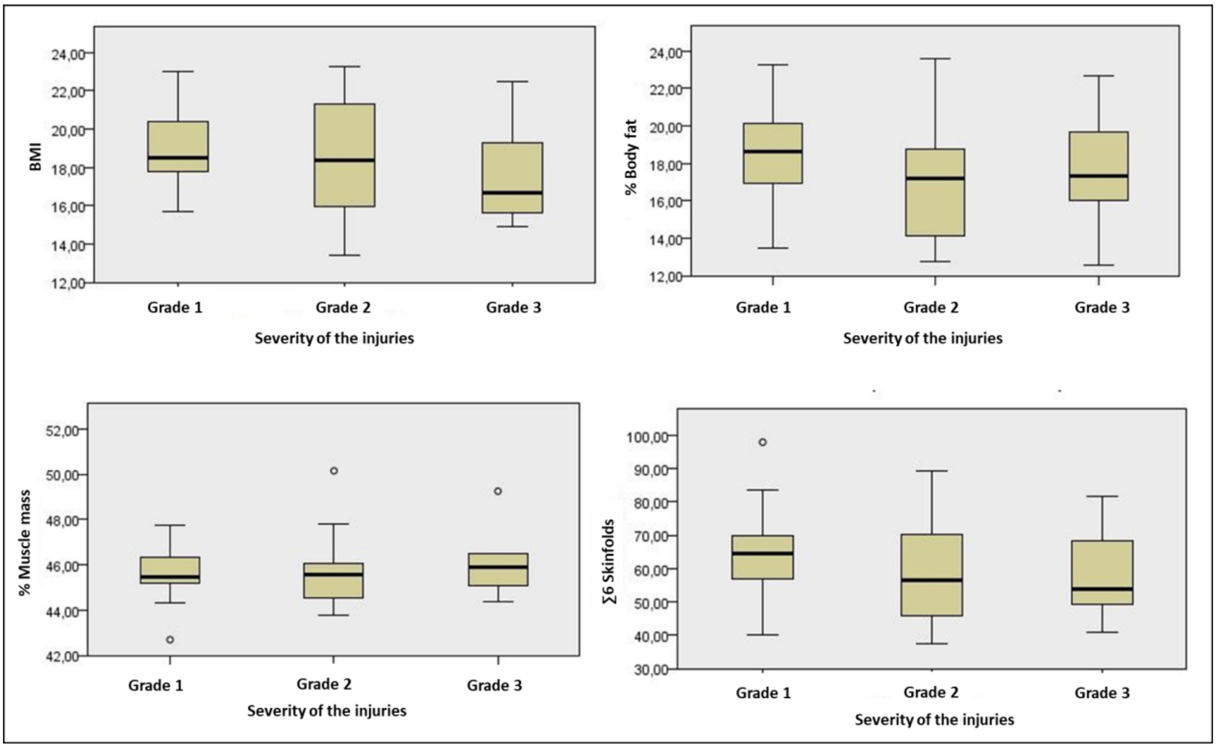

Figure 5 BMI, % body fat, % muscle mass, and sum of 6 skinfolds in the different grades of injury severity.

DISCUSSION

To the authors' knowledge, this is the first study to analyze anthropometric indices and body composition as possible predictors of injury in GA. The relationship between morphological profile and injury incidence was investigated in a sample of female AG practitioners. The results of our analysis revealed no significant differences between any of the variables analyzed except for the tendon injuries, where the injured gymnasts had a higher BMI, the percentage of body fat and the total sum of skinfolds. This may be due to the small size of the sample or to the existence of variables that may have a greater influence on the injuries, such as the motor pattern and the intrinsic characteristics of this gymnastic discipline. These results are consistent with those of Seow & Massey (2022), where no significant correlation was found between injury incidence and body composition variables in pre-season soccer players. On the contrary, in the sample of 160 female youth soccer players researched by Sugimoto et al. (2018) no correlation was found between higher weight/BMI and previous musculoskeletal injuries. However, our results are not in agreement with those found in the 606 climbers in the study by Backe et al. (2009) where a higher BMI was significantly associated with a higher risk of injury.

Based on the type of injury, the most frequent were ligament injuries followed by tendon and bone injuries. This result is in line with the studies of Grapton et al. (2013), Vernetta et al., (2018) and Vernetta-Santana et al. (2022).

Although this study highlights a higher proportion of gymnasts who did not suffer injuries throughout the season, it should be noted that the number of injured gymnasts remained high. As for the severity of these injuries, they were mostly mild or grade 1, followed by moderate or grade 2, corroborating the results of other research in Spanish gymnasts and gymnasts from other countries. (Cainer & Nassar, 2005; Grapton et al., 2013; Purnell et al., 2010; Vernetta et al., 2018; Vernetta-Santana et al., 2022). It should be noted that a non-negligible percentage (21.2%) of the gymnasts in this study had a severe or grade 3 injury, which made them unable to return to training for a long period of time (more than 22 days).

In the study by Ursej et al. (2019) that included 129 competitive hip hop dancers, 114 of them female, no significant difference was found between anthropometric and body development variables associated with the occurrence of injury. It should be pointed out that our gymnasts, categorized as underweight, and overweight, posted no significant differences between those who suffered injury and those who were not injured.

The studies by Vernetta et al. (2018) and Vernetta-Santana et al. (2022) point out that in acrobatic gymnasts there is a higher percentage of injuries. These data may agree with those of our study, although without significant differences, since gymnasts with joint injury have higher values for BMI, percentage of body fat and the sum of skinfolds. It should be noted that in the artistic gymnasts in the study by Jakše et al. (2021), there is a high number of injuries in gymnasts with both the higher BMI and the percentage of body fat than the average of the gymnasts in our study. Age could also influence this differentiation, 13.66 years is the mean age of our gymnasts compared to 17.4 years for the mentioned artistic gymnasts. In AG, Purnell et al. (2010) point out that the critical age for injury is between 11 and 15 years old. The sample of their study has a mean age similar to that of our gymnasts, 13.4 years (SD=3.6) and 13.6 years (SD=2.6) respectively. On the other hand, the sample of trampoline, tumbling and AG gymnasts analyzed by Grapton et al. (2013) presented a mean age somewhat above the highest risk range (15±3 years).

No significant differences were found between the severity of injuries grade 1, 2 and 3 and the analyzed variables of body composition. The main limitation was the lack of evidence from other sports to compare these results.

CONCLUSIONS

From the results obtained in this study we can conclude that there is a high percentage of injured gymnasts, with ligament injuries being the most frequent, but anthropometric indices and body composition do not seem to be related to the occurrence of injuries in AG women. It only seems to affect tendon injuries in the bases, with the injured gymnasts having a higher BMI, fat percentage and skinfold sum. Further studies with international level gymnasts are necessary.

It is important for coaches, gymnasts, physiotherapists and researchers to address the challenge of maintaining proper body composition, optimal recovery for return to training, and, most importantly, improved injury prevention that will enhance gymnasts' performance and health.

More studies are needed to investigate the prevalence of AG injuries as well as the factors associated with the occurrence of such injuries including among international level gymnasts, but also among initiation level gymnasts where the variation in body composition may be greater and could influence the injury profile in a more direct way. It would also be interesting to analyze whether the physical characteristics of one member of a competition group, and their relationship with those of their peers, can influence the injury tendency of the rest.

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ANALYZING THE CONNECTION BETWEEN GYMNAST'S STATURE AND MEDAL PERFORMANCE ON APPARATUSES IN MEN'S ARTISTIC GYMNASTICS

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Abstract

In order to achieve success in sports, certain physical fitness characteristics are necessary. This study aims to determine whether a relationship exists between the height of male gymnasts who have won medals in the World Championships and Olympic Games in Artistic Gymnastics, and the apparatus on which they achieved those medals. Competitions in Men's Artistic Gymnastics at World Championships and Olympic Games are held in six apparatuses for individuals: floor exercise, pommel horse, rings, vault, parallel bars and horizontal bar. Each apparatus follows specific rules for evaluating gymnastics routines. Airborne acrobatics dominate on floor and vault, while support holds prominence on pommel horse and parallel bars, and hanging manoeuvres characterize rings and the high bar. While a gymnast's body height influences all forms of gymnastics, the question remains: who can rise to the top on each apparatus?

Within the scope of the research, the results between the years from 2009 to 2021 were examined. In this context, data from three Olympic Games (2012, 2016 and 2020) and nine World Championships (2009, 2010, 2011, 2013, 2014, 2015, 2017, 2018 and 2019) were used. The heights (251 sets of data) of the gymnasts who won medals in these competitions were evaluated.

While the shortest of the medal-winning gymnasts was 150cm tall (floor exercise and pommel horse) and the tallest 183cm (floor exercise and horizontal bar), the average height of the medal-winning gymnasts was 164.67cm (± 6.12). There is statistically significant difference between the heights of the gymnasts who won medals on apparatuses ($p<0.05$).

Keywords: *gymnasts, body height, medal.*

INTRODUCTION

Scientific studies on sports show that there are certain morphological features that increase the athlete's chance of success. Furthermore, in the same sport, these morphological features vary depending on the position of the athlete, his role, and the type of competition he specializes in (Stanula et al., 2013; Taboada-Iglesias, Santana, & Gutierrez-Sanchez, 2017). Success in artistic gymnastics certainly depends on the morphological characteristics of the athletes, some of which are basic body height and weight (Almir Atikovic, 2020).

Gymnastics is one of the oldest sports branches. The International Gymnastics Federation (FIG) was founded in 1881. Gymnastics has been part of all Olympic Games organized since 1896 (Massidda & Calo, 2012). The first gymnastics World Championship was held in the Netherlands in 1903 (Almir Atikovic, 2020; Ivan Cuk et al., 2007). Since its inception, competition schedules have changed. However, men's gymnastics practiced in the mid-1930s is very similar to the current practices (Ivan Cuk et al., 2007).

The rules of the competition for artistic gymnastics are based on the COP. The first version of these rules dates back to 1949 (Almir Atikovic & Smajlovic, 2011). The competition rules are defined by: statutes of the FIG, FIG Technical Regulations, COP, Apparatus Norms which get changed and perfected by the FIG's commissions for each Olympic cycle (A. Atikovic, Kalinski, & Cuk, 2017; Almir Atikovic & Smajlovic, 2011).

Artistic gymnastics is a sport that includes multiple competitions, in contrast to many other sports branches. There are six apparatuses for men and four apparatuses for women, and each apparatus is performed in a series that requires branch specific skills (Prassas, Kwon, & Sands, 2006). There are four distinct competitions. The first is the qualification round, in which all gymnasts participate. The top eight teams from the qualifications advance to the team finals. Similarly, the highest-scoring 24 gymnasts in the qualifications earn a spot in the all-around final. A maximum of two gymnasts from each country can participate in the all-around finals. Another competition is the apparatus finals. To qualify for the apparatus finals, being among the top 8 athletes from the qualification is essential. A maximum of two gymnasts from each country can compete in the apparatus finals. (Committee, 2020).

A gymnast does not necessarily have to compete on all six apparatuses. Since 2007, World Cups have been organized, allowing competition on a single apparatus. This rule change has allowed gymnasts to specialize in single or more apparatuses according to their abilities and skills, rather than training on all six apparatuses (Sibanc, Kalichova, Hedbavny, Cuk, & Pajek, 2017). Since 2008, there has been more specialization in the apparatus competitions. Since FIG now allows gymnasts to compete in a single apparatus, characteristics of gymnasts, such as body height and weight, have become a determining factor in choosing their apparatus (Marijo Možnik 2013).

Competition apparatus used in artistic gymnastics adhere to specific norms determined by the FIG (International Gymnastics Federation). These apparatuses must be utilized in any competition sanctioned by the FIG, such as the World Championships and the Olympic Games. The dimensions of the floor are 12x12m, while the pommel horse stands 105cm high from the landing mat, and the vault is 135cm high. The rings are set at 280cm, the parallel bars at 180cm, and the horizontal bar at 260cm high from the landing mats (Erkut, 2021). This raises the question of whether the standardized height of the apparatus may confer an advantage to certain gymnasts based on their body height. Developments in training methods, equipment, and changes in competition rules also impact the criteria for athletes' body structures in the selection of sports disciplines (Stanula et al., 2013). Gymnasts have typically been of smaller stature, as it provides better balance and facilitates easier rotation during the flight phase. However, the diminutiveness of female gymnasts, in particular, has become more pronounced in recent times (Almir Atikovic, 2020).

The aim of this study was to investigate whether a relationship exists between the height of gymnasts who have won medals in the Artistic Gymnastics World Championships and the Olympic Games and the specific apparatus on which they achieved those medals.

METHODS

In this study, the results of three Olympics and nine world championships organized between 2009 and 2021 were evaluated. The heights of the athletes were obtained from FIG and national and international Olympic Committee data. In this context, 253 sets of data were evaluated. Only the heights of two gymnasts could not be obtained. MS Excel 2016 and Sigma Plot were used for statistical analysis. Kruskal-Wallis test was used for analysis of multiple groups.

Table 1
The included competitions and the number of medals obtained

	Gold	Silver	Bronze
2009 World Championships - London	7	7	7
2010 World Championships - Rotterdam	7	8	6
2011 World Championships - Tokyo	7	8	7
2012 Olympic Games - London	7	7	7
2013 World Championships - Antwerp	7	8	6
2014 World Championships - Nanning	7	7	7
2015 World Championships - Glasgow	7	7	7
2016 Olympic Games - Rio De Janeiro	7	7	7
2017 World Championships - Montreal	7	7	7
2018 World Championships - Doha	7	7	7
2019 World Championships - Stuttgart	7	7	7
2020 Olympic Games - Tokyo	7	7	7

Table 1 presents the evaluated competitions and the number of medals. In the 2010 competition, two gymnasts won silver medals on the PH. In 2011, two gymnasts achieved bronze medals on the FX, while two gymnasts won silver medals on the PH. At the 2013 World Championships, two gymnasts secured bronze medals on the PH.

RESULTS

Within the scope of our study, the Olympic Games and World Championships held between 2009 and 2021 were examined and the following data were obtained:

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Table 2

Height of gymnasts who won medals in all-around and the six apparatuses

Body Height	FX	PH	RI	VT	PB	HB	AA
150 cm - 159,9 cm	7	4	8	5	4	3	5
160 cm - 169,9 cm	24	12	27	29	22	16	26
170 cm - 179,9 cm	4	15	1	0	9	15	5
180 cm - 189,9 cm	2	5	0	1	0	2	0
Total	37	36	36	35	35	36	36
mean	163.51	169.61	161,47	162.57	164.20	167.58	163.67
max	183.00	180.00	170.00	180.00	178.00	183.00	173.00
min	150.00	150.00	158.00	154.00	156.00	158.00	157.00
sd	6.72	7.72	2.95	5.08	5,68	6.04	4.14

Table 2 provides the height ranges of the medal-winning gymnasts. The majority of gymnasts fall within the height range of 160 to 169.9cm (62.15%). However, on the pommel horse (PH), there is a distinct difference, as the majority of medal-winning gymnasts are 170cm and taller (75%), unlike on other apparatuses. The number of gymnasts on the HB apparatus is nearly equal for those above and below 170 cm (17-19). No gymnast with a height of 180 cm or taller has won a medal in the rings (RI), parallel bars (PB), or all-around events. RI and vault VT exhibit similar characteristics. In the RI, 97.2% of medal-winning gymnasts are shorter than 170 cm. Similarly, in the vault, 97.14% of medal-winning gymnasts are athletes shorter than 170 cm.

According to Table 3, there were statistically significant differences ($p < 0.05$) between FX and PH as well as HB, between PH and PB, between RI and PB as well as All-around (AA), between PB and HB, and between HB and AA. On the other hand, higher levels of statistical differences ($p < 0.01$) were found between PH and RI, VT, and AA, between RI and HB, and between VT and HB.

When examining the variations in height across Olympic cycles, a decrease in the heights of medal-winning gymnasts was observed in the 2013-2016 and 2017-2020 Olympic cycles on the FX and VT. A significant relationship was found between the heights of the gymnasts who won medals on FX and PH between 2013-2016 and 2017-2020 ($p<0.05$).

Table 3
Heights differences in gymnasts

	PH	RI	VT	PB	HB	AA
FX	0.001*	0.099	0.506	0.642	0.008*	0.907
PH		0,000**	0.000**	0.001*	0.219	0.000**
RI			0.267	0.013*	0.000**	0.012*
VT				0.210	0.000**	0.322
PB					0.018*	0,652
HB						0.002*

*p<0.05 **p<0.001

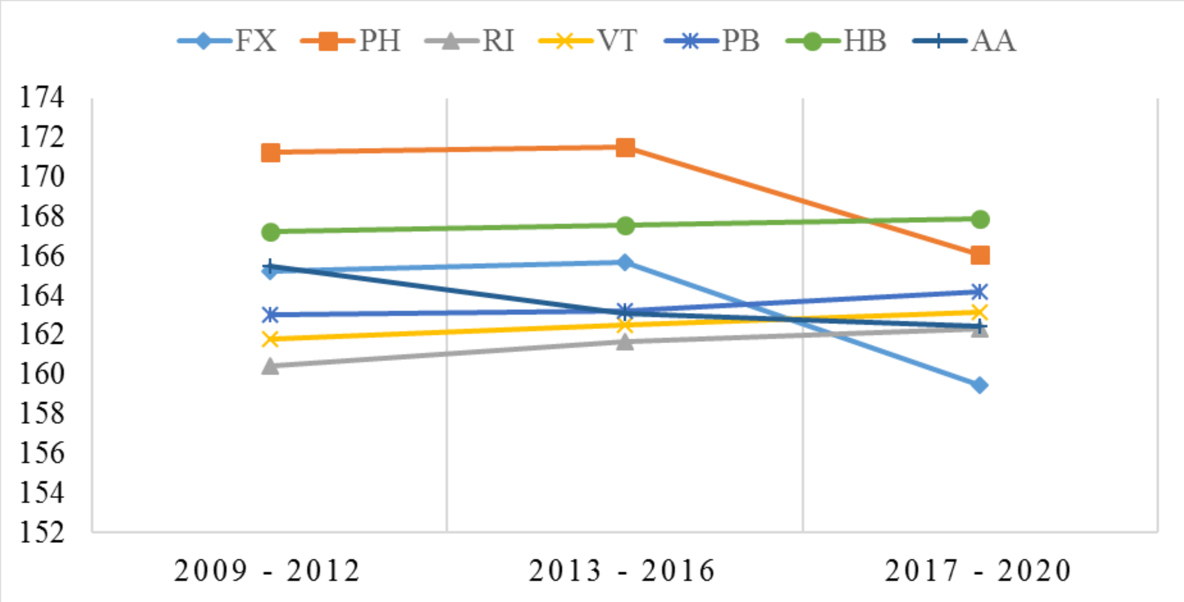

Figure 1. Average height of the gymnasts who won medals during Olympic cycles

DISCUSSION

Gymnastics has traditionally been perceived as a sport suitable primarily for shorter individuals. Height has been used as a criterion in athlete selection processes. However, when examining competition results, it becomes apparent that gymnasts of different heights excel on specific apparatuses. Particularly in team competitions, it has been observed that teams consist of gymnasts with diverse heights. These observations have prompted the need for a study on gymnasts' heights.

The aim of this study was to investigate whether there is a relationship between the height of the gymnasts who won medals in the Artistic Gymnastics World Championships and the Olympic Games, and the apparatus in which they won medals. Our study revealed statistically significant differences in terms of height among gymnasts who won medals on different apparatuses. There were significant differences ($p < 0.05$) between FX and PH as well as HB; between PH and PB; between RI and PB as well as AA; between PB and HB, and between HB and AA. Furthermore, higher levels of statistical differences ($p < 0.01$) were found between PH and RI, VT, and AA, between RI and HB, and between VT and HB.

In the 1930s, gymnastic was the most developed sports branch considering the number of competitors and quality level. This was the reason why first sports researchers, called anthropologists, became interested in gymnastics. The first major research was conducted at the Olympic Games organized in Amsterdam in 1928. The study concluded that short people could be successful in gymnastics wereas tall people could be successful in athletics (Ivan Cuk et al., 2007). Studies show that the height and weight of the gymnasts participating in the competitions between 1933-2000 did not change, but the width of the shoulders and hips did. Gymnasts today have wider shoulders and narrower hips than before. This is the result of complex movements involving horizontal and vertical rotation (Cuk, Pajek, Jakse, Pajek, & Pecek, 2012).

The gymnasts selected for recreational and performance purposes were shorter than their average age before they started training. In both genders, families of gymnasts were also reported to be shorter than average. This situation was interpreted as an indication that gymnasts had characteristics inherited from their families (Malina et al., 2013).

In the study conducted by Rozin and Ceburaev (2007), the heights of the gymnasts participating in the Olympic Games showed an average of 167.7cm in the 1964 Olympics, 167.9cm in the 1968 Olympics, 169.1cm in the 1972 Olympics, 166.7cm in the 1976 Olympics, and 168.2cm in the 1980 Olympics. (Ivan Cuk et al., 2007). These results are in line with our study. In fact, there is a similarity between the average height of the athletes participating in these competitions and the average height of the medal-winning gymnasts.

In another study, the details of 165 gymnasts at the world championship held in Rotterdam in 1989 show that the average height was 167.0cm; the shortest gymnast was 153.2cm tall, and the tallest 183.8cm (Claessens et al., 1991).

Success in applying a technique in artistic gymnastics depends on strength, flexibility, and the individual's somatotype characteristics (Sibanc et al., 2017). In their study on the characteristics affecting the success of young gymnasts, Cuk and Novak (2007) reported that gymnasts should possess a short stature, light body weight, high-quality muscles, a strong chest, and a low body fat percentage in terms of anthropometry. Based on this information, shorter body height seems to be more advantageous on the rings, considering the technical requirements of the apparatus. Gymnasts who have won medals on the pommel horse and horizontal bar, which do not require strength movements as much as rings, tend to be taller than those on the other apparatuses.

In our study, the height of 61.66% medallists was in the range of 160.00 - 169.99cm. 82.86 percent of vault medallists were in the 160.00-169.99cm category; showing that gymnasts in this height range have a better chance, especially on vault. In pommel horse, dominant height range was 170.00-179.99 cm, representing 41.67% of medallists.

Although artistic gymnastics is defined as a single sport branch, it requires different physical features to be at the forefront in each of the six different competition apparatuses (Morucci et al., 2014). This situation shows that gymnasts should be selected on the basis of apparatus. Our study indicates that relatively short people have better chance of winning medals, especially on rings and vault.

Gymnasts must possess distinct physical attributes tailored to each apparatus in which they compete. Success on the floor requires strong muscles in the lower part of the body, while strength in the upper body is crucial for the rings. Conversely, excelling in the all-around (AA) category demands above-average strength development across all body parts (Kalinski, Jelaska, & Knezevic, 2017). These and similar considerations lead to speculation that gymnasts with varying physical characteristics might enjoy advantages depending on the apparatus they compete in.

Another study found that the average height of the gymnasts who competed in the AA and ranked in the top 10 between 2007 and 2011 was 165.5 cm (Marijo Možnik

2013). In our study, it was observed that the gymnasts who won medals in AA, had a limited range of body height. In the apparatuses, the heights of the medal-winning gymnasts were in a wider range.

The study compared the physical characteristics of male gymnasts participating in the Artistic Gymnastics World Championships held in 2000 and 2015. Measurements were taken from competitors on a voluntary basis to observe changes in physical attributes over the past fifteen years. As a result of these measurements, the shortest gymnast who took part in the 2000 competitions stood at 157.4 cm in height, whereas in 2015, the heights of the two shortest gymnasts were recorded at 150 cm. In both years, the tallest gymnasts competed on the horizontal bar, with a height of 185.5 cm. The difference between the tallest and shortest gymnast's height was 28.1 cm in 2000, while this disparity increased to 33 cm in 2015 (Sibanc et al., 2017). Notably, allowing gymnasts to specialize in specific apparatuses has contributed to a rise in the number of taller gymnasts.

In a separate study, researchers examined the morphological characteristics of gymnasts participating in a World Cup competition and found that the average height of gymnasts was 168 cm, with an average body weight of 66 kg (Cuk et al., 2012).

Studies on the physical characteristics of gymnasts have not been conducted only in artistic gymnastics. Taboada et al. (2017) found a statistically significant difference between the heights of gymnasts competing in the mix pair category in their study on the morphological characteristics of acrobatic gymnasts (Taboada-Iglesias et al., 2017). In a study carried out by Carvalho et al. (2012) on an elite group of rhythmic gymnasts, it was found that being tall in rhythmic gymnastics had a positive effect on performance. Compared to the past, rhythmic gymnasts are taller today (Lurdes Avila-Carvalho, 2012).

CONCLUSIONS

While there is a prevailing notion that gymnasts should possess a short stature, various factors such as the technical attributes of the apparatus, specialized movement techniques, and competition regulations can introduce advantages or disadvantages based on the gymnast's height. The outcomes of our study demonstrate the height of medal-winning gymnasts can differ according to the apparatus they compete on, challenging the conventional belief that success is confined to individuals of shorter stature. This revelation contradicts the notion that artistic gymnastics exclusively favors those with reduced height. It is crucial to acknowledge that this study's scope is limited to male artistic gymnasts who partook in world and Olympic championships from 2009 to 2021.

In our study in which we evaluated the Olympic Games and World Championships between 2009 and 2021, the following conclusions emerged:

- While a gymnast with a height of 183cm on the floor and horizontal bar could win a medal, a gymnast taller than 170cm on the rings apparatus could not win a medal.
- While gymnasts taller than 170cm were able to win medals on other apparatuses, excluding rings, the tallest gymnast who won a medal in AA was 173cm tall.
- When the length differences are evaluated, the widest gap is on the floor (19.49cm), and the narrowest gap is on the rings (8.53cm).
- Considering the Olympic cycles, there was a 6.17cm decrease in the average height of

gymnasts on the floor in 2017-2020 compared to 2013-2016. A similar differentiation was observed on the pommel horse with 5.32cm.

Gymnasts who attain or approach a particular height threshold can be guided towards apparatuses where their potential for success aligns with their height. When contemplating modifications to apparatus norms, the FIG and relevant committees should factor in gymnasts' heights, ensuring a thorough assessment of these changes. In prospective studies, enhancing research methodologies to encompass measurements not only of height but also of the lengths of gymnasts' upper and lower extremities could offer further comprehensive insights into comprehending the influence of gymnastics apparatuses on physical structure. This avenue of research can also extend to encompass female gymnasts.

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TEMPERATURE DIFFERENCES OF THE PALMS AFTER STATIC AND DYNAMIC LOAD IN SUPPORT ON PARALLEL BARS

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Abstract
In sports and exercise science, thermography is used extensively to evaluate athletic performance, to study exercise-induced superficial vascular changes, and to monitor injuries. There is a lack of research and literature on palm temperatures after different loads and our question was how palm temperature differs after static and dynamic loading on the parallel bars since the application is so varied (competitive and recreational sports, physical education, rehabilitation). Thirty-eight students from the Faculty of Sport at the University of Ljubljana were measured using a high-quality thermal imaging camera. Palm temperatures were measured before the load was applied, immediately after the load, and every 30 seconds for a period of 5 minutes after the load. Each hand was divided into nine different regions of interest (ROIs). Mean (XA), standard deviation (SD), maximum and minimum, and number of pixels were calculated. Our study showed that the temperature in the palm decreased immediately after the load, and then began to increase. Within 5 minutes, it reached higher values than before the application of the load, and after swings (dynamic load), the temperature values were higher than after support (static load). Different loads have different effects on the temperature of the hand.

Keywords: *palm temperature; thermal imaging; parallel bars; support; swing in support*

INTRODUCTION

Infrared thermal imaging has gained widespread acceptance as a non-destructive testing method and is increasingly utilized across various research and industrial sectors. Infrared thermography is employed for several purposes, including the detection of internal manufacturing defects in materials, measurement of thermophysical parameters in materials, identification of internal damage within structures and material strength, assessment of energy efficiency in buildings, detection of leaks in buildings and electrical systems, as well as applications in civil engineering, aerospace for energy conversion detection, stress analysis, and healthcare (Qu, Jiang, and Zhang 2020).

The human body's temperature is closely associated with health status, with the normal body temperature range being defined as a relatively narrow span, typically ranging from 36.1°C to 37.2°C at room temperature. Hyperthermia, albeit rarely hypothermia, serves as an indicator of an underlying medical condition or physical abnormality that necessitates medical attention (Kesztyüs, Brucher, and Kesztyüs 2022).

The surface of the human body emits infrared radiation, which can be precisely measured within specific wavelengths using an infrared detector (Lahiri et al. 2012). In the realm of sports and exercise science, where human health promotion is a key focus, thermography finds extensive application. It serves as a valuable tool for evaluating athletic performance, investigating exercise-induced superficial vascular changes, monitoring injuries, and striving to develop optimal training techniques and outcomes (Gómez-Carmona et al. 2020; Gulyaev et al. 1995; Hildebrandt, Raschner, and Ammer 2010; Kasprzyk-Kucewicz et al. 2020; Kwon et al. 2010; Martínez-Nova et al. 2021; Perpetuini et al. 2021; Sousa et al. 2017; Zontak et al. 1998).

Gymnastics, considered the oldest organized sport, involves gymnasts performing routines that consist of various elements and combinations in competitive settings. The duration of routines performed on parallel bars, rings, uneven bars, high bar, and pommel horse typically ranges from 20 to 50 seconds, with an average duration of around 30 seconds. Each element is initially defined by the gymnast's position on a piece of apparatus, followed by their touch or grip on that apparatus. Finally, an element is described by the movement that leads to the final position (Aarkaev and Suchilin 2004).

Hand movements in gymnastics encompass two fundamental patterns: precision grip and power grip (Napier 1956). These gripping techniques are also employed in various other sports and activities such as fitness, sport climbing, crossfit, and more. However, there is a notable lack of knowledge concerning the effects of palm loading on the temperature of the hand and palm, taking into consideration environmental temperature variations.

In the context of a power grip, extrinsic muscles play a crucial role in generating movement and supplying the primary force required. In artistic gymnastics, where gymnasts' palms are exposed to frictional forces due to their interaction with the equipment, skin injuries can occur (Pušnik, Čuk, and Hadžič 2017; Zhang and Mak 1999).

One study (Zontak et al. 1998) demonstrated the influence of exercise on the skin temperature where loading was steady and led to a constant decrease in finger temperature. Later, in a resting stage the hands rewarmed as a result of the dominance and balance of thermoregulatory reflexes and hemodynamics. Finger temperature consistently decreases with graded loading due to the continuous dominant vasoconstrictor response. This response aims to reduce inflammation and swelling. In cases of intensive exercise or rehabilitation, local cooling has been employed as a method to alleviate these effects. The study by Kwon et al. (2010) investigated the impact of hand cooling on fatigue during intensive bench pressing.

Surprisingly, there is a limited body of research that focuses on the application of load to the palm or the handling of objects at room temperature within a specific timeframe. One study, conducted by Bennett, Goubran, and Knoefel in 2015, examined hand temperature after five minutes of pressure application, noting an immediate cooling effect upon load application.

Short-term loading effects on palm temperature were also explored in the context of different gymnastic ring shapes in a study by Pušnik et al. (2017). Following loading, variations in palm temperature decrease were observed, dependent on the specific ring shapes used. Additionally, the influence of magnesium carbonate on palm temperature was investigated during the execution of simple elements on uneven bars by Pušnik and Čuk in 2014. The study found that palm temperature increased when magnesium carbonate was used but remained constant when it was not.

Further insights were gained through research by Šibanc et al. (2021) during static and dynamic load applications while hanging on a high bar. In these experiments, temperatures initially decreased after load application, then began to rise. Within five minutes of measurement, the temperatures exceeded the levels recorded before the load was applied. Interestingly, the decrease in temperature was more pronounced after static load as compared to dynamic load, and for both types of loads, temperatures increased above their initial baseline levels before load application.

Support on the parallel bars is not only a basic element of artistic gymnastics, but it is also used in physiotherapy as an important tool for the rehabilitation process of patients with spinal cord injuries or acute strokes (Augustine and Nair 2021; Rowald et al. 2022; Shulga et al. 2020; Spiess, Steenbrink, and Esquenazi 2018). Furthermore, the parallel bars are versatile sports equipment that extends beyond competitive gymnastics. They serve as essential apparatus in home training, and also in recreational sports and physical education in schools (Kovač et al. 2011; Rasmussen 1971), where, according to the curriculum, children learn elements, such as hanging and supporting.

There are some studies on the palm temperature during hanging, swinging in hanging and performing different elements on rings or parallel bars (Pušnik and Čuk 2014; Pušnik et al. 2017; Šibanc et al. 2021), but there is still a lack of studies on the palm temperature and its differences after different loads. Therefore, in our study we have investigated the temperature differences in the palm after dynamic and static loads during the support on parallel bars. It is a frequently performed element, but we do not have data on the temperature distribution of the palms, the most important and only contact with the apparatus. What is needed is not only data on the temperature distribution and difference immediately after the application of various loads, but also for a certain time after the application of the load, when the human body reacts and tends to return to the state before the application of the load. A study conducted by Šibanc et al. in 2021 investigated temperature differences in the palms following the application of a load while hanging. We now wish to acquire data regarding palm temperature when supporting and swinging on the parallel bars, involving both static and dynamic loads. In training routines, exercises must often be repeated, as highlighted by Aarkaev and Suchilin in 2004. However, a continual increase in palm temperature due to loading may raise concerns about the development of blisters on the palms. This type of data is useful to optimize training scheduling, exercise repetitions, and breaks to avoid skin injuries.

METHODS

We measured 38 healthy subjects (11 men and 27 women), students at the Faculty of Sport, University of Ljubljana,. They had a body weight of 72.2 kg (±12.5), they were 1.73 m (±0.10) tall, and were 22.1 years (±2.9) old. All participating subjects provided written informed consent, as we adhered to the principles outlined in the Declaration of Helsinki. The study was approved by the Ethics Committee of the Faculty of sport of the University of Ljubljana (12_2018).

The measurement protocol was developed and adapted on the basis of our hypotheses:

1. temperature of the palm decreases after the static load in support;
2. temperature of the palm increases after the dynamic load in the swing in support.

Each load lasted 30 seconds. The subjects' hand temperatures were measured before loading (indicated as "-30 s" in the following tables), immediately after loading (indicated as "0 s" in the following tables), and then for 5 min (indicated as "300 s" in the following tables) at 30-second intervals. Thus, 12 thermograms were recorded per subject and per loading. For thermography (see Figure 1), each subject was seated in a chair with hands on the table, backs of hands up, and on an insulating surface to prevent heat loss into the table. Fingers were approximately at the level of the heart. Subjects performed two tasks on parallel bars (wooden surface, vertical axis of the profile 5 cm ± 0.1 cm; horizontal axis of the profile 4 cm ± 0.1 cm (Fédération Internationale de Gymnastique, 2022)). The first task consisted of standing still in support for 30 seconds (Figure 2a), and the second task consisted of swinging in support (hereafter noted as “swings”) for 30 seconds (Figure 2b), where the swing range was fixed (30-45° from vertical). Subjects were assigned tasks randomly. The rest period between loads was the thermal imaging period. The tasks were performed with a cylindrical power grip. The measurements took place in the gymnasium at the Faculty of Sport, University of Ljubljana. For acclimatization at 23°C and a relative humidity of 40% in the gymnasium, all subjects were in the hall 15 minutes before the start of the first measurement. Before the measurements, subjects were asked not to smoke or drink alcohol for 24 hours, not to consume caffeine for 12 hours, and not to use creams or lotions on their hands for 12 hours (Fernández-Cuevas et al., 2015). There was no visible damage to the skin on their hands.

In the study we used a high-resolution thermal imager (FLIR T650sc FLIR Systems, Oregon, USA). The specified accuracy of the imager in the temperature range of 5 °C to 120 °C is ±1% of reading or 1 °C, at environmental temperatures of 10 °C to 35 °C. Prior to our research, the imager was calibrated at LMK - Laboratory of Metrology and Quality at the Faculty of Electrical Engineering, University of Ljubljana[1], to confirm its accuracy, which

[1] LMK is the holder of a national standard for thermodynamic temperature in Slovenia. As a national laboratory for temperature and relative humidity and accredited calibration laboratory it holds CMCs – calibration measurement capabilities

was better in the applied range. The temperature corrections obtained during calibration were applied accordingly. The imager has an uncooled detector (microbolometer), operates in the spectral range of 7.5 µm to 14 µm, and has the noise equivalent temperature difference NETD < 30 mK. The imager has a wide-angle lens 45° (f = 13.1 mm), with the field of view FOV 45° x 34° mm, spatial resolution 1.23 mrad (IFOV), continuous zoom (8x) and the minimum focus distance 15 cm. The emissivity can be adjusted in steps of 0.01 from 0.10 to 1.00. Image analysis was performed in the associated software environment (ResearchIR Max from (FLIR Systems, Oregon, USA), which allows analyses of various regions of interest (ROIs), e.g. areas, spots, automatic detection of hot/cold spots, temperature differences, isotherms, line profiles, alarms, etc. The imager resolution is 640x480 pixels, which corresponds to 307200 pixels in a single thermogram. The high resolution is important for a detailed analysis of the selected ROIs (Perić et al. 2019).

Each hand we divided into nine ROIs (polygons) as shown in Figure 3: palm, thumb, proximal phalanx index finger, distal phalange, middle finger proximal phalanx, middle finger distal phalanges, ring finger proximal phalanx, ring finger distal phalanges and little finger. ROIs shown in Figure 3 are listed in Table 1 and the abbreviations are used in the following text for each ROI. Polygons 1-9 represent the right hand and polygons 11-19 represent the left hand. The boundaries of ROI are at least 7 pixels away from the edge of the observed area to minimize the influence of the size-of-source effect (Pušnik and Geršak 2021), a rather important issue in thermal image analysis, which was taken into account when drawing the ROIs.

From ResearchIR, data for each ROI were exported to Excel (Microsoft corp.): mean (XA), standard deviation (SD), maximum and minimum, number of pixels. We calculated two new variables : the sum of the temperature differences of the section before the task until the end of the 5th minute using the equation $\Sigma(T_n\text{-}T_n\text{+}1)$, where n represents the time series; and the temperature differences from the first to the last measurement using the equation $T_1\text{-}T_n\text{+}1$.

We used SPSS 25.0 (IBM corp.) for statistical analyses: Kolmogorov-Smirnov test, means (XA), standard deviations (SD), standard errors (SE), for each sector variable. A paired Student's t-test and Spearman-Brown rank correlation (to determine the reliability of the measurement) were calculated to compare the temperature difference between support and swing in support, to compare the temperature difference between left and right sectors, and to compare the temperature difference between time series in each task. Excel software was used to generate the figures and graphs.

that are among the best in Europe and worldwide in the respective fields of measurement.

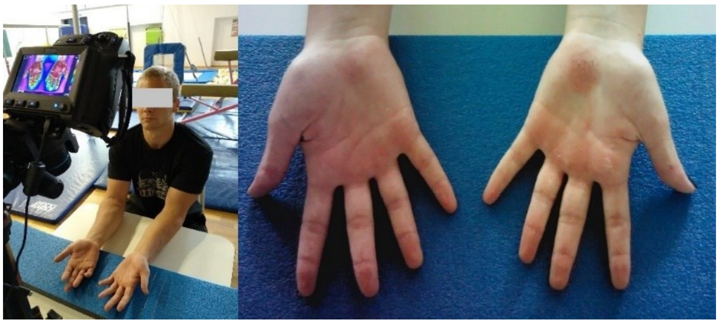
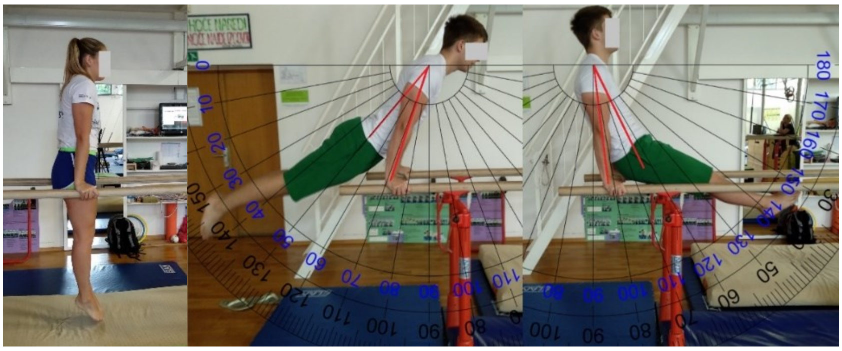


Figure 1. Camera setting for thermal imaging; position of hands during thermal imaging



(a) (b)

Figure 2. (a) Support and (b) Swing in support.

Figure 3. Thermal image and ROIs on hands.

Table 1.

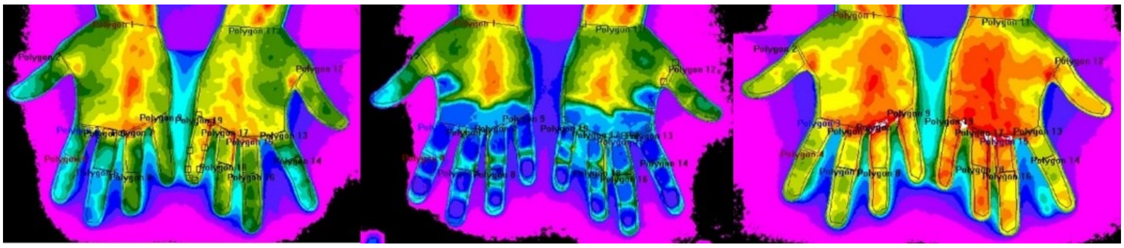
ROIs on each hands.

Polygon Right	**Polygon Left**	**ROI**	**Abbreviation Right**	**Abbreviation Left**
Polygon 1	Polygon 11	Palm	P-R	P-L
Polygon 2	Polygon 12	Thumb	T-R	T-L
Polygon 3	Polygon 13	Index Finger Proximal Phalanx	IPP-R	IPP-L
Polygon 4	Polygon 14	Index Finger Distal Phalanges	IDP-R	IDP-L
Polygon 5	Polygon 15	Middle Finger Proximal Phalanx	MPP-R	MPP-L
Polygon 6	Polygon 16	Middle Finger Distal Phalanges	MDP-R	MDP-L
Polygon 7	Polygon 17	Ring Finger Proximal Phalanx	RPP-R	RPP-L
Polygon 8	Polygon 18	Ring Finger Distal Phalanges	RDP-R	RDP-L
Polygon 9	Polygon 19	Little Finger	LF-R	LF-L

RESULTS

The variables were not normally distributed according to the Kolmogorov-Smirnov test. As noted in other studies and therefore expected, no significant difference was found between men and women. The results in our study are presented for the left hand (there were no significant differences between the left and right hands, as can also be seen in Figure 4).

Table 2 shows the temperature difference immediately after load application during support and swing, and 300 seconds after load application, while Figure 4 is presented as an example of temperatures after support. All values decrease immediately after load application for all ROIs, for both loads. The temperature drop is smaller after swinging than after propping, but the difference between support and swing is not significant. The greatest decrease of temperature immediately after load is after swinging for the little finger and the distal phalanges of the ring and middle fingers, and the greatest difference, although not significant, is for the thumb (see also Figure 6).



(a) (b) (c)

Figure 4. Example of Palm Temperature (a) before load, (b) immediately after support, (c) 300 s after support

Significant temperature differences by time and region before and after load application for 30 seconds each in a 5-minute period, where $p < 0.05$ indicates a significant difference in temperature by a paired t-test are shown in Table 3. After support for the palm, thumb, and all three distal phalanges, the temperature difference was significant up to 180 s immediately after loading, and up to 210 s for the little finger. After support for all three proximal phalanges, the temperature difference was significant over a longer period of time, between 240 s and 270 s. After swing for the palm, thumb, and index finger proximal phalanx, the temperature differences were significant for up to 240 s; for the other ROIs, the temperature differences were significant for a longer period, up to 270 s. For all distal phalanges and the little finger after swings the difference was not significant at 240 s.

The temperature differences between support and swing are shown in Table 4. For palm there was no significant difference, seen also in Figure 6. Immediately after the application of the load, a significant difference between loading was observed only for the thumb, where there was a significant difference of up to 120 s (and no significant difference at 90 s). For all three proximal phalanges, a significant difference was from 30 s (60 s for middle finger proximal phalanx) to 240 s; from 30 s to 210 s for distal phalange of index and middle finger, and from 30 s to 180 s for ring finger distal phalange and little finger.

The temperature differences between support and swing are shown in Table 4. For palm there was no significant difference, seen also in Figure 6. Immediately after the application of the load, a significant difference between loading was observed only for the thumb, where there was a significant difference of up to 120 s (and no significant difference at 90 s). For all three proximal phalanges, a significant difference was from 30 s (60 s for middle finger proximal phalanx) to 240 s; from 30 s to 210 s for distal phalange of index and middle finger, and from 30 s to 180 s for ring finger distal phalange and little finger.

Table 2.

Temperature difference for support and swing right after load ($XA0_{SU}$-$XA0_{SW}$) and after 300 seconds ($XA300_{SU}$-$XA300_{SW}$) for left hand by ROI.

Variable	XA0/°C	$XA0_{SU}$-$XA0_{SW}$ /°C	p(ttest) 0/°C	XA300/°C	$XA300_{SU}$-$XA300_{SW}$ /°C	p(ttest) 300/°C
Support P[a]-L	-2.05	-0.13	0.550	0.39	0.02	0.244
Swing P[a]-L	-2.18			0.41		
Support T[b]-L	-1.79	-0.52	0.743	0.34	0.02	0.156
Swing T[b]-L	-2.31			0.36		
Support IPP[c]-L	-2.03	-0.15	0.456	0.34	-0.33	0.710
Swing IPP[c]-L	-2.18			0.01		
Support IDP[d]-L	-2.22	-0.17	0.274	0.46	-0.24	0.339
Swing IDP[d]-L	-2.39			0.22		
Support MPP[e]-L	-1.91	-0.15	0.552	0.39	-0.3	0.718
Swing MPP[e]-L	-2.06			0.09		
Support MDP[f]-L	-2.26	-0.17	0.275	0.53	-0.23	0.337
Swing MDP[f]-L	-2.43			0.30		
Support RPP[g]-L	-1.88	-0.18	0.523	0.47	-0.31	0.729
Swing RPP[g]-L	-2.06			0.16		
Support RDP[h]-L	-2.56	-0.23	0.313	0.54	-0.25	0.312
Swing RDP[h]-L	-2.79			0.29		
Support LF[i]-L	-2.37	-0.29	0.556	0.56	-0.23	0.400
Swing LF[i]-L	-2.66			0.33		

Note: [a] P = Palm; [b] T = Thumb; [c] IPP = Index finger proximal phalanx; [d] IDP = Index finger distal phalanges; [e] MPP = Medial finger proximal phalanx; [f] MDP = Medial finger distal phalanges; [g] RPP = Ring finger proximal phalanx; [h] RDP = Ring finger distal phalanges; [i] LF = Little finger.

XA0= Sum temperature difference right after applying load, XA300 = Sum temperature 300 seconds after applying load

Table 3.
Differences based on t-test in temperature by time and region for support and swing for the left hand.

Variable	−30 / s	0 / s	30 / s	60 / s	90 / s	120 / s	150 / s	180 / s	210 / s	240 / s	270 / s	300 / s
Support P[a]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	0.116	0.155	0.320	0.088
Swing P[a]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.003**	**0.002**	**0.000**	**0.029**	0.129	0.871
Support T[b]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.008**	**0.016**	0.076	0.085	0.552	0.144
Swing T[b]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.003**	**0.001**	**0.001**	**0.009**	0.194	0.748
Support IPP[c]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.003**	**0.027**	0.878	0.440
Swing IPP[c]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.015**	**0.001**	**0.003**	**0.016**	0.326	0.635
Support IDP[d]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.014**	**0.016**	0.059	0.341	0.843	0.103
Swing IDP[d]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.014**	**0.002**	0.064	**0.021**	0.569
Support MPP[e]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.010**	**0.026**	**0.010**	0.588
Swing MPP[e]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.005**	**0.001**	0.216
Support MDP[f]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.004**	**0.008**	0.056	0.291	0.631	0.147
Swing MDP[f]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.007**	0.087	**0.007**	0.510
Support RPP[g]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.005**	**0.001**	0.064	0.505
Swing RPP[g]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.046**	0.175
Support RDP[h]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.017**	**0.025**	0.372	0.205	0.702	0.057
Swing RDP[h]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.002**	**0.001**	**0.011**	0.169	**0.024**	0.679
Support LF[i]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.008**	**0.018**	**0.038**	0.617	0.129	0.058
Swing LF[i]-L		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.017**	0.072	**0.011**	0.826

Note: [a] P = Palm; [b] T = Thumb; [c] IPP = Index finger proximal phalanx; [d] IDP = Index finger distal phalanges; [e] MPP = Medial finger proximal phalanx; [f] MDP = Medial finger distal phalanges; [g] RPP = Ring finger proximal phalanx; [h] RDP = Ring finger distal phalanges; [i] LF = Little finger.

Table 4.
Differences based on ttest between the support and swing time series (where stated values indicate difference by t-test (p < 0.05)) for left hand.

Variables	−30 / s	0 / s	30 / s	60 / s	90 / s	120 / s	150 / s	180 / s	210 / s	240 / s	270 / s	300 / s
P[a]-L		0.251	0.118	0.145	0.512	0.476	0.458	0.486	0.699	0.783	0.850	0.884
T[b]-L		**0.001**	**0.003**	**0.013**	0.059	**0.035**	0.121	0.179	0.380	0.489	0.638	0.968
IPP[c]-L		0.243	**0.027**	**0.017**	**0.008**	**0.006**	**0.003**	**0.008**	**0.010**	**0.020**	0.055	0.125
IDP[d]-L		0.286	**0.014**	**0.002**	**0.003**	**0.002**	**0.008**	**0.011**	**0.023**	0.055	0.141	0.388
MPP[e]-L		0.145	0.063	**0.014**	**0.020**	**0.005**	**0.008**	**0.012**	**0.035**	**0.042**	0.064	0.187
MDP[f]-L		0.319	**0.021**	**0.002**	**0.003**	**0.002**	**0.006**	**0.015**	**0.027**	0.054	0.145	0.377
RPP[g]-L		0.153	**0.031**	**0.007**	**0.004**	**0.002**	**0.009**	**0.016**	**0.030**	0.038	0.051	0.170
RDP[h]-L		0.235	**0.016**	**0.002**	**0.003**	**0.004**	**0.013**	**0.026**	0.075	0.094	0.208	0.467
LF[i]-L		0.065	**0.005**	**0.001**	**0.006**	**0.005**	**0.012**	**0.039**	0.078	0.272	0.277	0.542

Note: [a] P = Palm; [b] T = Thumb; [c] IPP = Index finger proximal phalanx; [d] IDP = Index finger distal phalanges; [e] MPP = Medial finger proximal phalanx; [f] MDP = Medial finger distal phalanges; [g] RPP = Ring finger proximal phalanx; [h] RDP = Ring finger distal phalanges; [i] LF = Little finger.

Figure 5 shows the mean temperature differences of all measured subjects for support and swing in support for the right and left hands for all measured ROIs.

There was little difference between the right and left hands for both loads, while the significant difference between the loads is shown in Figures 5 and 6, although Table 2 showed no significant differences immediately after the load was applied and 5 minutes later. For all ROIs, the temperature was higher 300 seconds after loading than before loading. After all loads, the ring finger distal phalanges had the greatest temperature drop (as also seen in Table 2); the palm recovered faster than all other fingers (1.5 minutes faster on average). For all ROIs, temperature recovered after bracing, and increased faster than after swings. In addition, the temperatures of the ROIs increased to greater values 300 seconds after support than after swings. After swings, the temperature decrease was larger than the temperature before loading.

As can be seen from the curves in Figure 5, the temperature rises above the initial value (before loading) for the support was between 100 seconds and 160 seconds after loading, while the temperatures of the ROIs after swings reached their initial values between 170 seconds and 250 seconds after loading. Temperature changes after support increased until 270 s and then began to decrease. A temperature decrease after swings was not observed after 300 seconds (except for the distal phalanges of the ring finger and the little finger on the left hand, as also shown in Figure 6).

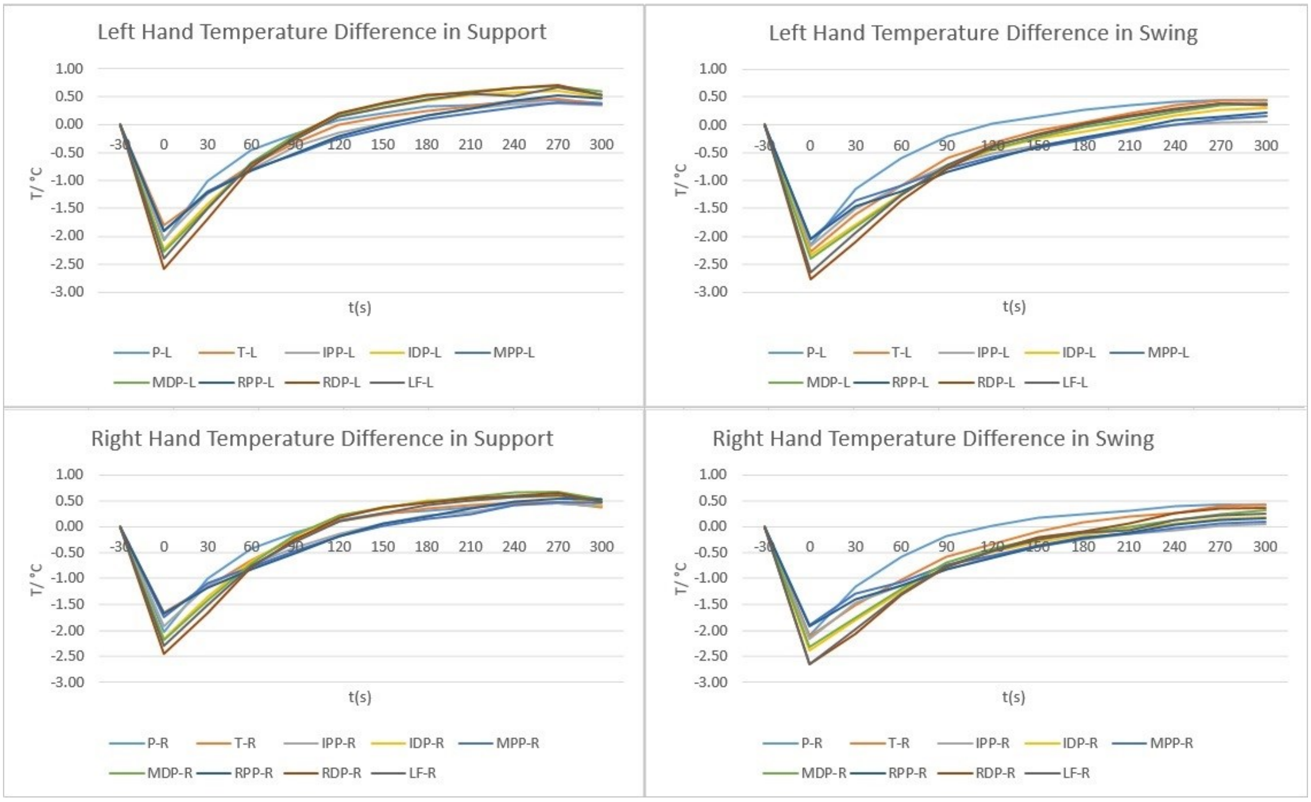


Figure 5. Temperature difference for the right and left hand during support and swings. The two graphs on the left side of the figure show the temperature differences for support, and the graphs on the right side of the figure show the temperature differences for swings. The top two diagrams show the left hand, while the bottom two diagrams show the right hand.


Palm
T/°C
t(s)
Support
Swing in Support
Thumb
Index Finger Proximal Phalanx
Index Finger Distal Phalange
Middle Finger Proximal Phalanx
Middle Finger Distal Phalange
Ring Finger Proximal Phalanx
Ring Finger Distal Phalange
Little Finger

Figure 6. Temperature differences of the left hand in support and swing for different ROIs. The graphs on the left side of the figure show the temperature values for the palm and all three proximal phalanges; the graphs on the right side show the values for the thumb, all three distal phalanges, and the little finger. The values for the index, middle and ring fingers are in the same row for each finger

Figure 6 shows the temperature difference between support and swing for each DOI separately. For the palm, there was no significant difference between support and swing in support, even for the thumb after 120 seconds (as also seen in Table 4). For the little finger and all distal phalanges, the temperature difference between support and swing in support was greater than for proximal phalanges. The increase in temperature above baseline was faster and greater after support than after swings, as can be seen in Figure 5. After support, distal phalanges of the index, middle, and ring fingers reached the initial temperature value after 90 seconds, while after swings they reached the initial value after 180 seconds. Only for the thumb, the temperature drop immediately after loading was different for support and swing (larger drop after swing by almost 1 °C compared to support). For all ROIs after support, temperature values begin to decrease after 270 seconds, which was not the case for temperature values after swing (except for the ring finger distal phalanges and little finger, as shown in Figure 5).

DISCUSSION

In our study, there was no significant difference in temperature distribution and no difference between the left and the right hands. The loads included in this study appeared to be symmetrical - supports and swings are symmetrical by positions and/or movements (compared to studies in artistic gymnastics that consider asymmetries (Čuk and Marinšek 2013; Dallas et al. 2022; Pajek et al. 2016)), and did not include movements such as hanging on one hand, rotations around the transverse or longitudinal axis. As a consequence, load application had no influence on the temperature differences of the palms due to possible body asymmetries. Something similar was observed in the study where temperatures were measured after hanging on high bar (Šibanc et al. 2021).

As shown in Tables 2, 3 and Figures 4, 5, and 6, the temperature decreased significantly immediately after the application of static and dynamic loading for all ROIs. In our measurements, the thumb was the only part of the hand where the temperature difference between support and swing was significant immediately after loading, implying that different loads affect the thumb differently. The skin contact with the bar and thumb was mainly on the inner side of the thumb, and the angle of our settings was not ideal for measuring the temperature of the thumb. Although thumb temperature decreased the least after bracing (also seen in a study for hang (Šibanc et al. 2021)– meaning that in both studies this occurred after a static load was applied), the temperature decrease after swings was the smallest for the proximal phalanges of the ring and middle fingers. The greatest temperature decrease was for the ring finger and distal phalanges after both loads. This implies that the distal phalanges mainly provide a secure grip, and balance the body on the bar. Further studies are recommended to confirm these results, although as personally experienced by authors, the distal phalanges of the ring finger are more stressed during bracing and swings, and the thumb ensures greater balance during the execution of swings than during support. Following the cylindrical power grip, in which the thumb is oriented differently compared to digits 2-5, is an important anatomical feature of the hand that allows for this opposite orientation and a much stronger grip (Anon 2016). The difference between the proximal and distal phalanges can be seen in Figure 5.

According to Table 3, temperatures differed significantly for longer periods after swings. With the difference in the rate of temperature rise (also seen in the curves in Figure 5) and the temperature difference, the load was higher during swings; during support, the response to the temperature rise was slower and lower. After support, the palm is the only ROI where there was no significant difference between support and swing in any measured time. Corresponding to the different biomechanics of support and swings - in swinging, the body's centre of gravity oscillates from back to front, whereas in support, the centre of gravity is above the point of support (Čuk, Ivan and Karacsony 2016; Čuk 1996; Kolar, Kolar, and Štuhec 2002). The fingers play a different role in different positions of the swing, while the load on the palm remains similar in supports and swings, which explains our results.

The temperatures reach the values before applying the load much faster after support than after swings (Figure 5). After 5 minutes of load application, no significant temperature difference was observed (Table 3), and according to Figures 5 and 6, the temperatures started to decrease after reaching the highest value between 240 and 270 seconds. In a similar study (Šibanc et al., 2021), where palm temperatures were measured after hanging and swinging in the hanging position, the temperatures increased to a higher constant level 3 or 4 minutes after hanging. Similar trends were not observed after swinging in the hanging position. Further research on this issue is needed.

A possible explanation for the lower palm temperature could be reduced blood flow to the palm during the performance of elements in the hanging position (Pušnik et al., 2017). Blood flow in the skin is usually measured with a laser Doppler flowmeter or venous occlusion plethysmography. Advantages of this method include high temporal resolution (measurements are performed continuously) and specificity for cutaneous microcirculation. To evaluate and investigate this hypothesis further, future studies should also measure blood volume flow through the radial artery.

Support and swings on the parallel bars are fundamental elements in gymnastics used at various athletic levels and in rehabilitation. These elements are not limited to competitive sports but are widely employed to achieve various goals.

Although swings in support were not executed exactly as in competitive gymnastics in our study, learning the elements of artistic gymnastics is a long-term process. The most crucial factor in learning is the use of appropriate methodological progressions (Čuk, Ivan and Karacsony, 2016; Čuk, 1996), and teaching progressions should adhere to basic pedagogical principles. “Each progression step should include a movement structure similar to the desired element” (Kolar et al., 2002). This means that our research marks a fundamental beginning on this topic to understand the differences in hand temperature after different loads. It represents an ongoing extension of research on the hand (Šibanc et al., 2021), where loads in the hanging position were one of the main areas of investigation. Another extreme and fundamental position of interest to researchers is the handstand, in which the entire body is above the point of grasp. Given the increasing development of outdoor gyms and equipment, similar studies under outdoor conditions and on bars made of different materials (wood, metal, plastic) should be considered.

CONCLUSIONS

We are aware that there are still many hidden facts about our human activities that we do not know. Exercise and sport science is trying to uncover these facts. One of the hidden facts is how the skin of the human palm responds to different loads. In a previous study, we investigated hanging and swinging on the high bar, where the heart was positioned below the plane of the grip during hanging, and all blood vessels were vertically oriented (to simplify). However, contrary to our expectations, we observed a decrease in palm temperature after the exercise. In our current article, we explore support and the generation of momentum during support, where the heart is positioned above the grip, and the blood vessels follow two distinct directions: first, vertically upward from the heart, and then vertically downward. This phenomenon has not been observed in previous literature. To ensure results that are comparable to those of the aforementioned study, it was necessary to replicate the measurement methods, enhancing the validity and reliability of our research. By doing so, we also enable other researchers to replicate our work.

The results are generally similar in the sense that the temperature decreases after the load and increases during regeneration. All the grips used in the study required the subject to handle their entire body mass. However, ergonomics may also benefit from these results, as the duration the palm skin is under load and the time it takes to recover to baseline are essential factors for a safe environment, not only in sports but also in the workplace.

To conclusively establish the general knowledge regarding expected changes in palm temperature, further studies should be conducted with subjects in a handstand position, with the heart directly over the vertical orientation of the grip.

Artistic gymnastics is a sport, but its elements find wide application in recreational sports, physical education classes in schools, home-based fitness, and more. In recent years, outdoor gyms with various exercise equipment have gained popularity, with parallel bars being one of the preferred choices for developing muscle strength (Fernandez-Rodriguez et al. 2020). The use of parallel bars in rehabilitation programs is also on the rise. Further research on this topic is necessary to comprehend the temperature dynamics in the palms.

Our study revealed a decrease in palm temperature immediately after the load was applied, followed by a subsequent increase. Within 5 minutes, higher values were reached compared to the pre-load state. As a result, our first hypothesis is accepted, and the second hypothesis is rejected. The temperature difference after swings is greater than after support. Different loads exert distinct effects on hand temperature. After support, the temperature decrease was the least pronounced for the thumb. The distal phalanges play a crucial role in providing a secure grip and maintaining balance on the bars, hence the temperature decrease was most significant in these regions.

STRENGTH AND LIMITATIONS

Because of the large database, tables including all values were not included.

According to our results, further studies should be conducted to obtain more information about the time when the skin temperature returns to its pre-load value. In the study where the load was suspended from the high bar, we began to question the effectiveness of rest in preventing skin injury. Further research is needed to determine when the skin is ready for the next load without the risk of potential skin damage. It may even be possible to calculate and plot a cooling curve for the hands. This information can be crucial for coaches and athletes during the training process.

While the values for the thumb are accurate for this measurement angle, given that the main contact with the apparatus occurs on the inside of the thumb, taking separate measurements from a different angle would yield different temperatures. To obtain more precise data, measurements of the thumb should be taken from a different angle.

To observe small temperature differences, typically on the order of a tenth of a degree Celsius, one should not rely on non-contact temperature devices, as inexpensive radiation thermometers and thermal imagers are not capable of consistently and accurately measuring such temperature differences. Therefore, the use of an accurate and calibrated non-contact temperature device is necessary.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethical Commission of the University of Ljubljana's Faculty of Sport (13. 9. 2018; 12_2018).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from its author.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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RELATION BETWEEN DOWNWARD AND UPWARD PHASES ON THE TRAMPOLINE BED DURING JUMPING

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Abstract

The time of flight in trampoline competitions relies on the jumping movement executed on the trampoline bed, which can be divided into a downward phase and an upward phase. These two phases of the jumping movement exhibit distinct characteristics. Therefore, the aim of this study was to investigate fundamental data regarding the vertical deflection length, time, velocity, and force involved in the vertical movement on the trampoline bed. The study involved ten trampoline athletes, including participants in the All Japan Championships and members of the Japanese national team. These athletes were instructed to perform 15 consecutive jumps on the trampoline bed, starting from a standing-still position, aiming for maximum height, and maintaining a straight trajectory in the center of the trampoline bed.

The findings revealed that all measured parameters were significantly greater in the downward phase compared to the upward phase. Interestingly, it was observed that the jumping height during a prolonged flight is predominantly determined by the actions in the downward phase of the trampoline bed, rather than the upward phase. As a result, the downward phase should be executed as an active jumping movement.

Keywords: *trampoline jumping, downward phase, upward phase.*

INTRODUCTION

Trampoline exercises enable athletes to achieve jumps exceeding 3 meters in height using a specialized trampoline apparatus (Ito et al., 2000). In trampoline competitions, athletes are scored based on the time spent in the air, as outlined in the Code of Points for Trampoline Gymnastics (2022-2024 CoPTG, 2021). Consequently, athletes strive for jumps with extended flight durations.

The competition trampoline apparatus typically comprises a trampoline bed equipped with 118 metal springs and enclosed within a metal frame, featuring a nylon net (EUROTRAP LTD.). In this gravitational environment, the mechanical vertical jump height primarily hinges on the initial jump velocity. Subsequently, the jumper undergoes free fall before landing. When executing jumps on a trampoline, it becomes crucial to maximize the jumping velocity by harnessing the trampoline bed's elastic properties. Therefore, the jumping velocity is expected to be influenced by the trampoline bed's restoring force, as it rebounds from its lowest-sinking position back to its original state (Matsushima, 2021).

Previous studies investigating the relationship between trampoline beds and jumping have utilized image analysis of test subjects' jumps to determine the length of vertical deflection on the trampoline bed and its correlation with time of flight (Yamada & Kumayama, 2012; Yamamoto et al., 1992). Ito et al. (2000) conducted research involving four subjects with varying levels of trampoline performance and found that individuals with longer vertical deflection on the trampoline bed did not necessarily achieve greater jump heights. Matsushima (2021) identified a significant positive correlation between the upward velocity, measured from the trampoline bed's lowest position to its return to the original position, and the time of flight. Furthermore, the length of vertical deflection on the trampoline bed, along with upward time and velocity from the lowest position to the original position, were employed as indices to characterize the trampoline bed's impact on the jumping movement.

In trampoline jumping movements, the downward phase occurs as the jumper descends from the landing to the lowest point, during which the trampoline bed is pushed downward through the extension of the hip and knee joints. Near this lowest point, the jumper typically adopts a near-straight posture and subsequently propels themselves upward directly, thanks to the restoring force of the trampoline bed returning to its original position (Ueyama & Fuchimoto, 2007; Matsushima et al., 2017; Matsushima & Yano, 2018a; Jingguang Qian et al., 2020). Essentially, the jumping motion on the trampoline exhibits significant variations between the downward and upward phases, with the lowest point serving as the boundary.

The length of vertical deflection of the trampoline bed and the velocity of the upward movement are predominantly determined by the downward phase of the jumping movement, commencing with the landing. Consequently, this study aimed to explore the relationship between the downward phase of the trampoline bed and the subsequent upward phase, wherein the trampoline bed returns to its original position. The objective was to gather fundamental data on the vertical movement of the trampoline bed during the jumping process.

METHODS

The subjects were ten trampoline athletes, 5 females and 5 males, participants in the All Japan Championships and Japanese national team members (age: 19.5 ± 1.6 years, height: 163.9 ± 6.7 cm, weight: 58.5 ± 8.2 kg, athletic career: 7.9 ± 4.2 years). Prior to participating in the experiment, the details of the experiment were fully explained to the subjects using the protocol of the Mukogawa Women's University research ethics review committee. Written consent was then obtained from the subjects.

The trampoline apparatus utilized in this experiment was a 4 x 4 Euro trampoline, measuring 5.20 meters in length, 3.05 meters in width, and 1.15 meters in height. This trampoline was manufactured by EUROTRAMP, a company approved by the International Gymnastics Federation.

For the trials, subjects were given instructions to execute 15 consecutive jumps on the trampoline bed, commencing from a stationary position, with the aim of achieving maximum height. These jumps were to be executed in a straight and upward trajectory while remaining centered on the trampoline bed. To ensure readiness and prevent injuries, subjects underwent a thorough warm-up period before the trials.

A compact tension/compression load cell (KYOWA ELECTRONIC INSTRUMENTS CO., LTD.: LUX-B-2KN-ID) was attached between the spring (17th spring counting from the right end) and the frame at the center of the trampoline apparatus's side. The points of landing (where the subject made contact with the trampoline bed), the lowest point (when the trampoline bed extended farthest downward), and the takeoff (when the subject left the trampoline bed) were determined through analysis software (KISSEI COMTEC CO., LTD.: BIMUTAS II) based on the output of the load cell (see Figure 1).

The load cell's output when connected between the trampoline apparatus and the spring ranged from 3.000 to 3.015 V. We considered the point at which the output of the load cell first exceeded 3.016 V as the landing, the highest recorded value as the lowest point, and the moment when the output dropped below 3.015 V as the takeoff. In other words, the landing and takeoff correspond to the moments when the feet make contact with and leave the trampoline bed, respectively. The downward phase was defined as the interval between landing and the lowest point, while the upward phase encompassed the period between the lowest point and takeoff. Data were sampled at a frequency of 1000 Hz.

One video camera (CASIO COMPUTER CO., LTD.: EX-F1) was placed at the side of the trampoline apparatus to capture the jumping motion at a 300 fps and 1/1000 s shutter speed. The video camera was placed at the same height as the trampoline bed (1.155m) and at a distance of 5.550 meters from the center of the trampoline bed's lateral side. Trials were recorded and analyzed by the two-dimensional motion analysis method (Q'sfix CO., LTD.: Frame-DIAS4). The coordinate system used in this study was the X-axis for the horizontal direction and Y-axis for the vertically upward direction. The reference points and reference lengths for the calibration were set at both ends of the trampoline bed (4.280m) on the camera side in the X-axis direction. The discrepancy between the actual coordinates of the reference point and the coordinates calculated using the two-dimensional motion analysis method's real-length conversion method ranged from 1 to 2 millimeters.

The load cell's output was recorded on a PC. The durations from landing to the lowest point and from the lowest point to takeoff, as determined from the load cell's output, were calculated and synchronized with the landing in the motion analysis software video. To achieve this synchronization, the time closest to the calculated time from the load cell data, sampled at 1000 Hz, was selected to match the time in the motion analysis software, which operated at 300 frames per second (fps).

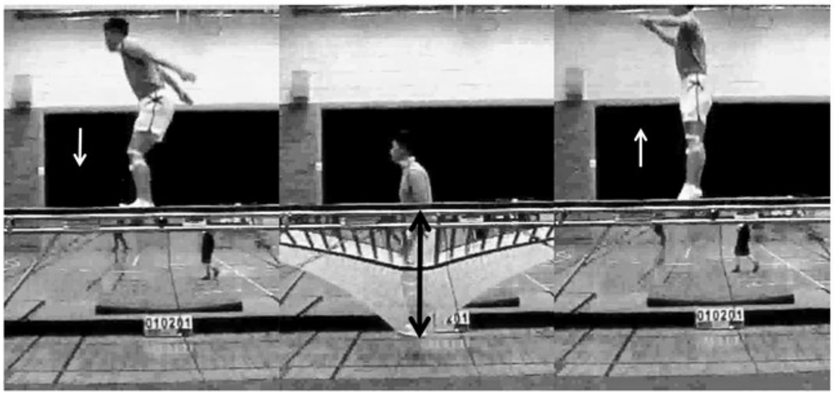

Figure 1. Definitions of the jumping phases.

Of the 15 trial jumps, 10 jumps, from the 6th to 15th jump, were included in the analysis. In trampoline competitions, the time of flight of athletes is measured based on the duration when the trampoline bed doesn't sink. Therefore, in this study, we used the time of flight (t, in seconds) derived from the load cell output data. This time represents the interval from when the subject takes off from the trampoline bed to when they land.

Additionally, we calculated the downward time (t_1, in seconds) from landing to the lowest point and the upward time (t_2, in seconds) from the lowest point to takeoff.

We determined the length of vertical deflection (l, in meters) of the trampoline bed by digitizing the lowest point and takeoff using motion analysis software. To calculate the velocity of downward movement (v_1, in meters per second) from landing to the lowest point of the trampoline bed (as per formula (1)), or the velocity of upward movement (v_2, in meters per second) from the lowest point of the trampoline bed to takeoff (as per formula (2)), we divided the length of vertical deflection (l, in meters) of the trampoline bed by the corresponding time (t_1 or t_2 in seconds)).

The average downward force (f_1 (N)) and upward force (f_2 (N)) for the downward phase were calculated using formula (3) and formula (4) respectively.

The mass (m (kg)) is the body weight. The velocity (v_3) immediately before landing on the trampoline bed from the highest point of the jump and the velocity (v_4) immediately after taking off from the trampoline bed were calculated using formula (5):

$$v_1 = l / t_1 \tag{1}$$

$$v_2 = l / t_2 \tag{2}$$

$$f_1 = (mv_3) / t_1 \tag{3}$$

$$f_2 = (mv_4) / t_2 \tag{4}$$

$$v_{3,4} = \sqrt{2g(g\, t^2 / 8)} \tag{5}$$

Each calculated value is presented as the mean ± standard deviation. We employed statistical analysis, including paired t-tests, to compare the means of each parameter between the downward and upward phases. Pearson's correlation coefficient was used to assess the correlations between different variables. A significance level of $p < 0.05$ was applied, and the analysis was conducted using Microsoft Excel 2016.

RESULTS

The calculated means ± standard deviations of time of flight (t (s)), length of vertical deflection (l (m)), downward time (t_1 (s)), upward time (t_2 (s)), downward velocity (v_1 (m/s)), upward velocity (v_2 (m/s)), downward force (f_1 (N)), and upward force (f_2 (N)) are presented in Table 1.

The downward time was significantly shorter than the upward time ($p < 0.01$). The downward velocity was significantly faster than the upward velocity ($p < 0.01$). The downward force was significantly greater than the upward force ($p < 0.01$).

As shown in Figure 2, correlations were shown between the time of flight and each variable.

Table 1
The measured values (mean ± standard deviation).

Time of flight (s)	Length of vertical deflection (m)	Downward time (s)	Upward time (s)
1.657 ± 0.129	0.842 ± 0.074	0.156 ± 0.011	0.169 ± 0.010

Downward velocity (m/s)	Upward velocity (m/s)	Downward force (N)	Upward force (N)
5.421 ± 0.601	5.000 ± 0.467	3034 ± 582	2821 ± 483

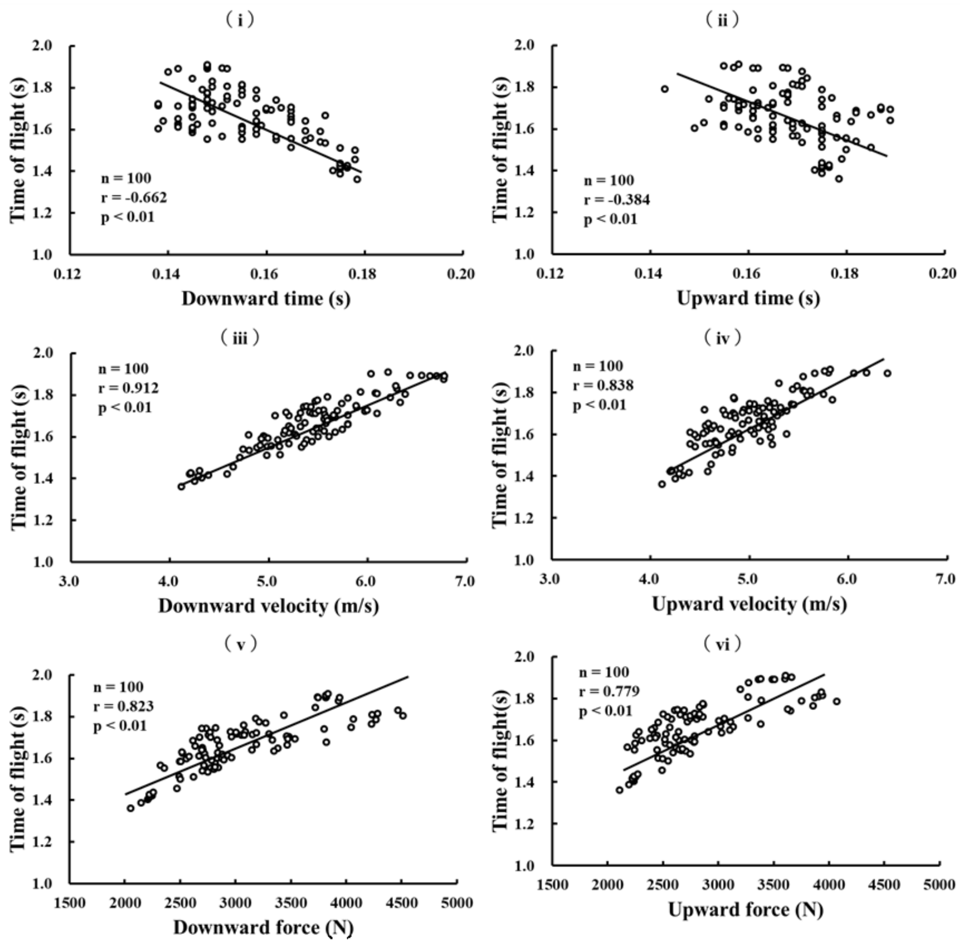

Figure 2. Correlation between the time of flight and downward and upward phases of time, velocity, and force.

DISCUSSION

A competitive trampoline bed is known for its remarkable elasticity, which allows it to stretch significantly during jumping movements. This elasticity plays a crucial role in facilitating high vertical jumps by utilizing the bed's restoring force to return to its original position.

In our study, we focused on comparing the downward and upward phases of the trampoline bed. We observed that the downward phase was notably shorter, faster, and stronger than the upward phase. During the downward phase, the extension of the hip and knee joints is more pronounced compared to the upward phase. Additionally, the trampoline bed experiences downward pressure due to the dorsiflexed position of the ankle joint (Matsushima & Yano, 2018b).

In the downward phase, the knee and hip joints contribute to generating substantial force, while the ankle joint, in its dorsiflexed position, exerts prolonged pressure on the trampoline bed. The greater range of motion in hip and knee joint extension during the downward phase resulted in significant differences in time, velocity, and force when compared to the upward phase.

It's worth noting that leg extensor strength (Ito et al., 2000) and anaerobic power (Baba, 2019; Baba, 2021) have a significant impact on increasing the vertical deflection length of the trampoline bed.

In terms of correlations with time of flight, all variables showed higher correlation coefficients during the downward phase compared to the upward phase (Figure 2). This suggests that the downward phase of the trampoline bed may influence the upward phase. During the upward phase, several factors, including frictional forces and the conversion of energy into vibrations, may contribute to the observed lower velocity and force compared to the downward phase.

In the downward phase, the jumping movement is active, as it involves pushing down on the trampoline bed. In contrast, the upward phase is passive, characterized by straightening the body at the lowest point and receiving the restoring force from the trampoline bed. Consequently, both velocity and force in the upward phase tend to be inferior to those in the downward phase. Gravity also plays a role in this difference.

The quality of the jumping movement during the downward phase and the skill of pushing down on the trampoline bed likely determine the initial velocity and time of flight. Matsushima (2021) categorized trampoline athletes' jumping movements based on two variables: the length of vertical deflection and upward time. Athletes with longer vertical deflection lengths and shorter upward times demonstrate superior jumping skills. It's worth noting that these jumping skills are also essential during the downward phase.

To enhance lower extremity movements for rapid pushes on the trampoline bed, power training is crucial. For instance, previous research has indicated that powerlifting training can improve lower extremity power output (Chiu, et al., 2009; Hori, et al., 2009).

The elastic trampoline bed becomes more elastic as the length of vertical deflection increases. Incremental load testing was performed in this study. It's important to note that the averages within each phase were calculated for all variables except the length of vertical deflection. Consequently, the maximum values for time, velocity, and force are expected to be higher than those reported in this study.

In a previous study by Yamamoto et al. (1990), a force plate was positioned on one of the legs of a mini-trampoline apparatus to measure the floor reaction force during free-fall. Their results revealed the existence of two maximum values of the vertical reaction force. Notably, the force required increases as the trampoline bed is pushed down to its lowest point.

CONCLUSIONS

The jumping height for a long flight is determined by the downward phase of the trampoline bed rather than the upward phase. The downward phase was significantly shorter, significantly faster, and significantly stronger than the upward phase. The downward phase should be performed as an active jumping movement.

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THE EFFECTIVENESS OF DIFFERENT HANDSTAND PLACEMENT TECHNIQUES IN HANDSTAND BALANCE CONTROL AND GENDER DIFFERENCES

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Abstract

The purpose of the study was twofold: (a) to examine the impact of various finger placements and utilization on the quality, control, and overall efficiency of handstand performance, and (b) to investigate potential gender differences in relation to these factors. Thirty-one young competitive gymnasts (15 males; age: 12.60 ± 2.08, and 16 females; age: 13.31 ± 2.21) participated in this study. A portable posturographic digital platform was used to record hand area (cm²), maximal pressure (kPa), CoP (center of hand pressure) sway area (mm²), CoP linear distance displacement (mm) and CoP velocity. Derived data were analyzed in an integrated software module (Foot Checker, version 4.0). The intra-class correlation coefficient and the coefficient of variation supported the reliability of the measurements. One-way MANOVA showed better balance control for all gymnasts for the handstand with flat palms and joined and fully stretched fingers, followed by that of flat palms and wide open and fully stretched fingers, and wide flat palms and open and flexed fingers. Results from one-way MANOVA indicated no differences between males and females in age, training age, body mass, height, and body mass index. With control for the effects of age, training age, personal characteristics and hand area of support in place, females had better balance control compared to males based on differences in CoP sway area, CoP linear distance displacement, and CoP velocity. Despite the study's limitations, the findings contribute to the existing literature on balance control techniques in handstands in relation to gender differences. The study provides recommendations for more effective training for coaches and suggests avenues for future research.

Keywords: *handstand, balance control, artistic gymnastics, males, females.*

INTRODUCTION

The handstand is a non-acrobatic skill (element), in which the body of the gymnast is maintained in the equilibrium position with all parts aligned vertically, with the hands pressed onto the floor or another apparatus (MAG; WAG, Code of points, Fédération Internationale de Gymnastique, 2020a, b). The handstand is considered a fundamental gymnastics skill for both male and female gymnast because it plays a crucial role in the quality and safety of gymnastics skill execution and the potential of gymnasts to develop and perform at a high level (Hedbávný, Sklenaříková, Hupka, & Kalichová, 2013; Uzunov, 2008; Živčić-Marković, Krističević, & Aleksić-Veljković, 2015). Maintaining balance in an error-free, and thus, stable manner during the handstand was the issue examined by several authors (Omorczyk, Bujas, Puszczałowska-Lizis, & Biskup, 2018; Slobonov & Newell, 1996; Sobera, Siedlecka, Piestrak, Sojka-Krawiec, & Graczykowska, 2007).

Performing a handstand with quality and balance control is more challenging biochemically when compared to an upright position. This is due to several factors: the smaller area of support provided by the palms and fingers, the increased distance between the base of support and the center of mass (CoM), and the lower and inverted position of the head (Hedbávný et al., 2013; Slobounov & Newell, 1996; Sobera, Serafin, & Rutkowska-Kucharska, 2019). To maintain balance in a handstand, it necessitates the coordination of various muscles involved in joint movements, such as wrists, elbows, shoulders, and hips; the management of different body shapes, and the control of the movement of the CoM (Blenkinsop, Pain, & Hiley, 2017; Gautier, Thouvarecq, & Chollet, 2007; Kerwin & Trewartha, 2001; Slobounov & Newell, 1996; Uzunov, 2008; Yedon & Trewartha, 2003). This entails maintaining a properly aligned body shape and balancing it over the wrists, employing a cohesive approach known as the "wrist strategy" (Hedbávný et al., 2013; Kerwin & Trewartha, 2001; Kochanowicz, Niespodziñski, Mieszkowski, Kochanowicz, & Sawczyn, 2018; Rohleder & Vogt, 2018; Slobounov & Newell, 1996; Uzunov, 2008; Yeadon & Trewartha, 2003). The equilibrium in the handstand primarily relies on the strength of the arm muscles and the adjustment of finger pressure on the supporting surface. This compensation occurs when the CoM shifts towards the fingers, necessitating increased pressure at the base of support, or when the CoM moves towards the wrist joints, necessitating heightened pressure beneath these joints (Gautier et al., 2007; Kerwin & Trewartha, 2001; Sobera et al., 2007; Slobounov & Newell, 1996; Yedon, & Trewartha, 2003).

Gymnasts may choose to place their fingers fully stretched and joint (it is possible for beginners), fully stretched or with the slightest bit of distributed flexion, or to use a tented/cambered/spider finger position where the distal interphalangeal joint and proximal interphalangeal joint are flexed. It has been suggested that the placement with outstretched tented/cambered/spider fingers is more effective. This technique allows gymnasts to generate more tension, exert greater pressure on the floor, and make more precise corrections to counterbalance during the posterior body tilt (falling over) (Bessi, 2009; George, 1980; Rohleder & Vogt, 2018). This approach is recommended as a more effective method for gymnasts to execute a handstand with proper form and balanced control. By positioning their weight over their fingers instead of the palm, gymnasts can avoid technical errors such as elbow bending, shoulder extension, and hip flexion, which are necessary for countering the forward tilt when descending (George, 1980). However, there is currently a lack of research supporting these recommendations regarding the various finger placements.

Research suggests that balance control in handstands is influenced by gymnasts' ability to manipulate the displacement and velocity of their (CoM) (Omorczyk et al., 2018). This control primarily relies on torque applied from the wrists, with support from the shoulders and hips (Kerwin & Trewartha, 2001; Rohleder & Vogt, 2018; Yeadon & Trewartha, 2003). This means that the displacement of the CoP towards the fingers or the wrist joint in the sagittal plane plays a decisive role in regulating the balance during handstand. Therefore, assessing stability and performance parameters should include measuring the sway signal of the CoP using pressure or force assessment systems (Scoppa, Capra, Gallamini, & Shiffer, 2013). The CoP represents the point where vertical forces interact with the supporting surface and determines the overall effectiveness of the postural control system and gravity (Duarte & Zatsiorsky, 2000). The area of CoP sway serves as an indicator of a gymnast's performance while attempting to maintain balance in a handstand, with smaller sway surfaces indicating better performance. Additionally, the mean velocity of the CoP indicates the fluctuation in muscular force and can be used to assess balance control, with lower velocity values reflecting higher quality balance control in handstands (Asseman, Caron, & Crémieux, 2005).

The impact of gender on balance performance and balancing strategies has been a subject of interest among researchers (Hedbávný et al., 2013). Research exploring the influence of gender on balance control has found that, in comparison to girls, boys:

(a) Showed signs of being less attentive and more agitated under the age of 10 years (Odenrick & Sandstedt, 1984; Riach & Hayes, 1987; Steindl, Kunz, Schrott-Fischer, & Scholtz, 2006) and exhibited more swaying (Hirabayashi & Iwasaki, 1995; Riach & Hayes, 1987). (b) Demonstrated inferior balance performance across most age groups, except for 8-year-olds (Holm & Vøllestad, 2008). (c) Displayed greater center of pressure excursion during one-legged tasks between the ages of 7-11 years (Lee & Lin, 2007) and 12-15 years (Milosis & Siatras, 2012). (d) Achieved lower scores in a composite score calculated from six different test conditions at the age of 11-12 years (Steindl et al., 2006).

Conversely, research results (Eguchi & Takada, 2014; Smith, Ulmer, & Wong, 2012; Steindl et al., 2006) affirm that, compared to boys of the same age, girls exhibit better balance performance, enhanced sensory integration (Steindl et al., 2006), advanced neuromuscular development (Eguchi & Takada, 2014), lower levels of hyperactivity (Hirabayashi & Iwasaki, 1995), and employ more adult-like postural control strategies (Smith et al., 2012). Furthermore, females tend to show a greater rate of improvement in stability until the age of 11-12 years and enter the adult range of stability earlier than boys. Conversely, males appear to have a greater rate of improvement in stability as they age compared to females (Riach & Hayes, 1987).

However, some researchers speculate that girls and boys perform equally well in terms of balance control (Butz, Sweeney, Roberts, & Rauh, 2015; Libardoni et al., 2017). Some studies produced inconsistent results (Kejonen, 2002; Peterson, Christou, & Rosengren, 2006; Steindl et al., 2006), although different instruments and procedures were used making it difficult to generalize the results (Kejonen, 2002). Therefore, it has not been confirmed with certainty whether there are differences between the two genders regarding balance control, in what way, to what extent, and under what conditions.

Gymnastic training plays a vital role in developing balance control and achieving exceptional stability, even in challenging positions like the handstand. When it comes to the handstand skill in gymnastics, the Code of Points (MAG; WAG, 2020a, b) outlines slightly different requirements for men and women. Specifically, a momentary handstand is required as a skill for: (a) Female gymnasts as early as 7-8 years old, for the balance beam and floor exercise, and 11-12 years old for the single bar. (b) Male gymnasts starting at 8-9 years old for the floor exercise and 10-11 years old for the parallel bars exercise.

Moreover, static handstand skills are mandated for males starting at the age of 12-13 for the floor, rings, and parallel bars exercises. Handstand performance displays both commonalities and variations between males and females, influenced by differences in apparatuses. For instance, the handstand serves as a foundational component within broader motor sequences for both genders, such as executing forward or backward handsprings on the floor or vault. Additionally, it is a crucial element in various gymnastic skills, including transitioning with straight arms into a handstand (e.g., from a long hand swing, a free hip circle, or a cast) on horizontal bars and uneven bars.

In contrast, the handstand is employed differently on the balance beam (e.g., jump, press, or swing to handstand, kick to the side or cross handstand (2sec), backward roll to handstand, cartwheel), rings (e.g., swing to handstand, press to handstand), pommel horse (e.g., scissor through handstand), and parallel bars (e.g., executing a basket or a giant swing to handstand).

On the other hand, the assessment of strength, power, and endurance for males and females includes activities such as press to handstand and handstand hold on parallel bars, rings, and balance beam (Fink, Hofmann, & Scholtz, 2021; Fink, Lopez, &, Hofmann, 2021). These gender-specific differences, especially within the age group development, lead to deliberate training specifically designed for different apparatus for male and female gymnasts. This training can potentially cause long-term differences in balance control and regulation during handstands between the two genders.

Considering that the handstand is one of the most important fundamental skills of gymnastics, decoding motor behavior in handstands has received considerable attention in recent research (Blenkinsop et al., 2017; Gautier et al., 2007; Kerwin & Trewartha, 2001; Kochanowicz et al., 2018; Omorczyk et al., 2018; Sobera et al., 2007) in the available technical and scientific literature (George, 1980; Hedbávný et al., 2013; Kerwin, & Trewartha, 2001; MAG, 2020; Uzunov, 2008; Yedon, & Trewartha, 2003; Živčić-Marković et al., 2015).

However, there is a lack of studies investigating the performance of gymnasts in handstands using different palm/finger placements and activation methods, as well as potential differences in balance control between male and female gymnasts. The objective of this study was to examine the effectiveness of three distinct hand placement and activation methods in regulating handstands, both for the entire sample and separately for male and female gymnasts.

Specifically, we investigated differences between the following variations in hand placement:

(a) Flat palms, wide-open and flexed fingers (also known as spider fingers or tented fingers).

(b) Flat palms, wide-open and fully stretched fingers.

(c) Flat palms, joined and fully stretched fingers (as shown in Figure 1).

These variations were assessed for all gymnasts and separately for male and female gymnasts. Additionally, we examined differences in balance control and regulation during handstands between male and female gymnasts while considering the three different techniques of finger placement and activation. We controlled for the effects of age and personal characteristics.

Hypotheses derived from the literature review suggested that utilizing hand placement characterized by flat palms, wide-open, and flexed fingers would optimize handstand performance. Based on existing research findings and study design factors (e.g., age and training experience of the gymnasts), we anticipated that female gymnasts would demonstrate superior balance control in handstands compared to their male counterparts.

METHODS

Participants

Thirty-one young competitive gymnasts (15 males and 16 females) without any medical or orthopedic problems volunteered and participated in the study (Table 1). A sample of 31 gymnasts can provide a power of 0.80 to detect differences between genders using an alpha of 0.05 and medium to large effect size ($\eta^2 > 0.25$) (G*Power 3.1.9.7). Only gymnasts who were able to maintain a static base of support with an aligned body shape for a minimum of 10 seconds during a handstand were included in the study. All gymnasts had 4 to 11 years' experience of structured training and competitive gymnastics at the national level. Young gymnasts acquire the ability to freely maintain static body balance in handstand on a flat surface, such as floor, usually after 3-4 years of specific gymnastics training (Kochanowicz, Kochanowicz, Niespodziński, Mieszkowski, & Biskup, 2015). All gymnasts who participated in the study trained six times a week for about three hours each afternoon on weekdays and on Saturday morning. The gymnasts trained and competed on every apparatus (floor, horse, rings, vault, parallel bars, horizontal bar for males, and vault, uneven bars, beam, floor for females).

All gymnasts participating in this study were exclusively dedicated to gymnastics and did not engage in other sports activities. They also attended two hours of physical education classes per week at their public school.

In accordance with the ethical guidelines established by the Ethical Committee of Aristotle University of Thessaloniki, comprehensive information regarding the study's purpose and testing procedures was provided to the parents, coaches, and gymnasts. The parents of the gymnasts granted written consent before measurements were conducted.

Data collection

The distribution of weight and the stability in handstand steadiness was recorded and analyzed on a vertical posturographic digital platform (Foot Checker, Comex S.A./LorAn Engineering Srl; Castel Maggiore, Bologna, Italy). This floor-positioned instrument, measuring 700 X 500mm, contained 2304 resistive sensors with a measurement accuracy of .001 kPa, sampled at a frequency of 60 Hz. Hand area (cm^2), maximal pressure (the amount of force acting vertically on the surface of the support; kPa), center of pressure (CoP) sway area (defined as an ellipse containing 90% of all displacement points; mm^2), CoP linear distance displacement (LDD; a measure of both the distance and direction that CoP travels; mm), and CoP mean velocity (sum of the cumulated CoP displacement divided by the total time; mm/s), were analyzed using an integrated software module (Foot Checker, version 4.0).

Procedures

All participants were subjected to identical experimental conditions during all measurements. These tests were conducted by the same researcher in a controlled environment to minimize distractions. The portable platform was positioned in a designated area. All measurements were taken in the afternoon, prior to the start of the training session, to mitigate the potential influence of training fatigue on the results.

The measurements focused on the 'press to handstand hold' technique, which began with participants in a standing position, feet apart, and hands placed shoulder-width apart on the platform. Participants received specific instructions for hand placement, as follows:

(a) Place your hands with flat palms, wide open, and flexed fingers (also known as spider fingers or tented fingers) to ensure that the palm of the hand, the first knuckle of all fingers, and the fingertips are in contact with the floor. (b) Place your hands with flat palms, wide open, and fully stretched fingers so that the entire surface of the fingers touches the floor. (c) Place your hands with flat palms, joined and fully stretched fingers so that the entire surface of the fingers touches the floor (as illustrated in Figure 1).

Participants were also instructed to maintain parallel index fingers pointing forward in all conditions. Following a brief warm-up, all participants familiarized themselves with the testing protocol and practiced the three variations of the press to handstand hold.

Subsequently, participants were instructed to perform a press to handstand hold for a minimum of 10 seconds while maintaining stillness with their eyes open on the platform. Each test was conducted in a random order, with a two-minute rest period between trials. An experimenter provided assistance by lightly touching the sides of the gymnast's upper legs to help them achieve a stable handstand position with proper body alignment. Once the stable handstand was attained, the legs were released, and the assessment was carried out and recorded for a duration of 10 seconds.The reason for choosing this specific duration for the handstand was based on the research-backed evidence that suggests a decline in stability beyond a 15-second handstand (Slobounov & Newell, 1996). Throughout all trials, the gymnasts were instructed to maintain a static base of support; attempt to remain still using their wrists and fingers; fixate their gaze in front of their wrists in the space between their hands (Asseman et al., 2005); keep their head in a neutral position (Asseman et al., 2005), and maintain straight arms, and body as tight, strong, and still as possible. Specifically, the participants were instructed to press their fingertips vertically into the floor to push the body weight back if they were falling forward in the handstand, and to push the palms of the hands onto the floor and lift the fingers off the floor to shift the body weight forward if they were falling backwards. Any change to the base of support, such as a shuffle or step, or a fall before completing at least 10 seconds in a stable handstand, was considered a failure to maintain balance, leading to the termination of the trial.

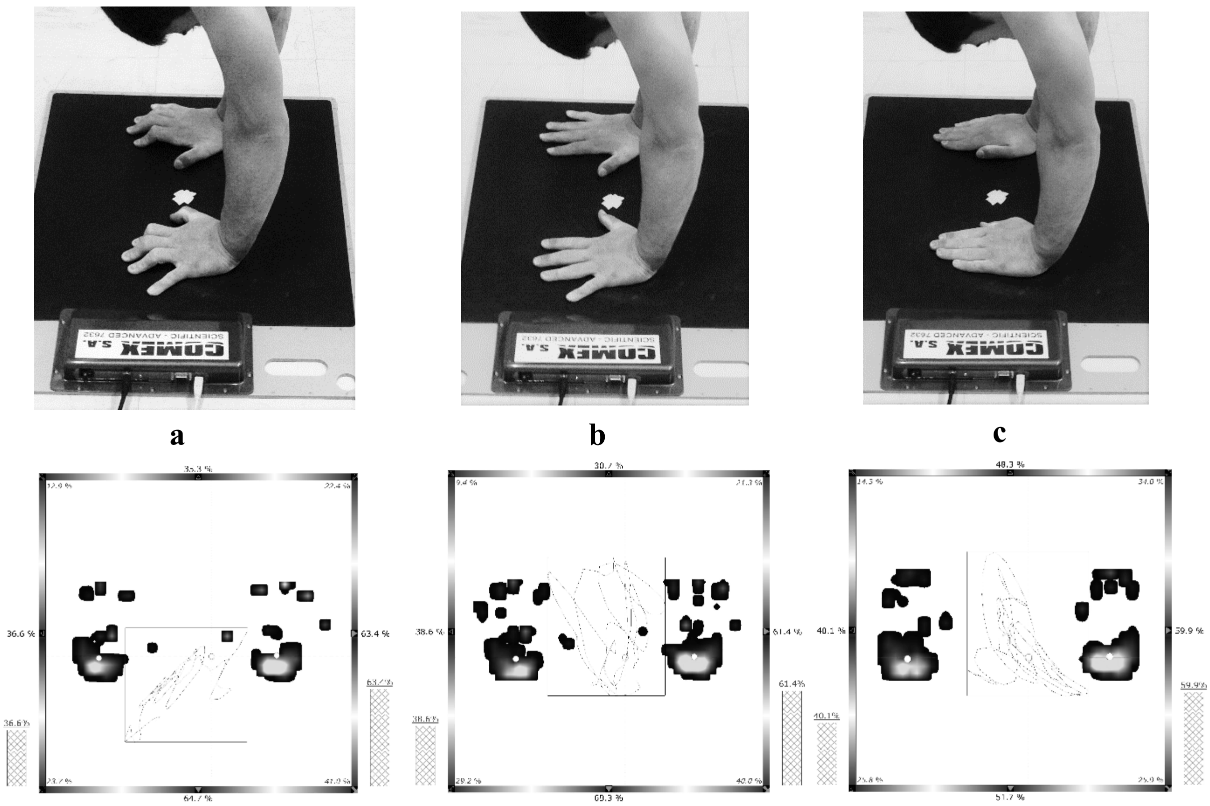

Figure 1: The hand placement on the platform located above and the graphical illustration displayed below: (a) flat palms with wide open and flexed fingers (also known as spider fingers or tended fingers); (b) flat palms with wide open and fully stretched fingers, and (c) flat palms with joined and fully stretched fingers.

Statistical analyses

All statistical analyses were performed using the SPSS software (SPSS v. 28, SPSS Statistics, IBM Corp., NY). The Shapiro-Wilk test was used to test the normality of the data. A *p* value less than 0.05 was considered significant. To verify the reliability of the measurements, all tests were repeated twice (test-retest), under the same conditions by the same experienced examiner, within a one-week period. The test-retest reliability was examined using the intra-class correlation coefficient (ICC), based on a one-way ANOVA that compares within-subject variability and between-subject variability. One-way multivariate analysis of variance (MANOVA) was applied to examine the effect of the three different techniques of hand placement on balance control during a handstand. To identify significant differences in the dependent variables, multiple univariate ANOVAs with Bonferroni correction were conducted, followed by post hoc analyses with pairwise comparisons between groups for the statistically significant univariate ANOVAs. One-way MANOVA was used to examine age, training age, body mass, height, and body mass index (BMI) differences between male and female gymnasts. One-way multivariate analyses of covariance (MANCOVA) were performed to determine statistically significant differences between male and female gymnasts in handstand steadiness variables while controlling for gymnasts' age and personal characteristics. Age and personal characteristics (e.g., body mass, height, BMI) have been used as factors that affect the human balance system (Faraldo-García, Santos-Pérez, Crujeiras-Casais, Labella-Caballero, & Soto-Varela, 2012; Liaw et al., 2009; Olchowik, 2015). Firstly, differences in the hand area of the left hand (HALH; cm^2) and the hand area of the right hand (HARH; cm^2) between the two genders were examined, with gymnasts' age and personal characteristics as covariates. Then, the differences between the two genders in (a) maximal pressure of the left hand (MPLH; kPa), (b) maximal pressure of the right hand (MPRH; kPa), (c) center of pressure (CoP) sway area (mm^2), (d) CoP linear distance displacement (mm), and (e) CoP velocity (mm/s) were evaluated. In these MANCOVAS the variables gymnasts' age, training age, body mass, height, BMI, HALH, and HARH were used as covariates.

RESULTS

Assumptions and reliability of the measurements

The independent variables satisfy the criteria for a normal distribution. The skewness (-1.0 to +1.0) and the kurtosis (-1.6 to +1.6) of the distribution, and the Shapiro-Wilk test provided support for the normal distribution of all variables (p >.05). The Box's test provided support for the equality of variance-covariance matrices across groups. The results of the Bartlett's test of sphericity confirmed that the variances were equal across groups, and the Levene's test provided support for the equality of error variance across groups (p > .05). The single measures intra-class correlation coefficient values ranged from .62 to .95 for males, and from .64 to .93 for females (Tables 2, 3).

Differences between handstand variations

For all gymnasts (both genders). The one-way multivariate analysis of variance (MANOVA) yielded a multivariate main significant effect for handstand with different hand placement, Wilks' λ = .378, $F(7,14) = 7.51$, $p < .001$, $\eta^2 = .39$. The ANOVAs performed on each of the dependent variables revealed significant effects for handstand with different hand placement on all the dependent variables. Finally, a series of post-hoc analyses were performed to examine individual mean difference comparisons across all three handstand variations and all seven dependent variables. The results are illustrated in Table 1.

For male gymnasts. The one-way multivariate analysis of variance (MANOVA) yielded a multivariate main significant effect for handstand with different hand placement, Wilks' $\lambda = .183$, $F(7,14) = 6.89$, $p < .001$, $\eta^2 =.57$. The ANOVAs conducted on each of the dependent variables revealed significant effects for handstand with different hand placement on the dependent variables MPLH, MPRH, CoP sway area, and CoP LDD. Finally, a series of post-hoc analyses were carried out to examine individual mean difference comparisons across all three handstand variations and all seven dependent variables. The results are presented in Table 1.

For female gymnasts. The one-way multivariate analysis of variance (MANOVA) yielded a multivariate main significant effect for handstand with different hand placement, Wilks' $\lambda = .448$, $F(7,14) = 2.75$, $p < .01$, $\eta^2 =.33$. The ANOVAs conducted on each of the dependent variables revealed significant effects for handstand with different hand placement on the dependent variables HALH, HARH MPLH, CoP sway area, and CoP LDD. Finally, a series of post-hoc analyses were carried out to examine individual mean difference comparisons across all three handstand variations and all seven dependent variables. The results are shown in Table 4.

Gender differences

Gymnasts' characteristics. The one-way multivariate analysis of variance (MANOVA) yielded a main effect for gender, Wilks' $\lambda = .605$, $F(5,25) = 3.26$, $p = .021$, $\eta^2 =.40$. However, as shown in Table 1, the univariate analyses of variance (ANOVAs) that followed indicated that the between-subjects effects were not statistically significant for all the examined variables (age, training age, body mass, height, and BMI).

Gymnasts' hand area in the handstand. The one-way multivariate analysis of covariance (MANCOVA) showed significant effect of the covariate age, Wilks' $\lambda = .552$, $F(6,19) = 2.57$, $p = .054$, $\eta^2 =.45$. In addition, after controlling for the effects of covariates, the multivariate main effect of gender on the dependent variables was not significant, Wilks' $\lambda = .584$, $F(6,19) = 2.26$, $p = .082$, $\eta^2 =.42$. The ANOVAs conducted on each of the dependent variables revealed significant differences between male and female gymnasts for the variables HALH-HOFF, HARH-HOFF, HALH-HOSF, HALH-HJSF, and HARH-HJSF. Comparing the estimated marginal means showed that males had higher scores compared to females (Table 3).

Table 1

Results of one-way MANOVA for all dependent variables between handstand variations

	All gymnasts							
	HOFF (a)		HOSF (b)		HJSF (c)			
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	η^2
HALH	46.98**c**	12.06	54.02	13.01	57.60**a**	13.47	5.46**	.11
HARH	47.87**bc**	11.52	56.40**a**	13.12	59.56**a**	14.73	6.52**	.13
MPLH	206.91**c**	19.91	193.72**c**	21.14	170.86**ab**	27.94	18.14***	.29
MPRH	217.05**c**	12.49	210.28	17.03	202.20**a**	21.65	5.62**	.11
CoP sway area	1143.85**c**	544.02	930.64**c**	458.37	622.23**ab**	270.26	11.05***	.20
CoP LDD	367.53**bc**	120.84	296.74**a**	91.29	289.36**a**	92.13	5.51**	.11
CoP velocity	36.26**c**	11.88	31.33	9.54	29.67**a**	9.76	3.32*	.07
	Male gymnasts							
	HOFF (a)		HOSF (b)		HJSF (c)			
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	η^2
HALH	50.47**c**	13.54	55.97	15.62	62.00**a**	16.37	2.15	.09
HARH	52.30**c**	13.09	58.87	15.26	64.37**a**	18.81	2.17	.09
MPLH	207.02**c**	22.09	193.48**c**	21.93	170.24**ab**	23.49	10.24***	.33
MPRH	213.97**c**	12.31	200.65	18.50	194.58**a**	18.12	5.39**	.20
CoP sway area	1470.73	495.78	1202.52	383.88	768.11	220.32	12.81***	.38
CoP LDD	438.01**bc**	87.26	357.01**a**	55.97	358.70**a**	77.31	5.77**	.22
CoP velocity	42.64	9.14	37.56	7.28	36.73	8.32	2.24	.10
	Female gymnasts							
	HOFF (a)		HOSF (b)		HJSF (c)			
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	η^2
HALH	43.72**bc**	9.79	52.19**a**	10.17	53.47**a**	8.67	4.91**	.18
HARH	43.72**bc**	8.21	54.09**a**	10.73	55.06**a**	7.69	7.85***	.26
MPLH	206.80**c**	18.37	193.93**c**	21.09	171.44**a**	34.78	7.72***	.26
MPRH	219.93	12.34	219.31	9.00	216.19	12.25	2.26	.09
CoP sway area	837.40**c**	394.32	675.76	373.43	485.45**a**	243.57	4.21*	.16
CoP LDD	301.45**c**	111.70	240.22	81.89	255.35**a**	88.97	3.74*	.14
CoP velocity	30.27**c**	11.18	25.50	7.59	23.05**a**	5.43	3.05	.12

Abbreviations: HOFF, handstand with open and flexed fingers; HOSF, handstand with open and fully stretched fingers; HJSF, handstand with joined and fully stretched fingers; HALH, hand area of the left hand; HARH, hand area of the right hand; MPLH, maximal pressure of the left hand; MPRH, maximal pressure of the right hand.

The index in boldface below the means indicates statistically significant differences between the respective variables.

$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 2

Results of a one-way MANOVA for male and female gymnasts' characteristics

	Males		Females			
	M	*SD*	*M*	*SD*	*F*	η^2
Age	12.60	2.08	13.31	2.21	.85	.03
Training age	6.33	2.38	7.44	2.31	1.72	.06
Body mass	37.80	10.31	39.93	7.07	.46	.02
Height	144.07	13.04	150.88	7.47	3.23	.10
BMI	17.83	1.97	17.41	1.85	.37	.01

Abbreviations: BMI, body mass index (body mass/height²); M, mean; SD, standard deviation, F, significant differences; η², magnitude of difference between the two means.
**p < .05, **p < .01, ***p < .001*

Table 3

Results of one-wway MANCOVAs and ICC for hand area between male and female gymnasts

	Males			Females				
	M	*SE*	ICC	*M*	*SE*	ICC	*F*	η^2
HALH-HOFF	51.68	2.50	.92	42.59	2.41	.93	5.51*	.19
HARH-HOFF	53.03	2.05	.88	43.03	1.97	.75	9.98**	.29
HALH-HOSF	57.48	2.27	.93	50.77	2.18	.77	3.64	.13
HARH-HOSF	60.75	2.37	.88	52.33	2.28	.70	5.26*	.18
HALH-HJSF	63.42	2.50	.95	52.14	2.40	.72	8.54**	.26
HARH-HJSF	68.32	2.81	.66	51.36	2.70	.73	15.16***	.39

Abbreviations: M, mean; SE, standard error of the mean; ICC, intraclass correlation coefficient; HALH-HOFF, hand area of the left hand; HOFF, handstand with wide open and flexed fingers; HARH, hand area of the right hand; HOSF, handstand with wide open and fully stretched fingers; HJSF, handstand with joint and fully stretched fingers.
The variables gymnasts' age, training age, body mass, height, and BMI were used as covariates.

Handstand with wide open and flexed fingers. The one-way multivariate analysis of covariance (MANCOVA) showed that the effect of the covariates was not significant. However, there was a significant multivariate main effect of gender after controlling for the effects of covariates on the dependent variables, Wilks' $\lambda = .513$, $F(5,18) = 4.02$, $p = .013$, $\eta^2 = .53$. However, the ANOVAs conducted on each of the dependent variables revealed significant differences between male and female gymnasts for the variables CoP sway area and CoP LDD. Comparing the estimated marginal means showed that males had higher scores compared to females (Table 4).

Handstand with wide open and fully stretched fingers. The one-way multivariate analysis of covariance (MANCOVA) showed that the effect of the covariates was not significant. In addition, after controlling for the effects of covariates, the multivariate main effect of gender on the dependent variables was not significant, Wilks' $\lambda = .625$, $F(5,18) = 2.16$, $p = .105$, $\eta^2 = .38$. However, the ANOVAs performed on each of the dependent variables revealed significant differences between male and female gymnasts for the variables CoP sway area, CoP LDD, and CoP velocity. Comparing the estimated marginal means showed that males had higher scores compared to females (Table 4).

Handstand with closed and fully stretched fingers. The one-way multivariate analysis of covariance (MANCOVA) showed that the effect of the covariates was not significant. In addition, after controlling for the effects of covariates, the multivariate main effect of gender on the dependent variables was not significant, Wilks' λ = .811, $F(5,18) = .84$, $p = .540$, η^2 =.19. The ANOVAs performed on each of the dependent variables revealed significant differences between male and female gymnasts only for the variable CoP LDD. Comparing the estimated marginal means showed that males had higher scores compared to females (Table 4).

Table 4

Results of one-way MANCOVAs and ICC for all dependent variables between male and female gymnasts

	Handstand with wide open and flexed fingers (HOFF)							
	Males			Females				
	M	*SE*	ICC	*M*	*SE*	ICC	*F*	η^2
MPLH	213.30	7.16	.77	200.92	6.84	.64	1.11	.30
MPRH	217.36	3.77	.62	216.76	3.45	.65	.01	.00
CoP sway area	1518.72	159.71	.81	792.41	156.65	.73	7.71**	.26
CoP LDD	440.59	33.46	.78	299.03	31.98	.76	6.68*	.23
CoP velocity	42.11	3.43	.72	30.77	3.28	.77	4.08	.16
	Handstand with wide open and fully stretched fingers (HOSF)							
	Males			Females				
	M	*SE*	ICC	*M*	*SE*	ICC	*F*	η^2
MPLH	197.17	7.40	.71	190.47	7.09	.73	.32	.01
MPRH	207.62	3.49	.69	212.77	3.34	.66	.85	.04
CoP sway area	1195.42	133.56	.84	682.42	127.92	.69	5.76*	.21
CoP LDD	357.67	21.73	.72	239.61	20.81	.69	11.52**	.34
CoP velocity	37.19	2.51	.62	25.84	2.41	.69	7.96**	.27
	Handstand with joined and fully stretched fingers (HJSF)							
	Males			Females				
	M	*SE*	ICC	*M*	*SE*	ICC	*F*	η^2
MPLH	175.46	9.21	.72	166.55	8.79	.77	.34	.02
MPRH	199.49	6.72	.73	204.74	6.41	.84	.22	.01
CoP sway area	672.84	75.99	.74	574.77	72.50	.91	.60	.03
CoP LDD	324.77	19.65	.71	256.17	18.75	.66	4.38*	.17
CoP velocity	33.23	2.40	.72	26.34	2.29	.63	2.97	.12

Abbreviations: MPLH, maximal pressure of the left hand; MPRH, maximal pressure of the right hand; CoP, center of pressure; LDD, linear distance displacement.

The variables gymnasts' age, training age, body mass, height, and BMI, HALH-HOFF and HARH-HOFF for HOFF, HALH-HOSF and HARH-HOSF for HOSF, and HALH-HJSF and HARH-HJSF for HJSF were used as covariates.

$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$

DISCUSSION

The aim of the present study was to evaluate the effectiveness of different techniques regarding hand placement in handstand control and regulation. Additionally, gender differences in handstand performance were examined. Previous research has suggested that hand placement tented/cambered/spider fingers is more effective. This approach allows gymnasts to generate greater tension, exert more pressure on the floor, and make more precise corrections to prevent falling over (Bessi, 2009; George, 1980; Rohleder & Vogt, 2018). The findings of the present study do not align with either the aforementioned recommendations or the study hypothesis regarding the most effective hand placement for improved performance during a handstand. Despite gymnasts applying more pressure, especially on the left hand, during a handstand with wide open and flexed fingers compared to a handstand with open and fully stretched fingers and a handstand with joined and fully stretched fingers, this did not result in better handstand control.

The results showed a consistent pattern among both male and female gymnasts, with more effective control and regulation observed in the handstand with joined and fully stretched fingers, followed by the handstand with open and fully stretched fingers, and finally the handstand with wide open and flexed fingers. In most cases, all gymnasts, regardless of gender, exhibited lower values for CoP sway area, CoP displacement, and CoP velocity, particularly when comparing the handstand with joined and fully stretched fingers to the handstand with wide open and flexed fingers.

However, it's worth considering that pressure is defined as force per unit area exerted in a direction perpendicular to the support surface. The progressively increasing maximum pressure values observed in the order mentioned could be attributed to the smaller support area in the handstand with wide open and flexed fingers compared to the other hand placements.

Additionally, it's possible that younger gymnasts, who lack experience with hand placement variations during handstands, may not have the necessary strength to effectively manage CoP sway with open and fully stretched or even further open and flexed fingers. Alternatively, an opposing hypothesis suggests that gymnasts with greater strength capabilities may be more inclined to perform corrective movements during a handstand with their fingers open and fully stretched, or even further apart and flexed, which could result in larger deviations in their CoP (Hedbávný et al., 2018). However, it's important to note that these hypotheses cannot be confirmed in the present research since the gymnasts' strength was not assessed or considered.

Additional support for these findings can be found in the hand area of support, which was larger for both hands during the handstand with joined and fully stretched fingers, followed by the handstand with open and fully stretched fingers, and the handstand with wide open and flexed fingers.

In the case of the handstand with joined and fully stretched fingers, the joint fingers may offer more stable support due to their contact with a solid surface. Additionally, in this hand placement, the palm-to-finger lever arm is longer compared to the other two variations. This longer lever arm allows for better sensitivity in both applying force at the fingertips and sensing changes in weight distribution at the palms and fingers, providing enhanced support, particularly in the anterior-posterior plane.

It is also possible that some gymnasts do not sufficiently align their shoulders over the wrists, which can affect their ability to effectively utilize the action of their fingers. Furthermore, it's important to note that the current study did not explore whether gymnasts had practiced and mastered a particular hand placement technique for executing the handstand.

Researchers reviewing the literature concerning the influence of anthropometric characteristics in balance performance reported conflicting results (Baker, Newstead, Mossberg, & Nicodemus, 1998; Kejonen, 2002; Odenrick & Sandstedt, 1984; Peterson et al., 2006), but they used different methods and systems, therefore any comparison of results should be made with caution (Kejonen, 2002). Training experience is another factor that could affect balance performance. Several studies confirmed the significant impact of professional gymnastic training on body stability in natural and unnatural balance positions (Gautier, Marin, Leroy, & Thouvarecq, 2009; Hedbávný et al., 2013; Kochanowicz et al., 2018). The results of the present study showed no differences between male and female gymnasts regarding age, body mass, height, BMI, and training age. However, although not statistically significant, there were some differences between male and female gymnasts. For example, females were older and had higher training age compared to males. To account for any potential effects of these variables on the gymnasts' performance during the handstand, as explained in detail below, it was decided to include these variables as covariates in the statistical analyses of the study.

Based on previous research evidence (Baker, et al., 1998; Winter, Patla, Prince, Ishac, & Gielo-Perczak, 1998), it could be hypothesized that the stability of the body during handstand in both directions is dependent on the width of the hand placement, while stability in the sagittal plane is additionally influenced by the hand surface area. In the present study, after controlling for the effects of age and personal characteristics of the gymnasts, there were significant differences between the two genders regarding hand placement area. Specifically, male gymnasts had a bigger area of each hand support in all cases, except for the hand area of the left hand during the handstand with wide open and fully stretched fingers. Considering these differences and based on the results of previous research (Baker, et al., 1998; Winter, et al., 1998), it could be expected that male gymnasts have better control and regulation of balance during the handstand. However, statistical analysis that controlled for age, personal characteristics, and hand support area did not reveal any differences in maximal pressure between genders. This lack of difference in force, which is directly related to the gymnasts' weight, and surface area may explain the absence of gender-based variations in maximal pressure.

In terms of maximal pressure, although statistical significance was not observed, it's noteworthy that in all cases, for both genders, the maximal pressure of the right hand was higher compared to the corresponding pressure on the left hand. These findings align with previous studies, which have indicated that both more and less experienced gymnasts tend to place more load on their right hand than on their left hand during handstand maintenance.

This suggests the predominant role of the right hand in bearing the main load, as the ground reaction force, during a handstand, regardless of the gymnast's level of experience (Sobera et al., 2019).

The results of the applied MANCOVAs showed that female gymnasts exhibited lower values in the CoP sway area during handstands with open and flexed fingers, as well as handstands with open and fully stretched fingers. They also had lower CoP linear distance displacement values in all cases, which included handstands with wide open and flexed fingers, handstands with open and fully stretched fingers, and handstands with joined and fully stretched fingers, when compared to males. Additionally, females demonstrated lower CoP velocity values, although this was significant only for handstands with joined and fully stretched fingers.

It's widely accepted by many researchers that less motion is positively correlated with better control over sways, resulting in smaller CoM displacements during handstands (Asseman et al., 2005; Hrysomallis, 2011). Taking these findings into account, the results of the present study provide evidence that female gymnasts exhibited superior balance performance in handstands compared to their male counterparts. This aligns with the findings of several previous studies (Eguchi & Takada, 2014; Smith et al., 2012; Steindl et al., 2006) that reported better balance performance in young females when compared to males of the same age.

Considering the age of the gymnasts who participated in the present study and research findings (Hirabayashi & Iwasaki, 1995; Steindl et al., 2006) which confirm that adolescents compared to children demonstrate better balance performances, it could be assumed that the different rate of maturation of parameters affecting balance control between the two genders could be a contributing factor to the variability in maintaining handstand. For example, maturation of the neurological, visual, vestibular, and proprioceptive systems appears to occur earlier in young females (Cratty, 1970). Thus, the better females' performance in handstand compared to males could be attributed to parameters such as improved sensory integration (Steindl et al., 2006), advanced neuromuscular development (Eguchi & Takada, 2014), and the use of more adult-like postural control strategies (Smith et al., 2012). Additionally, it has been suggested that compared to females, males tend to exhibit higher levels of hyperactivity (Hirabayashi & Iwasaki, 1995) and lower attentiveness during balancing skills, which could potentially have a negative impact on the visual, vestibular, and proprioceptive systems crucial for postural stability (Steindl et al., 2006). In summary, considering the possible differences in maturation between genders, it could be argued that the observed differences in balance control in the present research, where they were statistically significant, might be limited or even non-existent.

Another crucial factor believed to play a significant role in maintaining a handstand is the mobility and stability of the shoulder joint, particularly its relationship to upper body mechanics. During handstand execution, the shoulder joint is positioned almost at 180° (Rohleder & Vogt, 2018). Therefore, the active range of motion in the shoulders, especially in terms of flexion to open the shoulder angle, becomes a critical factor contributing to handstand control (Rohleder & Vogt, 2018; Uzunov, 2008).

As a result, gymnasts' ability to effortlessly straighten their shoulders plays a vital role in their capacity to maintain balance during handstands since the shoulder joints significantly influence the shifting of the center of mass (CoM) (Kerwin & Trewartha, 2001; Yeadon & Trewartha, 2003). When a gymnast lacks adequate active mobility in the shoulder joint, combined with potentially limited expertise, they may end up engaging not only the wrist joint (acting as a single-segment inverted pendulum) but also the hip joint (forming a double-segment inverted pendulum), leading to larger angular displacements (Blenkinsop et al., 2017; Gautier et al., 2009).

Taking these considerations into account, it's plausible to hypothesize that the gender differences in balance control during handstands observed in the present study could be attributed, at least in part, to variations in shoulder active mobility. Numerous studies have indeed reported that females tend to exhibit a higher range of motion in shoulder flexion compared to males (Armstrong, 2018; Gómez-Ladero, López-Bedoya, Vernetta, 2013).

Nevertheless, the current study did not uncover significant differences between male and female gymnasts in all the variables affecting handstand control that were examined. In contrast, prior research has shown that females and males exhibit similar levels of balance performance (Butz et al., 2015; Libardoni et al., 2017). Therefore, it remains uncertain whether and to what extent gender-related differences in young gymnasts' handstand performance are present.

However, due to the limitations of the present study, any generalization of these findings should be approached with caution. Specifically, aside from the small sample size of participants and the age range, this study did not assess certain gymnast characteristics, such as biological maturation, passive and active flexibility, and strength of shoulder flexion and wrist flexion and extension. Furthermore, performing the handstand on a posturographic platform with specific dimensions may have added difficulty for some gymnasts in controlling their balance, as they were required to place their hands within a narrower range than they were accustomed to. Additionally, this study did not consider the technical aspects of gymnasts' handstand performance, including the compensatory movement strategies employed to maintain balance. The inclusion of complementary kinematic methods in future studies could enhance the interpretative possibilities of the findings.

Future studies might evaluate handstand performance using different force plates, involve larger sample sizes with narrower age and training differences, consider factors such as gymnasts' biological and technical developmental stage, assess passive and active flexibility and strength in shoulder flexion and wrist flexion and extension, analyze technical characteristics of handstand performance using kinematic analysis or expert judges, explore longer handstand trial durations (e.g., >20 or 30 seconds), or determine the maximum time each gymnast can maintain a handstand, and investigate the relationships between different strategies for maintaining a handstand on the floor and on other apparatus, as well as their impact on overall gymnastics performance. Such studies may yield more consistent and applicable results that can be generalized.

CONCLUSIONS

This study examined the effects of different hand placement techniques employed during handstands on balance control, taking gender variance into account.

Regarding hand placement, both genders effectively control their balance during handstands with joined and fully stretched fingers, followed by handstands with open and fully stretched fingers, and finally handstands with wide-open and flexed fingers. After controlling for age, training experience, and personal characteristics, female gymnasts demonstrated superior balance control during handstands.

Considering the study's limitations, coaches are advised to initially teach the handstand without emphasizing specific hand placement (especially regarding palms and fingers). Instead, they should prioritize developing young gymnasts' specific flexibility and strength, including passive and active flexibility of shoulder and wrist flexion and extension, as well as body position and control. As gymnasts progress and gain experience, coaches can gradually introduce hand placement techniques, starting with flat palms and wide-open fingers and eventually progressing to open and flexed fingers. Additionally, taking gender into account when practicing or evaluating handstands in gymnastics is advisable.

In summary, while acknowledging the limitations of this study, its reliable findings contribute to the existing body of literature on balance control techniques during handstands, with a specific focus on gender differences. However, it's essential to recognize that these are preliminary findings that require further in-depth examination in the future, considering the recommendations outlined in the research limitations section.

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COMPARISON OF THE TRADITIONAL TRAINING METHOD TO TEACH HANDSTAND AND TRAINING THROUGH A RESEARCHER-MADE DEVICE AND THEIR IMPACT ON THE HANDSTAND DURATION, PAIN AND QUALITY OF PERFORMANCE IN 8-10-YEAR-OLD BEGINNER GYMNAST GIRLS

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Abstract

This research was conducted with the aim of comparing traditional handstand training and handstand training using a researcher-made device among beginner gymnast girls aged 8 to 10 years. To achieve this, 30 qualified female gymnasts were purposefully and conveniently selected and randomly assigned to two groups: one receiving educational assistance with the researcher-made device (n=15) and the other using the traditional method (n=15). Over a span of eight weeks, handstand movements were taught, with one group following traditional methods and the other utilizing the researcher-made device. Upon completion of the training period, various measurements were taken, including the duration of balance maintenance, balance quality as judged by experts, the range of motion in the wrist, elbow, shoulder, and ankle joints, and the assessment of pain in the wrist, elbow, shoulder, and lower back areas. Data were analyzed using independent t-tests, MANOVA, and the Mann-Whitney test, with a significance level set at P≥ 0.05, and the analysis was conducted using SPSS 22 software. The results demonstrated that the use of the researcher-made balance training device led to a significant improvement in balance quality from the perspective of judges, as well as a notable reduction in pain in the shoulder, back, and wrist areas compared to the traditional training method. Additionally, there were no significant differences between the traditional method and the use of the device when considering factors such as balance performance quality as measured by deviation from the vertical line in various body joints, the duration of balance maintenance, the range of motion in the wrist, elbow, shoulder, ankle, and pain in the elbow and knee.

Keywords: *Handstand, aiding device, gymnastics, training quality, pain.*

INTRODUCTION

As a mother sport, gymnastics has taken root in all parts of the world due to its unique characteristics and charms, attracting many enthusiasts' attention.

'Handstand' is one of the principal gymnastic skills, playing an essential role in this sport; however, sometimes, due to the lack of proper training and attention by coaches, as well as physical and biomechanical incompetence in this movement, other gymnastics skills are also affected. In this skill, keeping the body straight and stretched along with the contraction of the abdominal and pelvic muscles and knowing the rules of balance and orientation are of utmost importance (Razavi, 2004). Transitioning from an upright standing posture to an inverted stance, or 'handstand balance', relies initially on large changes in body positioning and once inverted, on subtle changes of hand pressure and limb actions to control posture during the stabilizing period. The performer is required to transition through a period of instability to reach a balanced posture. The interplay between the numerous neurophysiological and biomechanical control processes is anticipated to be vital to the duration of handstand balance and has the potential to differentiate more and less successful handstand performance (Wyatt HE et al., 2021)

Besides its musculoskeletal benefits, practicing handstand has some positive physiological consequences. In a case study, researchers examined a Chinese man who practiced handstands (balance) for 40 years and found that this movement can strengthen cerebral vessels and delay the signs of aging (Liu et al., 2020).

It takes a lot of time and skill to perform many gymnastics movements. Elite gymnasts usually practice between 20 and 40 hours a week (Ghasempour, 2008), and repeated movements are often essential to mastering different skills in the field. Unlike many sports, movements and skills are practiced and repeated in gymnastics. Due to these repeated pressures or the wrong implementation of severe twists and blows during landing, the likelihood of acute and overuse injuries increases.

An investigation into injury rate during 2014-2019 among women's gymnastics athletes in the National Collegiate Athletic Association (NCAA) shows that the overall injury rate was 8.00 per 1000 athlete exposures; injury incidence was greater in competitions than in practices, though practice injury rates increased from 2015–2016 through 2018– 2019. Findings also suggest that the etiologies of overuse injuries and inflammatory conditions as well as the biomechanical aspects of concussions warrant further attention (Chandran et al 2021). Researchers showed that most upper limb injuries in female gymnasts occur in the wrist and continue with elbow injuries. This type of injury has been seen more in female gymnasts aged 10 to 14 (Webb and Retting, 2008). Filming a person standing on their hands for five seconds showed that the most changes were in the wrist, followed by the shoulder, hip joint, knee, and elbow. Also, the most angular changes were observed in the wrist area. Therefore, the wrist plays the most crucial role in maintaining the center of gravity on the support (Mohammadi et al., 2011). DiFiori et al (2006) emphasized that 25% of non-professional gymnasts had severe or advanced distal radial physical stress injury (injury due to weight pressure) in the wrist (DiFiori et al., 2006). Upper and lower limb injury prevalences have been reported at 32.2% and 58%, respectively (Jafari and Bam, 2001). In their review research, Caine and Nassar (2005) investigated gymnastics injuries. The results showed that injuries differ according to the gender of individuals. Most injuries were reported in the ankle joints and the lower back area at the advanced level (Caine and Nassar, 2005).

Among the causes of injuries, the type of equipment (ground movements) (56.8%), incorrect technique, and not using educational aids (36.4%) were the most common causes of injuries (Jafari and Bam, 2001). In this regard, appropriate training aids, safety mattresses, and other requirements can be helpful. Training aids can be used in more desirable learning techniques and the source of potential mistakes in skills implementation should be found. Therefore, with the aim of reducing sports injuries and promoting athletes' health during championships, it is recommended to use training facilities, and appropriate safety equipment (Jafari et al., 2011).

Training tools and devices are consistently employed to enhance the training of sports skills. Some of these tools not only promote safety but also facilitate the training process (Shojauddin, 2003). According to the outcomes of utilizing training aids such as modeling and display, which enhance the effectiveness of learning, there is a need to encourage educators and instructors to adopt more effective teaching methods and training aids instead of conventional approaches (Maleki et al., 2012). Additionally, biomechanical aspects of gymnastics sports equipment were investigated through videography, highlighting the significance of equipment in evaluating, analyzing, and measuring dynamic and kinematic structures within the field of gymnastics (POTOP, 2013).

Unfortunately, studies about specific movements in gymnastics, including handstands, are limited. Handstand is one of the basic movements of this sport, and there is no training aid to increase training efficacy and decrease pain or injury risks. It motivated the researchers to build a device to facilitate training of this skill. The absence of specialized studies addressing specific movements in gymnastics, including handstands (Woods et al., 2002), coupled with the elevated incidence of injuries associated with this manoeuvre, and the inadequacy of appropriate training aids for its instruction, have served as the foundational motivation for undertaking this research. The primary objective of this study is to compare the effectiveness of traditional handstand training methods with a novel researcher-developed device in relation to the movement quality, balance duration, range of motion, and the occurrence of pain (specifically in the wrist, elbow, shoulder, and ankle) among beginner gymnast girls aged 8-10 years.

METHODS

30 physically and mentally healthy, relatively less skilled gymnast girls, aged 8 to 10 years (8.8±0.8 years, 131.7±15.6cm, 26.9±7.7 kg) elected to participate in this study. They were randomly placed in two groups: one training with a researcher-made device (1: n=15), and another as a control group, using the traditional training method (2: n= 15). The subjects practiced handstand balance for at least three months, three days a week.

The semi-experimental method was employed using a post-test design with the control group. An open call for participation was made by reaching out to a gymnastics academy located in western Tehran, and an unrestricted number of questionnaires were distributed among relatively less-skilled gymnasts. To ensure the participants' health status, all volunteers were examined by a physician. Consent forms for participation in the research were provided to the parents, and subjects were included based on predefined inclusion criteria.

The duration of maintaining handstand balance, the quality of performance, and the range of motion and pain were measured after the intervention.

The duration of maintaining handstand balance was measured using a stopwatch. The examiners stopped the stopwatch upon observing any swinging or movement in the gymnast's body, and recorded the time during which the balance was maintained.

The performance quality of the handstand was evaluated using both the score of the judges and the deviation of the joints from the vertical line.

Opening the hands less than or more than shoulder width, creating cervical hyperlordosis in the head which can lead to lumbar hyperlordosis, bending and spreading the legs apart, failing to transfer weight onto the hands, and shifting the shoulders forward were the factors that affect the quality of the handstand movement according to international rules.

Deviation from the vertical line*:* The analysis was conducted using motion capture software, Cortex 6.0.0.1645, and Kinovea 0.9.4. Cortex is a motion analysis software tool designed to manage all aspects of motion capture within a single program, encompassing tasks such as initial setup, calibration, tracking, and post-processing. On the other hand, Kinovea is a free software application used for video analysis, comparison, and assessment in sports and training context. It is particularly suitable for physical education teachers and coaches (Nor M, et al, 2018).

The range of motion for wrist hyperextension, shoulder internal rotation and flexion, hip flexion with a bent knee, knee extension, and ankle dorsiflexion was measured using a goniometer according to the Kendall method (2005).

Visual Analogue Scale (VAS) was employed to gauge pain intensity. Observational evaluation indices for the handstand posture were established after verifying their validity, reliability, and the hierarchy of technical issues (Kojima et al., 2021). The measurement criterion consists of a 10cm long horizontal strip graded from 0 (no pain), 1-3 (mild pain), 4-7 (moderate pain), and 8-10 (severe pain). This scale has high reliability and reproducibility (70 / 69) with a reliability coefficient of ICC=0.91. Subjects refrained from using anti-inflammatories and painkillers 72 hours prior to the pain evaluation test, and they were instructed on how to use the measurement criteria.

Intervention: Traditional handstand method (control group): A progressive teaching model for introducing the handstand to beginner gymnasts was employed, drawing upon theoretical and contemporary skill training methods found in scientific and textbook literature. This approach was realized by reviewing pertinent research studies available via Medline, contemporary gymnastic textbooks, coaching manuals, as well as the author's personal knowledge and experience. The model proposed outlines four distinct stages in the progression of handstand development, featuring a distinctive strategy aimed at enhancing the gymnast’s proprioceptive and kinesthetic awareness for maintaining balance (Uzunov,2008).

Researcher-made device method: The transition from an upright standing posture to an inverted stance, commonly referred to as 'handstand balance,' initially relies on significant changes in body positioning. Once inverted, fine adjustments in hand pressure and limb movements are essential for posture control during the stabilization phase. Special emphasis has been placed on understanding the mechanics in the anterior-posterior (AP) or sagittal plane (Wyatt HE et al., 2021).

Building upon this understanding, a balance training aid was developed with the specific goal of managing movement in both the sagittal and frontal planes. The objective behind designing this tool was to incrementally expand the range of balance, up to 15 degrees, in accordance with the gymnast's proficiency level. As depicted in the original design in Figure 1, this device comprises several components, including:

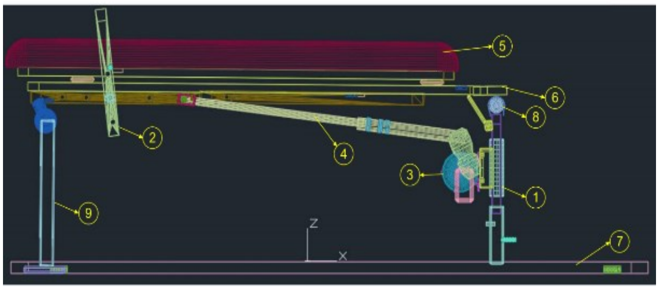

Figure 1. 3D image of the device, side view: 1. The adjustable base of the device; 2. A holding bar to prevent the gymnast from falling during the peak phase; 3. An electric motor to move the jack and lift the gymnast's body along with the bottom plate; 4. A pneumatic jack - to transfer the power of the engine to lift the bottom plate; 5. Foam on the bottom plate - to prevent injuries and provide comfort; 6. The metal frame of the lower plate - to keep in place; 7. The lower metal frame of the device for stability; 8. A hinge - for joint movement of the bottom plate; 9. A support base - to maintain the bottom plate in its original state before and after the movement.

This device comprises two vertical bars positioned on both sides of the gymnastic mat, allowing for height adjustment. These bars are connected at the top by a horizontal bar and a rectangular plate. The rectangular plate serves as the platform for the individual's body, with hands placed on the mat on the floor to initiate the exercise from a horizontal position. A controller, held by the coach, regulates the movement of this rectangular platform.

With each press of the control key, the rectangular plate incrementally moves 15 degrees vertically before coming to a stop. This pause allows for wrist adjustment and subsequent adaptation of other body organs to the new position. Subsequently, the key is pressed again to advance by the next 15 degrees. This process continues until the individual reaches the vertical position, achieving balance.

Additionally, a semicircular horizontal bar is provided in the area where the feet are placed. This bar allows for foot movement and acts as a safety measure, preventing the person from tipping over to the opposite side (see Figure 2).

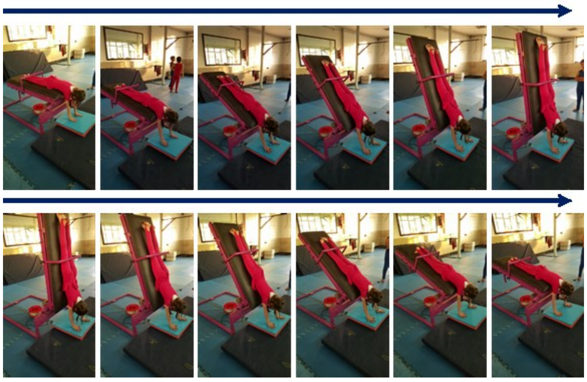

Figure 2. the handstand training using a researcher-made device.

All data analysis was conducted using SPSS statistics computing program version 22 (SPSS Inc. _ 1993–2007). Descriptive statistics (Means±SD) for all variables were calculated. Next, data were analyzed with Shapiro-Wilk normality tests to ensure normality, and student Independent T-test, MANOVA, and Mann-Whitney tests were used to compare the differences. Differences were considered statistically significant at the $p \leq 0.05$ levels.

RESULTS

The average and standard deviation of the research variables, including performance quality based on time (judges' score), handstand stabilization time, pain (in the areas of the wrist, elbow, shoulder, low back, and ankle), range of motion (areas of the wrist, elbow, shoulder, and ankle), and the deviation from the vertical line (in the areas of the elbow, shoulder, knee, thigh, and ankle) are presented in Table1.

Table 1

The average and standard deviation of the research variables

Variable		Traditional group Mean± SD	Device group Mean± SD	Variable		Traditional group Mean± SD	Device group Mean± SD
Performance quality (judges' score)		4.40±1.40	7.08±2.60	Range of motion (degree)	Wrist	90.20±5.60	95.80±8.50
Handstand stability (seconds)		1.07±0.60	3.11±2.90		Elbow	173.70±7.70	173.80±7.70
Pain (VAS)	Wrist	0.66±0.89	0.00		Shoulder	167.06±12.6	166.40±12.50
	Elbow	0.00	0.00		Ankle	154.06±15.3	152.70±16.40
	Shoulder	1.86±0.51	0.93±0.90	Deviation from the vertical line (degree)	Elbow	1.30±1.10	1.55±1.70
	Waist	4.13±1.60	0.00		Shoulder	2.65±1.80	2.09±2.06
	Ankle	0.00	0.00		Thigh	6.16±4.70	4.69±5.20
					Knee	5.26±5.10	4.39±5.20
					Ankle	5.82±5.40	4.87±6.80

The results of the Shapiro-Wilk test showed that the data of performance quality and deviation from the vertical line are normally distributed (P>0.05), Therefore, independent t-test and MANOVA were used to analyze the data of these variables.

In contrast, the data for time to maintain balance and range of motion are not normally distributed (P<0.05); therefore, a non-parametric Mann-Whitney test was used to analyze these data.

The performance quality of the handstand was assessed using both judges' scores and the deviation from the vertical line at various body joints. Consequently, the hypothesis was tested twice: first, based on judges' scores and then based on the degree of deviation from the vertical line.

Based on the results of the independent t-test (Table 2), a significant difference was found in the performance quality of the handstand movement when evaluated from the judges' perspective between the researcher-made device and the traditional method. In other words, the performance quality of the balance movement using the researcher-made device was significantly superior to that achieved through the traditional method.

For a more precise analysis, the MANOVA test was applied, focusing on the deviation from the vertical line. As indicated in Table 3, when assessing performance quality based on the deviation from the vertical line, there was no significant difference observed between the researcher-made device and the traditional method.

The results of the Mann-Whitney test (Table 4) show no significant difference in balance maintenance time between the researcher-made device and the traditional method.

The results of the Mann-Whitney test (Table 5) show no significant difference in the range of motion in the wrist, elbow, shoulder, and ankle between the researcher-made device and the traditional method; therefore, this hypothesis is also rejected.

The results of the Mann-Whitney test (Table 6) show a significant difference in the pain experienced in the wrist, shoulder, and back regions when comparing the researcher-made device and the traditional method. In other words, the use of the researcher-made device significantly reduced wrist, shoulder, and lower back pain in comparison to the traditional handstand training approach.

However, it is noteworthy that there is no significant difference observed in elbow pain between the researcher-made device and the traditional method

Table 2
Independent t-test results for performance quality (judges' score)

Levine test		t-test		
F	Sig.	T	Df	Sig.
9.950	0.004	-3.570	23.700	0.001
				0.002

Table 3
Results of MANOVA test for performance quality (deviation from the vertical line)

Effect	Value	F	Df	Df	Sig.
Intercept	0.702	11.770	5	25	0.000
Group	0.116	0.659	5	25	0.658
Effect	Value	F	Df	Df	Sig.
Intercept	0.702	11.770	5	25	0.000
Group	0.116	0.659	5	25	0.658

Table 4
Results of the Mann-Whitney test for Balance maintenance time

U	Z	Sig.
156	1.42	0.163

Table 5
Mann-Whitney results for a range of motion in wrist, elbow, shoulder, and ankle

Variable	U	Z	Sig.
Wrist	161.5	1.860	0.101
Elbow	124.0	0.162	0.871
Shoulder	116.5	-0.140	0.889
Ankle	113.0	-0.277	0.800

Table 6
Mann-Whitney results for wrist, elbow, shoulder and back pain

Variable	U	Z	Sig.
Wrist	64	-3.03	0.027
Elbow	120	0.00	1.000
Shoulder	49	-2.99	0.004
Waist	0	-5.11	0.000

DISCUSSION

This research aimed to compare traditional handstand training with handstand training using a researcher-made device in 8-10-year-old beginner gymnast girls, focusing on both the duration and quality of handstand training. The study's findings revealed that when assessing the quality of handstand movement from the judges' perspective, the researcher-made device yielded significantly better results than the traditional handstand training method (P=0.002).

However, when using the amount of deviation from the vertical line as the measure of handstand movement quality, no significant difference was observed between the traditional handstand training method and the training aid device.

According to the findings reported by the researchers, the control and regulation of body posture are closely tied to the practice of sports skills, indicating a direct link between the level of physical exercise and one's body posture capabilities. Consequently, the researcher-made device used in this study appears to be better suited for designing training programs aimed at injury prevention during training rather than for increasing the duration of training sessions.

Additionally, the research demonstrated that the device did not outperform the traditional method in terms of the duration of handstand balance maintenance. It's worth noting that the correct execution of this skill relies on having adequate hand muscle strength to support the entire body weight within the shoulder girdle, particularly on the wrists (Vuillerme et al., 2001; A'boub et al., 2017).

It is worth mentioning that the handstand training device made by researchers was not made to enhance muscle strength, rather, it facilitates controlled movement. Maintaining balance requires the engagement of visual, proprioception sense, and vestibular systems (Vuillerme et al., 2005; Fransson et al., 2004). The better these systems function, the quicker one can learn and demonstrate balance skills. Given that four joints (wrist, elbow, shoulder, and thighs) are involved in maintaining balance, the strategies for achieving balance are more intricate (Asseman et al., 2004).

In this context, the research findings suggest that when handstand training is complemented by a live model and animation, skill acquisition and retention are improved. However, in this study, there was no discernible difference in the learning duration of the handstand between the two groups, likely due to the device's primary purpose, which does not focus on enhancing the abilities of the visual, proprioceptive, and vestibular systems. Consequently, variations in the duration of balance maintenance among beginners may be considered typical (Maleki et al., 2012).

The findings concerning the range of motion revealed that this variable in the wrist, elbow, shoulder, and ankle areas remained unaffected by the use of the teaching aid device. It's worth noting that alterations in the connective tissues surrounding the joints can impact joint range of motion (Michlovitz et al., 2004). Various approaches, including stretching exercises and techniques such as stretching exercises with heat, can be employed to facilitate a positive restoration of joint range of motion (Nakano et al., 2012).

It has been observed that more experienced gymnasts exhibit a narrower body sway range at a lower frequency when maintaining body posture in the standing position, in contrast to less experienced gymnasts. In simpler terms, experienced gymnasts manage to minimize body sway by applying greater force on the ground surface. Less experienced athletes may struggle to achieve this even after several years of training (Hart et al., 2018).

The outcomes of this study, however, indicate that the range of motion of the joints remains unaltered during handstand training when utilizing the teaching aid device developed by the researchers.

While the study findings indicated that the researcher-made teaching aid device didn't make a difference in elbow pain compared to the traditional method, it did lead to a significant reduction in pain experienced in the shoulder, back, and wrist areas. Given that the primary load-bearing responsibility for maintaining balance on the hands falls on the wrist and shoulder joints, the absence of thigh pain in the participants can be justified.

Furthermore, the nature of the researcher-made teaching aid device involves a gradual progression in which, as the learner advances, the height of the legs and the deviation of the COP (center of pressure) shift toward the wrist and shoulder. This gradual shift means that the entire body weight is progressively supported by these joints. It appears that this is why the amount of pain in the wrist and shoulder was lower in the group learning the handstand with the researcher-made device compared to the group trained with the traditional method. In the traditional method, the center of pressure is not immediately transferred to the wrist and shoulder, which may explain the higher pain levels. However, it is crucial to enhance beginners' awareness of the correct function of the wrist, tailored to their skill level (Rohleder and Vogt, 2019).Practical applications: Utilizing an assistant device for handstand training in gymnastics results in reduced pain by redistributing central pressure from the wrists to the shoulders, hips, knees, and ankles over time. It also affirms that the device does not impact the range of motion or timing of the participants.

This research suggests that further investigations can be undertaken by other researchers to enhance and refine this device, exploring its effectiveness in enhancing neuro-mechanical control among gymnasts. This approach could potentially address the unresolved issues of the current device.

CONCLUSIONS

In summary, when considering the same training conditions as the traditional method, including training duration, maintaining the quality of handstand performance, and not altering the range of motion of the joints, the researcher-made teaching aid device demonstrates the ability to reduce pain in the wrist, shoulder, and back areas. Given that research has shown the positive impact of teaching style on learning (Khouri et al., 2020), it can be concluded that incorporating this instrument into the teaching of handstand movements is a more suitable approach than the traditional method. Therefore, its utilization is recommended in the teaching and training process.

Supplementary Materials*:* None.

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KEY PERFORMANCE INDICATORS OF INDIVIDUAL MEDALISTS IN RHYTHMIC GYMNASTICS COMPETING AT THE 2020 OLYMPIC GAMES

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Abstract

This study aims to analyze the contribution of each apparatus' score component to the overall score and to identify the key performance indicators that distinguish medalists from non-medalists among the 10 finalists in rhythmic gymnastics at the 2020 Olympic Games, Tokyo. Medalists (n=3) and non-medalists (n=7) were separated in the sample. Each apparatus (hoop/ball/clubs/ribbon) had seven components [body difficulty (DB), apparatus difficulty (DA), D total, artistic execution (EA), execution technical (ET), E total, total score (TS) of apparatus, and a total final score (TFS-sum of four apparatus scores)]. A total of 350 scores were analyzed. The Mann–Whitney U tests and Cohen's d effect size (ES) calculation were used to calculate differences. The following variables were determined to differentiate the TFS of the medalist and the non-medalist gymnasts: the large effect with Ball-DA/D total/EA/E total/TS (ES=1.550–1.879), Clubs-DA/D total/EA/TS (ES=0.316–2.080), Hoop-DA/D total/TS (ES=1.897–2.316), Ribbon-EA (ES=1.879), and with a low-effect Clubs-AD(ES=0.316) components. Hoop-DA and Hoop-D-TS (ES=2.316, p< 0.05) have the greatest impact, while all DB and ET scores (p>0.05) have no effect on TFS. The impact of apparatus-specific score components on Olympic medal outcomes varies significantly. Notably, difficulty scores (both total and apparatus-specific) and artistic scores emerged as key performance indicators for achieving high total scores and securing a medal in rhythmic gymnastics at the Olympic Games. Coaches should prioritize choreography planning aimed at enhancing difficulty, particularly the apparatus difficulty score, while also focusing on enhancing artistic quality through flawless execution of routines by the gymnasts.

Keywords: *apparatus difficulties, body difficulties, individual routines, Olympic medalists, performance analysis, rhythmic gymnastics.*

INTRODUCTION

Rhythmic gymnastics (RG) is an Olympic sport in which gymnasts present choreography combining elements of art, classical ballet and sport in individual and group events (Agopyan, 2014, 2021; Gram & Bo, 2020). RG was first introduced in the Olympic Games in the individual event at the 1984 Los Angeles OG, followed by the group events at the 1996 Atlanta OG (Hamza & Ahmed, 2020; Kwitniewska et al., 2009).

Gymnasts in RG are expected to present body and apparatus (rope, hoop, ball, clubs, and ribbon) elements in competitions with delicacy and artistic features, without errors, according to the discipline-specific rules and difficulty level. An individual rhythmic gymnast's routine lasts 75 to 90 seconds and is performed at high intensity (Zetaruk et al., 2006), requiring the incorporation of complex apparatus and body skills into the choreography (Kwitniewska et al., 2009). RG competition rules are known as the Code of Points (CoPs) in this complex structure. The FIG-RG Technical Committee CoP determines the CoP, which is updated every 4 years during each Olympic cycle (Örs, 2021; Toledo & Antualpa, 2016). The main aim and target of the RG-CoP rules are to provide a more objective evaluation of compounds affected by the quantity and quality criteria and parameters to evaluate gymnasts' difficulties, execution, and artistry.

The evaluation of RG (Rhythmic Gymnastics) routines consists of four major components that influence a routine's total score:

- Difficulty Score: This score reflects the combined difficulty of body difficulties (DB: balances, rotations, and jumps/leaps) and the difficulty of apparatus (DA: technical apparatus elements performed with specific criteria related to the apparatus).
- Artistry (EA) Score: The artistry score is an assessment of the athlete's artistic performance, based on the standard of aesthetic perfection.

Execution Technique (ET) Score: This score is based on the execution of elements involving both the body and the apparatus. These elements should be performed with aesthetic and technical perfection.

The total score for a routine is determined by adding the difficulty, artistry, and execution scores, and then subtracting any penalty scores (FIG, 2018).

All of these different components are evaluated by technically expert judges, and the ability to perform a difficult exercise with a high execution score is the primary determinant of success in RG (Agopyan & Örs, 2019). Considering all of these structures, RG is a sport that develops various motor abilities (whole-body coordination, dynamic balance and static balance, sense of kinaesthesia, whole-body movement in time, and hand-eye coordination) and perceptual abilities (whole-body reaction time, anticipation of coincidence, and depth perception; Purenović-Ivanović et al., 2016). Because of these structures, RG is defined as a sport that requires early athlete selection, intensive training during childhood and adolescence, and early termination of the sports career (Rutkauskaitė & Skarbalius, 2012). Successful performance in RG requires many years of practice and consistency in training (Ivanova, 2022).

One of the most important goals in this long and difficult process is to win a medal by competing in the OG. Gymnasts can qualify to compete at the OG, the most prestigious competition in their career, as early as at the age of 16. However, it is extremely difficult to compete at the OG, let alone win a medal. Gymnasts must train systematically to maximize their technical development. It is also important to be able to quickly adapt to the competition rules, which change every 4 years, and to adjust their choreography accordingly.

After becoming a world-class Olympic discipline, RG has evolved dramatically. Changes in competition rules are also implemented to encourage the development of sports (Agopyan, 2014; Ávila-Carvalho et al., 2012), and revisions of the CoP improve athlete's technical skills. This sport has undergone significant changes in recent years, owing primarily to an increase in technical skill as a result of the constant revision of the requirements imposed by the FIG-CoP rules (Chiriac, 2020).

Most published studies on the content of RG routines include an understanding of the number and level of difficulty elements in each apparatus (Agopyan, 2014, 2021; Agopyan & Örs, 2019; Ávila-Carvalho et al., 2012; Ávila-Carvalho, Leandro, & Lebre, 2010; Batista et al., 2019; Leandro et al., 2016). On the other hand, few studies in the literature have examined the influence of total score components on the final scores in group and individual events at world championships (WCh) and world cups (Kutlay et al., 2021; Örs, 2020; Tatlibal et al., 2021, 2022). Some studies place emphasis on the contribution of each type of element evaluated by the judges comrpising the final score (Tatlibal et al., 2022; Örs, 2020). Each apparatus and each score component do not have the same impact on qualifications. It has been noted that the total ball difficulty score has one of the largest effects on rankings in senior RG-2019 WCh (Örs, 2020), whereas the clubs difficulty score had the best results in junior RG-2019 WCh (Tatlibal et al., 2022). It is also concluded that establishing a balance between the impact of total score components for each apparatus on final scores may enhance routine integrity and artistic expression (Tatlibal et al., 2022). These results may vary depending on the nature of gymnastics as a sport, the participating countries, the athletes, and the dynamics of each competition. Moreover, changes in the CoP after each Olympics can lead to divergent outcomes due to disparities in rules (Kosova & Kosova, 2021).

Therefore, it is proposed that future studies investigate whether the difference between difficulty scores and final difficulty scores is influenced by the type of apparatus (Leandro et al., 2016). In rhythmic gymnastics, routine elaboration entails the choices scored and considered by the CoP, reflecting what is practically achievable by the gymnast. From this perspective, comprehending the performance indicators of medal-winning gymnasts, including body and apparatus difficulties, artistic components in the choreography, and excellent execution, is crucial for making adjustments in the periodization and training regimens of gymnasts to ensure well-prepared participation in future international events.

Despite the significance of prior studies in elucidating the effects of RG total scores on rankings, there remains a need to conduct further research focused on understanding the performance of Olympic-level medalist gymnasts from diverse perspectives and considering various key performance indicators.

To the best of our knowledge, no study has investigated the scores of the top three gymnasts during an Olympic Games (OG). Given that only three medals are awarded at the OG, analyzing the scores of the top three gymnasts can yield crucial insights for coaches in choreography preparation. It is also essential to comprehend the score levels achieved by Olympic athletes in rhythmic gymnastics routines (hoop, ball, clubs, and ribbon) and the contributions of each component, including difficulty, artistic, and execution, to adapt to evolving standards, grasp the foundations of high-level performance, and assist coaches in refining their training plans. In the light of this information, this study aims to analyze the contribution of the score components of each apparatus to the overall score in the RG Summer OG-2021 (officially known as XXXII OG, Tokyo 2020) competitions and to identify the key performance indicators that distinguish the medalists from non-medalist finalists. It is hypothesized that non-medalists' scores and the subcomponents of all apparatuses may have a significant impact on the total score of medalist gymnasts.

METHODS

This study is designed as both a descriptive and inferential analysis, utilizing publicly available official data from the Tokyo 2020 Summer Olympics (OG). The primary focus of this study is to examine the impact of the total score components of each apparatus (hoop, ball, clubs, and ribbon) on the final performance scores of both medalist and non-medalist individual senior Olympic finalist rhythmic gymnasts. Demographic characteristics of the gymnasts and competition data were extracted from the official website of the International Olympic Committee (IOC, https://olympics.com/tokyo-2020/olympic-games/en/results/rhythmic-gymnastics/reports.htm) and Official Results Book of the OG in Tokyo 2020 FIG (https://olympics.com/tokyo-2020/olympic-games/en/results/rhythmic-gymnastics/reports.htm).

This study was conducted as an observational study with publicly available data in an unprocessed format and was not collected through experimentation. Competition data were obtained from the result books of the 2020 Summer OG in RG (links provided in the Participants section). Therefore, there are no ethical concerns regarding the use of data from open access websites (Morley & Thomas, 2005). Additionally, in accordance with the European General Data Protection (Regulation, 2016) legislation, all gymnasts participating in the present study have been coded to safeguard their identities.

The data of the participants in the study were taken from the official competition scores of the senior individual elite rhythmic gymnasts who finished the 2020 Summer OG as the top 10 finalists. The event was postponed to summer 2021 due to the Covid-19 pandemic and was held in Tokyo (Japan) on August 6 and 7, 2021.

The individual all-around qualification competitions for the 2020 Summer Olympics featured 26 rhythmic gymnasts. Among them, 10 rhythmic gymnasts secured spots as finalists based on their qualification results. These finals were held to determine the first, second, and third-place gymnasts in the senior individual rhythmic gymnastics standings at the 2020 Summer Olympics. These 10 gymnasts represented Israel (ISR, two gymnasts), the Russian Olympic Committee (ROC, two gymnasts), Belarus (BLR, two gymnasts), Bulgaria (BUL, one gymnast), and Ukraine (UKR, two gymnasts). The gymnasts' ages ranged from 19 to 22 years old, with an average age of 20.32 ± 1.54 years.

The gymnasts scores were divided into two groups for the analysis: medalists (n = 3), i.e., the top three gymnasts (the recipients of the OG medals), and non-medalists (n = 7), i.e., the remaining seven gymnasts.

Data were collected from a total of 40 routines, which included senior individual all-around finals 2020 Summer OG hoop, ball, clubs, and ribbon apparatus scores. Difficulty (D) and execution (E) scores of each apparatus and subcomponents of these scores were analyzed. The D and E scores and subcomponents were determined using the RG-CoP 2017-2021 (FIG, 2018) as follows:

- The D score is divided into two subgroups: body difficulty (DB) and apparatus difficulty (DA).
- The E score is divided into two subgroups: artistic execution deductions (EA) and execution technical deductions (ET).

The total score of each apparatus is calculated by adding the D total and E total scores (if there is a penalty, it is deducted from the final score of the apparatus).

The research data consisted of eight components for each apparatus: DB, DA, D total, EA, ET, and E total and, for the hoop, ball, clubs, and ribbon, the total apparatus score for each of the four apparatuses and the total final score (the sum of four apparatus scores). During the current study, 350 scores were analyzed. The following RG-CoP 2017-2021 (FIG, 2018) scores were calculated:

1. DB scores include the number and value of the DB and dance steps (DSs).
2. DA scores include the number and technical value of dynamic elements with rotation (DER) and apparatus difficulty. DA scores of each apparatus were evaluated separately.
3. D total scores are calculated by adding the DB and DA scores for each apparatus
4. EA scores include artistic component penalties for each apparatus and include the following features: unity of composition (guiding idea and connections), music and movement (rhythm: dynamic changes), body expression (the body segments or the face; two different body waves), variety (in the use of directions and trajectories, floor area, level, planes, directions, techniques of apparatus elements), and fundamental apparatus elements.
5. ET scores include penalties for technical errors in body movements and apparatus elements for each apparatus. Both EA and ET components are scored on a scale of 20.00 points, with each component accounting for 10.00 points.
6. E total scores are included by the addition of the EA and ET scores for each apparatus.
7. The total score for each apparatus is calculated by adding the D total score (DB + DA scores) and the E total score (EA + EA scores); any penalties are deducted from the final score for each apparatus.
8. The total final score (the sum of all scores) is calculated by adding the total scores for the hoop, ball, clubs, and ribbon. This final score determines the Olympic champion.

For each variable, the minimum, maximum, mean, and standard deviation (SD) were calculated. The Shapiro–Wilk test was used to confirm the normality of the quantitative variables, and it was determined that all variables had a normal distribution. Due to the small number of participants, nonparametric tests (Mann–Whitney U test) were used to evaluate the significance of differences between the two groups' variables (medalists and non-medalists). The effect sizes (ESs) calculated using the Cohen's d calculation, which was used when the parameter had a normal distribution, were interpreted as small when results were 0.20 or greater; medium when results were 0.50 or greater, and large when results were 0.80 or greater (Cohen, 1992). All statistical procedures were carried out using SPSS (Version 25.0, Chicago, IL), with the level of significance set to $p > 0.05$.

RESULTS

The means and standard deviations of the OG scores of the medalist and non-medalist gymnast's according to the components in all apparatus are presented in Table 1. Comparisons between groups based on components in all apparatus are presented in Table 2. It was determined that there were statistically significant differences ($p < 0.05$; Table 2) between the medalist and non-medalist group scores in terms of DA (hoop, ball and sum of all apparatus), D-Total (hoop, ball, clubs, sum of all apparatus), EA (ball, clubs, ribbon, sum of all apparatus) E-Total (ball, sum of all apparatus) and Total Scores (hoop, ball, clubs, sum of all apparatus) These differences were found to be in favor of the medalist group and the effect sizes were also large (ES = 1.550–2.316). It was determined that for the clubs, the DA score of medalist gymnasts was higher ($p < 0.05$) and the effect size (ES = 0.316) was smaller compared to non-medalist group scores.

There were no statistical differences ($p > 0.05$) between the medalist and non-medalist in terms of DB (hoop, ball, clubs, ribbon, sum of all apparatus), DA (ribbon), D-Total (ribbon), EA (hoop), ET (hoop, ball, clubs, ribbon, sum of all apparatus), E-Total (hoop, clubs, ribbon), and Total Score (ribbon) (Table 2). On the basis of apparatus scores, it was determined that the medalist gymnasts had higher performance scores in hoop-DA (ES = 2.316) (Figure 1a) and hoop-D-total (ES = 2.316) (Figure 1b) with the largest effect size. These differences in Hoop-DA (1.519 points) and Hoop-D-total (1.543 points) scores were found to be the most significant differences between the medalist and the non-medalist gymnasts (Table 2).

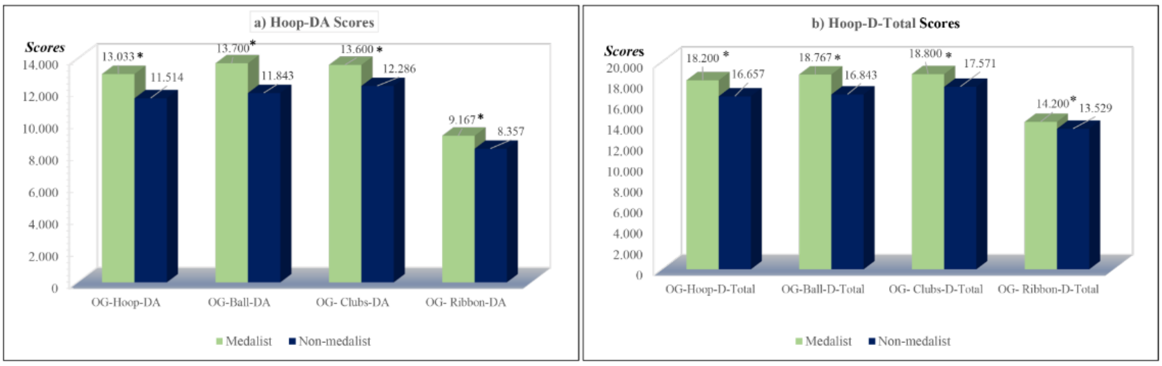

*Figure 1***.** The hoop DA (Figure 1a) and hoop D-total (Figure 1b) scores have the greatest effect on the overall score. The first three gymnasts with Olympic medals had statistically significant and higher hoop DA (Figure 1a) and hoop D total (Figure 1b) scores than non-medalist gymnasts (*$p<0.05$).

Table 1

Descriptive statistical analysis of the choreographic scores on all apparatuses the individual rhythmic gymnastics finalists participating in the 2020 Summer OG final (n = 10).

Apparatus Variables Scores	OG-DB	OG-DA	OG-D-Total	OG-EA	OG-ET	OG-Total E	Total Score
				Hoop			
Mean ± SD	5.150±0.251	11.970±0.938	17.120±0.984	0.560±0.250	0.888±0.239	8.552±0.445	25.673±1.351
Min-Max	4.700-5.500	10.600-13.300	15.500-18.500	0.200-1.000	0.450-1.200	8.000-9.350	23.700-27.550
				Ball			
Mean ± SD	5.020±0.361	12.400±1.156	17.420±1.369	0.630±0.343	0.985±0.528	8.385±0.819	25.805±2.065
Min-Max	4.300-5.600	10.900-14.000	15.500±19.100	0.200-1.100	0.400-2.000	7.200-9.300	23.000-28.300
				Clubs			
Mean ± SD	5.260±0.375	12.680±0.733	17.940±0.793	0.510±0.311	0.740±0.313	8.750±0.601	26.690±1.327
Min-Max	4.700-5.800	11.800-13.900	16.900-19.400	0.200-1.100	0.300-1.250	7.800-9.500	24.900-28.650
				Ribbon			
Mean ± SD	5.130±0.306	8.600±0.899	13.730±0.884	0.660±0.212	1.205±0.416	8.135±0.592	21.805±1.414
Min-Max	4.500-5.400	6.800-10.000	12.000-15.000	0.300-1.000	0.500-2.000	7.000-9.200	19.550-24.000
				Total Final Score (Sum of four apparatus)			
Mean ± SD	20.560 ±1.046	45.650 ±3.049	66.210±3.321	2.360±2.582	3.818±1.134	33.823±2.031	99.973±5.190
Min-Max	18.500-21.900	42.400-51.100	62.300-72.000	1.200-4.100	1.850-5.725	31.400-36.950	93.350-107.800

OG: Olympic games; DB: Body difficulty; DA: Apparatus difficulty; D-Total: Total difficulty score; EA: Execution artistic score; ET: Execution technique score; Total E: Total execution score

Table 2 :
Descriptive statistical analysis values of the choreographic scores on all apparatuses between the medalist and non-medalist individual rhythmic gymnasts participating in the 2020 Summer OG final (n = 10.)

		MEDALIST (n=3)				NON-MEDALIST (n=7)					
		Min	Max	Mean	SD	Min	Max	Mean	SD	p-value	*Effect size*
	OG-Hoop-DB	4.900	5.500	5.167	0.306	4.700	5.400	5.143	0.251	1.000	0.072⸸
	OG-Hoop-DA	12.800	13.300	13.033	0.252	10.600	12.600	11.514	0.701	*0.017**	*2.316§*
H	OG-Hoop-D-Total	17.900	18.500	18.200	0.300	15.500	17.500	16.657	0.768	*0.017**	*2.316§*
O	OG-Hoop-EA	0.300	0.400	0.367	0.058	0.200	1.000	0.643	0.257	0.084	1.285§
O	OG-Hoop-ET	0.600	1.000	0.750	0.218	0.450	1.200	0.946	0.237	0.240	0.773§
P	OG-Hoop-E-Total	8.600	9.050	8.883	0.247	8.000	9.350	8.411	0.446	0.084	1.285§
	OG-Hoop-Total Score	26.500	27.550	27.083	0.535	23.700	26.850	25.068	1.105	*0.030**	*1.879§*
	OG-Ball-DB	5.000	5.100	5.067	0.058	4.300	5.600	5.000	0.440	0.908	0.072⸸
	OG-Ball-DA	13.200	14.000	13.700	0.436	10.900	13.300	11.843	0.856	*0.030**	*1.879§*
B	OG-Ball-D-Total	18.200	19.100	18.767	0.493	15.500	18.600	16.843	1.198	*0.030**	*1.879§*
A	OG-Ball-EA	0.200	0.300	0.233	0.058	0.300	1.100	0.800	0.252	*0.020**	*2.080§*
L	OG-Ball-ET	0.400	0.600	0.500	0.100	0.400	2.000	1.193	0.497	0.067	1.411§
L	OG-Ball-E-Total	9.200	9.300	9.267	0.058	7.200	9.300	8.007	0.671	*0.049**	*1.550§*
	OG-Ball-Total Score	27.500	28.300	28.033	0.462	23.000	27.900	24.850	1.667	*0.029**	*1.879§*
	OG-Clubs-DB	4.800	5.500	5.200	0.361	4.700	5.800	5.286	0.406	0.732	0.217⸸
	OG- Clubs-DA	13.000	13.900	13.600	0.520	11.800	12.900	12.286	0.334	*0.016**	*0.316§*
C	OG- Clubs-D-Total	18.300	19.400	18.800	0.557	16.900	18.300	17.571	0.559	*0.022**	*2.080§*
L	OG- Clubs-EA	0.200	0.200	0.200	0.000	0.200	1.100	0.643	0.276	*0.034**	*1.705§*
U	OG- Clubs-ET	0.350	0.550	0.467	0.104	0.300	1.250	0.857	0.301	0.086	1.285§
B	OG- Clubs-E-Total	9.250	9.450	9.333	0.104	7.800	9.500	8.500	0.544	0.086	1.285§
S	OG- Clubs-Total Score	27.600	28.650	28.133	0.525	24.900	27.800	26.071	1.030	*0.030**	*1.879§*
	OG-Ribbon-DB	4.800	5.400	5.033	0.321	4.500	5.400	5.171	0.315	0.563	0.366⸸
R	OG- Ribbon-DA	7.900	10.000	9.167	1.115	6.800	9.200	8.357	0.755	0.304	0.686γ
I	OG- Ribbon-D-Total	12.800	15.000	14.200	1.217	12.000	14.100	13.529	0.723	0.304	0.686γ
B	OG- Ribbon-EA	0.300	0.600	0.433	0.153	0.600	1.000	0.757	0.151	*0.028**	*1.879§*
B	OG- Ribbon-ET	0.500	1.300	0.967	0.416	0.950	2.000	1.307	0.401	0.424	0.521γ
O	OG- Ribbon-E-Total	8.300	9.200	8.600	0.520	7.000	8.450	7.936	0.530	0.202	0.864§
N	OG-Ribbon-Total Score	21.100	24.000	22.800	1.513	19.550	22.450	21.379	1.237	0.210	0.864§
A	OG- All App-DB	19.600	21.500	2.467	0.961	18,500	21.900	20.600	1.152	0.569	0.366
L	OG- All App -DA	46.900	51.100	49.500	2.272	42.400	45.600	44.000	1.279	*0.016**	*2.316§*
L	OG-All App -D-Total	67.200	72.000	69.967	2.483	62.300	67.500	64.600	2.101	*0.030**	*1.879§*
	OG- All App -EA	1.100	1.4000	1.233	0.153	1.500	4.100	2.843	0.814	*0.016**	*2.316§*
A	OG- All App -ET	1.850	3.100	2.683	0.722	2.800	5.725	4.304	0.915	0.051	1.550
P	OG- All App -E-Total	35.500	36.950	36.083	0.765	31.400	35.700	32.854	1.530	*0.030**	*1.879§*
P.	OG-All App -Total Score	102,700	107.800	106.050	2.902	93.350	102.100	97.368	3.350	*0.017**	*2.316§*

OG: Olympic games; DB: Body difficulty; DA: Apparatus difficulty; D-Total: Total difficulty score; EA: Execution artistic score; ET: Execution technique score; E-Total: Total execution score
§ Large effect size; γ medium effect size; ⸸ small effect size; p<0.05* effect size= Cohen's d

It was determined that all score components and the total result score in the ribbon were at the lowest level compared with the other apparatus. All gymnasts received the highest score in the club apparatus.

DISCUSSION

The current study compared the contribution of each apparatus score components to the overall score and to identify the key performance indicators that distinguish medalist and non-medalist RG finalists in the 2020 Summer OG Tokyo.

Analyzing the context of difficulty elements was not within the scope of the study's main goal. Our research was based on the judges' evaluation scores for the finalist gymnasts during the competition. The results revealed that medalist gymnasts had significantly higher scores than non-medalists on all apparatuses when performance criteria were considered, and the research hypotheses were partially confirmed.

"The primary finding of this study reveals that when considering the cumulative performance across all apparatuses in winning an Olympic medal in rhythmic gymnastics, the influence of total apparatus difficulty, overall difficulty, and execution artistry scores on the final total score is substantial. However, it was discovered that the effects of score components on the total final score vary depending on each apparatus. It was found that the ball apparatus had the greatest impact on the total score with five different components (DA, D-Total, EA, E-Total, Total scores). Following closely were the clubs apparatus with four components (DA, D total, EA, and Total score) and the hoop with three components (DA, D total, and Total score). Finally, among the four apparatuses with only one component (execution artistry), the ribbon had the least impact. Furthermore, the hoop-DA and D total components had the greatest impact on the total score."

Gymnasts attempt to adapt quickly to major changes in RG-CoP that are amended every 4 years by the FIG-RG technical committee. They try to gain grounds by making strategic changes in their choreographies (Sierra-Palmeiro et al., 2019). Changes in the RG-CoP may have varying effects on the number of elements performed and the final scores (Sierra-Palmeiro1 et al., 2019). The complexity of the interaction between the gymnast and the apparatus or the degree of coordination during the difficulties could be the reason for the RG-CoP updates (Leandro, 2018). For this reason, it is crucial in modern RG to perform strategically well-planned routines (Hashimoto et al., 2017). Olympic gymnasts aiming for the highest scores in RG perform routines with higher levels of difficulty combined with good execution (Agopyan, 2014). The current study found that medalist and non-medalist gymnasts had similar, high levels of body difficulty average scores (5.00–5.20 points). This finding indicates that Olympic gymnasts have similar abilities when it comes to performing body difficulties. The results of the current study also show that body difficulty score is not the most important factor in determining an Olympic medal. On the other hand, the first top three gymnasts with Olympic medals had statistically significant and higher DA average scores (9.1–13.7 points) than non-medalist gymnasts (8.3–12.8 scores). Dynamic elements with rotation (DER) are one of the elements evaluated within the scope of DA, with a value of 0.20.

According to the RG-CoP 2017–2021 (FIG, 2018), gymnasts are permitted to perform a minimum of one and a maximum of five DERs in a single routine. Furthermore, many gymnasts can perform the DER elements with higher values (e.g., 0.50–1.00 points or higher) by adding additional criteria based on the apparatus characteristic. In addition, apparatus difficulty, with values ranging from 0.20 to 0.40, is another crucial aspect within the domain of DA. Under the RG-CoP 2017–2021 (FIG, 2018), these elements were permitted to be performed without any limit within a single routine. Notably, gymnasts with Olympic medals scored approximately 1.30–1.90 points higher in the DA component compared to non-medalists, indicating their ability to execute elements with significantly higher criteria or numbers. These findings also corroborate assertions in the existing literature (Chiriac, Teodorescu, & Bota, 2020) that gymnasts tend to incorporate a substantial number of high-difficulty apparatus elements to attain the best possible results.

Furthermore, our study revealed that the influence of the DA component on the total score, except for ribbon, exhibited a high impact in the hoop and ball routines but a lower impact in clubs. This discrepancy suggests that the effect of DA scores on the total score varies depending on the specific apparatus. In comparison to ribbon, hoop, ball, and clubs offer gymnasts the opportunity to execute a wide variety of DA elements, including DER and apparatus difficulty. The frequent use of rolls in apparatus difficulty with hoop and ball, along with their adaptability for use in different ways with clubs, may explain the effectiveness of apparatus difficulty in achieving higher scores. Additionally, the ease with which various throwing and catching criteria, such as those occurring outside the visual area and without the use of hands, can be executed in these three apparatuses (hoop, ball, and clubs) during DER and apparatus difficulty likely contributes to this divergence.

Individual skill performance in RG varies with difficulty level and requires good coordination between body and apparatus elements (Tsopani et al., 2012). The demanding coordination requirements associated with execution of apparatus difficulty elements are particularly important (Sierra-Palmeiro et al., 2019) for achieving better competitive performance (Chiriac et al., 2020). Additionally, the findings of this study underscore that medalists excel in executing apparatus difficulties in the hoop, ball, and clubs, leading to higher scores. This outcome emphasizes the importance of designing training programs to enhance apparatus-specific difficulty scores.

Another important finding of the current study was that Olympic medalists (18.2–18.8 points) had significantly higher total difficulty scores in the hoop, ball, and clubs than non-medalists (16.6–17.5 points). This finding indicates that the total difficulty score, which is the sum of BD and DA scores and includes body and apparatus difficulty, is one of the most important factors in determining the Olympic medal.

The findings of this study indicate that, on an apparatus-specific basis, the hoop had the most significant impact on the total difficulty score, followed by the clubs and ball, in that order. This result aligns with Örs's observation in 2020 that the total difficulty score, regardless of apparatus type, served as the most robust predictor of success in rhythmic gymnastics at the 2019 World Championships (WCh). Furthermore, Örs (2020) discovered that the difficulty score in routines performed with the ball had the most substantial influence on gymnasts' qualifying scores and rankings, accounting for 79.3% of the variation. Additionally, Tatlibal et al. (2022) emphasized the significance of the difficulty score in clubs routines as one of the key factors affecting the final score at the 2019 Junior World Championships.

Existing literature studies emphasize that the connection between the quantity of technical elements and the final score in rhythmic gymnastics is contingent on the specific apparatus involved (Sierra-Palmeiro et al., 2019). Moreover, an analysis of World Championships data spanning the last two decades has disclosed that comprehensive changes in the CoP influence the number of technical elements performed, leading to varying results scores across different apparatuses (Sierra-Palmeiro et al., 2019). These findings are consistent with the results of our study.

Rhythmic gymnastics (RG) is a sport that demands the presentation of technical, aesthetic, and artistic qualities in an optimal manner, encompassing both form and execution (Elce et al., 2022). In our study, we assessed execution scores, considering artistic and technical components, alongside the difficulty score components in the choreography. Judges evaluate the artistic execution scores in competitions based on several subcomponents, including the choreographic structure, the integration of body/apparatus movements with music, dynamism, variety in the use of apparatus and space, and the overall quality of meeting these requirements.

Our study revealed that the artistic execution score's impact on the final total score varies depending on the apparatus when determining Olympic rankings. With the exception of the hoop, we found that the artistic execution score significantly influences the final total score in three apparatuses. Notably, medalist gymnasts demonstrated substantially lower deduction scores (ranging from 0.2 to 0.4 points) with a more substantial effect on ball, clubs, and ribbon routines compared to non-medalist gymnasts (where deductions ranged from 0.6 to 0.8 points).

While both DB (Difficulty of Body) and DA (Difficulty of Apparatus) components are objectively evaluated in choreographies, it is widely recognized that the evaluation of artistic features is more subjective. Notably, differences in the artistry execution (EA) scores suggest that the artistic performances of medalist gymnasts, particularly in choreographic structure and the execution of elements in line with aesthetic standards, approach perfection. These findings underscore the significance of the artistic execution average total scores in ball, clubs, and ribbon routines as pivotal factors in determining medal status, with similarly high effect sizes.

Conversely, our study found no significant differences in technical execution scores between groups. Surprisingly, the execution technique scores of medalist gymnasts (ranging from 0.4 to 0.9 points) for all apparatuses were lower than those of non-medalist gymnasts (ranging from 0.8 to 1.3 points). This discovery implies that Olympic gymnasts perform comparably in terms of body-specific and apparatus-specific technical elements. While there may be no statistical difference in the technical execution scores, it's important to acknowledge the significance of even the slightest score variations when striving for an Olympic medal.

As a result, it can be argued that performing only the elements with a high degree of difficulty is insufficient to improve one's ability to compete in RG. It also emphasizes the importance of expressing individual characteristics, the principle of uniqueness (Hashimoto et al., 2017), and the presentation of artistic components with minimal mistakes in choreographies.

Another notable result of the current study is that total average final scores of medalist gymnasts (ranging from 27.083 to 28.133 points) for all three apparatuses, except ribbon, were significantly higher than those of non-medalists (24.850–26.071 points). This outcome highlights the pivotal role of average total scores in hoop, ball, and clubs routines in determining medal status, with equally substantial effect sizes.

Additionally, both medalist and non-medalist gymnasts achieved higher scores in body, apparatus, and total club routines compared to all other apparatuses. Clubs, unique in rhythmic gymnastics as it is used in pairs and possesses a rigid structure (Jastrjembskaia & Titov, 1999), offers a platform for intricate, technically challenging, and diverse maneuvers. The distinct nature of clubs may account for the observed differences in scores.

However, when compared with the other apparatuses, it becomes apparent that the impact of all ribbon scores (all subcomponents and total score) on the final total final score is the least significant. Our results are consistent with the findings of a 2019 study that examined the WCh (Örs, 2021; Tatlibal et al., 2022), which consistently observed the lowest final scores in ribbon routines and the highest final scores in clubs.

Another significant finding in our study was that the total execution score for ribbon was consistently the highest, regardless of medal status. This observation suggests that the execution of ribbon routines is prone to more frequent artistic and technical errors, possibly due to the unique structural features and the complexity of apparatus technique associated with the ribbon. Ribbon is the longest apparatus in rhythmic gymnastics, measuring 6 meters. Consequently, the demand to maintain the ribbon's movement throughout the routine while executing challenging elements can make its technical use particularly challenging.

Gymnasts may encounter difficulties when using this long and smooth apparatus, especially when performing elements like throws, catches, spirals, snakes, and boomerangs, which involve apparatus difficulty scores. Notably, in our study, we found that the apparatus difficulty scores of Olympic-level gymnasts were consistently lower for ribbon compared to the other three apparatuses, regardless of their medal status. This observation further supports our perspective.

Although this research has several strengths, it also has its limitations. Firstly, it's worth noting that the present study's findings were analyzed within the framework of the 2017–2021 Code of Points and exclusively within the context of the 2020 Tokyo Summer Olympics. Furthermore, the analysis solely relied on judging scores to evaluate the outcomes. As a recommendation for future studies, it may be beneficial to delve into the impact of choreography content, encompassing elements such as body challenges, rotational dynamics, and apparatus challenges, on the total score. This approach could aid in identifying key performance indicators that differentiate medalist and non-medalist rhythmic gymnasts in individual senior Olympic finals.

CONCLUSIONS

To the best of our knowledge, this is the first study to analyze the contribution of each apparatus' (hoop, ball, clubs, and ribbon) score components to the overall score and to identify the key performance indicators that distinguish medalist from the top 10 non-medalist finalists in rhythmic gymnastics at the 2020 Olympic Games, Tokyo.

The findings of the present study indicate several factors that contribute to the success of Olympic medalist gymnasts:

- The gymnasts achieved the highest and lowest total scores with clubs and ribbon, respectively. However, it's notable that the ball apparatus, which encompasses five subcomponents related to difficulty, artistry, and execution (DA, D-Total, EA, E-Total, and Total Score), had the most significant influence in terms of securing an Olympic medal. In contrast, ribbon, with only one subcomponent (EA), had the least impact.
- When considering the total scores across all four apparatuses, it becomes evident that to achieve a substantial difference and secure an Olympic medal, the greatest impact is primarily attributed to the apparatus difficulty and artistic components. However, D-total and E-Total scores also make notable contributions to this outcome. It is worth noting that, for all apparatuses, the DB (Difficulty of Body) and ET (Execution Technique) scores displayed no significant effect on the final score. This finding, while intriguing, warrants careful consideration. It suggests that Olympic gymnasts, whether medalists or not, have a preference for incorporating high-difficulty elements in their routines and perform similarly in terms of both apparatus and body elements. Nevertheless, it should be acknowledged that these results may vary based on error rates or differences in difficulty values.

This study provides reference values for key performance indicators and highlights the differences in choreographic components among the four apparatuses (hoop, ball, clubs, and ribbon) for individual senior rhythmic gymnastics finalists who either won or lost medals in the Olympics.

Based on these findings, coaches should prioritize choreography planning aimed at enhancing difficulty, particularly the apparatus difficulty score, while maintaining or even improving execution scores. Additionally, coaches should consider each gymnast's potential to incorporate artistic components with both body difficulties and apparatus challenges. This approach can elevate the initial scores of routines in a multidimensional manner.

While high scores in hoop, ball, and club apparatus routines play a crucial role in winning Olympic medals, coaches may consider devising new strategies for their gymnasts in the future by emphasizing technical excellence in ribbon routines.

In the future, coaches may have the opportunity to monitor the progress of gymnasts in choreography planning and Olympic Games preparation by analyzing the contribution of score components from Olympic gymnasts in each apparatus to the total score. Furthermore, the analysis of these score components can facilitate the optimization and personalization of gymnasts' training processes.

The findings of this study hold significance as they offer a fresh perspective on the ever-evolving competition rules, which are regulated every four years by the FIG-RG-TC authorities.

Overall, more research is needed to confirm the current findings in different OGa with varying levels of rhythmic gymnast expertise.

Based on the results presented in the current study, it can be concluded that:

• The combined results of the four apparatuses are not equal to the overall result.
• The DA, D total, and EA scores in all four apparatuses play an important role in winning an Olympic medal.
• The influence of total score components (DB, DA, EA, and ET) on the final score varies depending on the specific apparatus.
• The ball is the most influential apparatus for securing Olympic medals, while ribbon has the least effect in this regard.

Coaches can use the current research findings in their planning of preparation strategies for gymnasts competing in all-around, team, and apparatus competitions.

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SOURCES OF ORGANIZATIONAL STRESS AMONG YOUTH RHYTHMIC GYMNASTS: AN INTERPRETATIVE PHENOMENOLOGICAL ANALYSIS

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Abstract
The aim of the study was to explore sources of organizational stress among Brazilian youth rhythmic gymnasts. Semi-structured interviews were conducted with six female athletes aged approximately 15 years (M = 14.50; SD = 1.76) with approximately seven years of experience in the sport on average (M = 6.83; SD = 3.25). Deductive categorical analysis was used to analyze the raw data. Our analysis revealed that sport entrapment, time management, and body image concerns are some of the stressors experienced by rhythmic gymnasts. Coach-pressure, peer-pressure, and parental-pressure are additional sources of stress reported by the athletes. Finally, the athletes reported experiencing competitive anxiety before, during, and after competition. Collectively, our findings suggest that rhythmic gymnasts reported a multitude of sport-related stressors. To counter these pressures, coaches, and practitioners need to equip athletes with a variety of coping skills in order to promote well-being and increase peak performance in the sport.

Keywords: *Organizational Stress, Gymnastics, Cross-Cultural Research.*

INTRODUCTION

Numerous types of stressors (i.e., sources of stress) are experienced by athletes in competitive settings, such as logistics preparation, performance expectations, and relationships with coaches and peers (Arnold, Fletcher, & Daniels, 2016). In turn, the ability of athletes to cope with different stressors is related to their mental health in general and athletic performance in particular (Rice et al., 2016). Broadly conceived, stress pertains to individuals' subjective perception of disturbing stimuli and related ability to cope with these demands

(Folkman & Lazarus, 1985). Noteworthy, stress arises from the individual, the environment, and its compound interactive effects (Gustafsson & Skoog, 2012; Hanton, Fletcher, & Coughlan, 2005).

Recently, scholars have studied stress in sports from a broader organizational standpoint. Organizational stress pertains to the stress demands associated with the organization wherein an individual is operating (Arnold & Fletcher, 2012; Arnold, Edwards, & Rees, 2018). Within the sport context, the competitive demands of a given sport are thought to generate different sources of stress (Arnold et al., 2016; Hanton et al., 2005; Mansell, 2021; Woodman & Hardy, 2001). In this context, Arnold and Fletcher (2012) analyzed 34 studies on organizational stress and identified over 600 different sources of stress, which can be clustered into four categories: (a) leadership and personal matters, (b) issues related to the team or culture, (c) environmental issues or logistics, and (d) issues related to personal performance.

Indeed, the bulk of extant research suggests that elite athletes tend to experience various sources of organizational stress, as related to environmental (e.g., financial pressures), personal (e.g., injury), leadership (e.g., coaching styles), and team issues (e.g., communication; see Woodman & Hardy, 2001). Moreover, there is evidence that elite athletes experience more stress demands associated with their sport organization than with their competitive performance (Hanton et al., 2005). There is, however, sparse research on organizational stress among youth athletes (Hayward, Knight, & Mellalieu, 2017). Historically, most research in sport psychology has been focused on a population of Caucasian and male collegiate athletes (Schinke, McGannon, Parham, & Lane, 2012). Accordingly, research targeting youth athletic populations is generally needed, especially among athletes from minority backgrounds. Research in the so-called "intersect" of social minorities, such as young female athletes from poor and developing countries/nations, remains scarce (see Watson & Scraton, 2013).

In fact, previous research suggests that the adaptation mechanism developed by athletes in developing countries tends to differ from those experienced by athletes in North America and Western Europe (Ferreira, Penna, Costa, & Moraes, 2012; Salmela & Moraes, 2003). For instance, in richer countries, parents drive kids to practice and even move around the country to allow them access to the best coaches, support staff, and training centers (see Coté, Saimela, Trudel, Baria, & Russell, 1995). In contrast, in developing countries such as in Brazil, parental support consists of allowing perceived "talented kids" to practice a sport discipline rather than requiring them to work at young ages in order to help with the household expenses. In the developing world, the organization of try-outs, practice and competition is less structured and more informal, thus contributing to higher stress demands on young athletes (Ferreira et al., 2012). This informality scenario has been modified little by little over time, with the improvement of the organization and training systems of the RG in Brazil. This is also reflected in the increase in studies on the modality (Menezes et al., 2022). Moreover, the mechanisms of sport and talent development among boys and girls differ, and more studies on the unique paths of female athletes are necessary (Curran, MacNamara, & Passmore, 2019).

In the present study, we sought to explore sources of organizational stressors among Brazilian youth in Rhythmic Gymnastics (RG), an individual sport in which participants are exposed to a variety of stressors at very young ages (e.g., performance pressure, high volume of practice), and usually before 15 years of age (Law, Côté, & Ericsson, 2007). Peak performance in RG generally occurs at young ages, and thus athletes are often required to specialize at an early age (DiCagno et al., 2009). In turn, early specialization may negatively impact the bio-psycho-social health of young athletes (Malina, 2010). Moreover, participation in RG often requires a specific body type, most notably a small stature and low level of body fat, which in turn can trigger body-image and self-objectification feelings (see Kosteli, Van Raalte, Brewer, & Cornelius, 2014; Nordin, Harris, & Cumming, 2003; Sick, Sabiston, Maharaj, & Pila, 2022). Finally, evaluation of RG performance in competitions is subjective in nature, and the presence of judges is thought to generate stress and related cognitive somatic and anxiety symptoms (Tsopani, Dallas, & Skordilis, 2011).

The present study is theoretically grounded in the Organizational Stress framework (Arnold & Fletcher, 2012; Arnold, Fletcher, & Daniels, 2016). Moreover, our study is aligned with the need to explore the organizational stressors experienced by young athletes from diverse ethnic and cultural backgrounds. Congruent with the call for culturally diverse studies (Schinke et al., 2012), we explored the potential sources of stress experienced by young RG athletes in Brazil. Specifically, in Brazil, RG is considered a sport for the wealthy, and thus we were interested in exploring the experiences of young females from one of the poorest regions in Brazil. More specifically, we sought to address the following research question: What are the main sources of organizational stress experienced by young RG athletes?

METHODS

The present study consisted of an interpretative phenomenological analysis (IPA) implemented through the use of semi-structured interviews. IPA is an idiosyncratic qualitative approach, and thereby considered an ideal platform for studies with small sample sizes (Patton, 2015). IPA is concerned with the detailed examination of personal lived experience and how participants make sense of this experience (Smith, 2011). IPA represents an interpretive post-positivist ontological and epistemological stance to qualitative inquiry (see Patton, 2015). Specifically, our study is based on a realistic ontological stance and reflects an interpretivist approach (Patton, 2015). In other words, we aimed to explore and interpret gymnasts' perceived realities of organizational stress.

Six female RG athletes from two clubs participated in the study. The athletes were between 12 and 17 years old ($M = 14.50$; $SD = 1.76$) and had on average 6.83 years of experience ($M = 6.83$; $SD = 3.25$) in the sport. All participants competed at the national level, had at least three years of competitive experience in the sport, and practiced between two and four hours per day, five days per week. To maintain the anonymity of the reports, each athlete was given a pseudonym (G1 through G6). This study was approved by the leading author's University Ethics Committee of (protocol number 46561715.3.0000.0018).

A semi-structured interview script, based on the Organizational Stress framework (Arnold and Fletcher, 2012), was developed over a series of peer-debriefing meetings involving the first and last author. The script covered six thematic areas: (1) general information and sports; (2) family support; (3) sport environment; (4) impact on social life; (5) body image; and (6) bio-psycho-social consequences. Examples of questions asked during the interview include, among others: “Tell me about the positive and negative elements of your sport?” and “Does being an RG athlete influence your social life with family and friends?”

The leading author contacted all RG clubs (N = 4) in a large city in North Brazil and explained the overarching purpose of the study to the club manager. Two clubs agreed to take part in the study. Once the club manager agreed to participate, a date and time were arranged to brief the athletes and their parents/guardians on the purposes and methods of the study. Given that the participants were under 18 years old, the researcher contacted the athletes in the presence of their parents/guardians to explain the objectives of the study and obtain permission for participation. Following this briefing meeting, a time to interview those athletes willing to take part in the study was arranged. Prior to the commencement of the interviews, the athletes and their parents/guardians signed an informed consent form. The interviews were conducted at a date and time chosen by each gymnast. The parents and coaches of the gymnasts were in the same building during the time of the interviews, however, each interview was conducted individually with each athlete alone by a female researcher, as parental and coaching pressure could influence the athletes’ responses. All interviews were conducted in a quiet room, free from distracting noise. The interviews lasted approximately 30 minutes on average (M =29 min, 19 sec; SD= 3 min, 26 sec) and were recorded using a digital video recorder (Sony DCR-SX20 model).

The data was analyzed through direct categorical analysis, which consists of a deductive approach of searching for predetermined categories (see Elo & Kyngäs, 2008; Hsieh and Shannon, 2005). Specifically, in the present study, the predetermined categories used for the direct categorical analysis consisted of those identified by the taxonomical study of Arnold and Fletcher (2012). More specifically, the coding process followed the steps proposed by Hsieh and Shannon (2005). Initially, the first and last author independently read and reread the verbatim transcripts of each individual interview. Next, they independently searched for meaning units consistent with the major themes in the Organizational Stress framework, namely (a) leadership and personal matters, (b) issues related to the team or culture, (c) environmental issues or logistics, and (d) issues related to personal performance. Subsequently, the first and last author met several times to discuss each other’s analysis until an initial consensus was reached. Next, to increase the validity of the findings, the second author served as a “critical friend” and independently reviewed the findings reached by the first and the last author (see Smith & Sparkes, 2020). Additional peer debriefing meetings were carried out among these three independent coders in an effort to maximize the trustworthiness of the findings. A total of 223 meaning units were initially identified by the three independent coders. The authors then discussed these meaning units until consensus was reached, and selected quotes to illustrate the data within the manuscript write-up.

RESULTS

As noted above, our direct content analysis was based on the four first order themes proposed by Arnold and Fletcher (2012), namely: *leadership and personal matters*, *issues related to the team or culture, environmental issues or logistics*, and *issues related to personal performance.* Additionally, each of these themes was defined a priori, outlined by the second order themes, which were defined a posteriori, based on the athletes' records. First and second order themes are graphically depicted in Figure 1. Representative meaning units illustrating each second order theme were selected and are presented next.

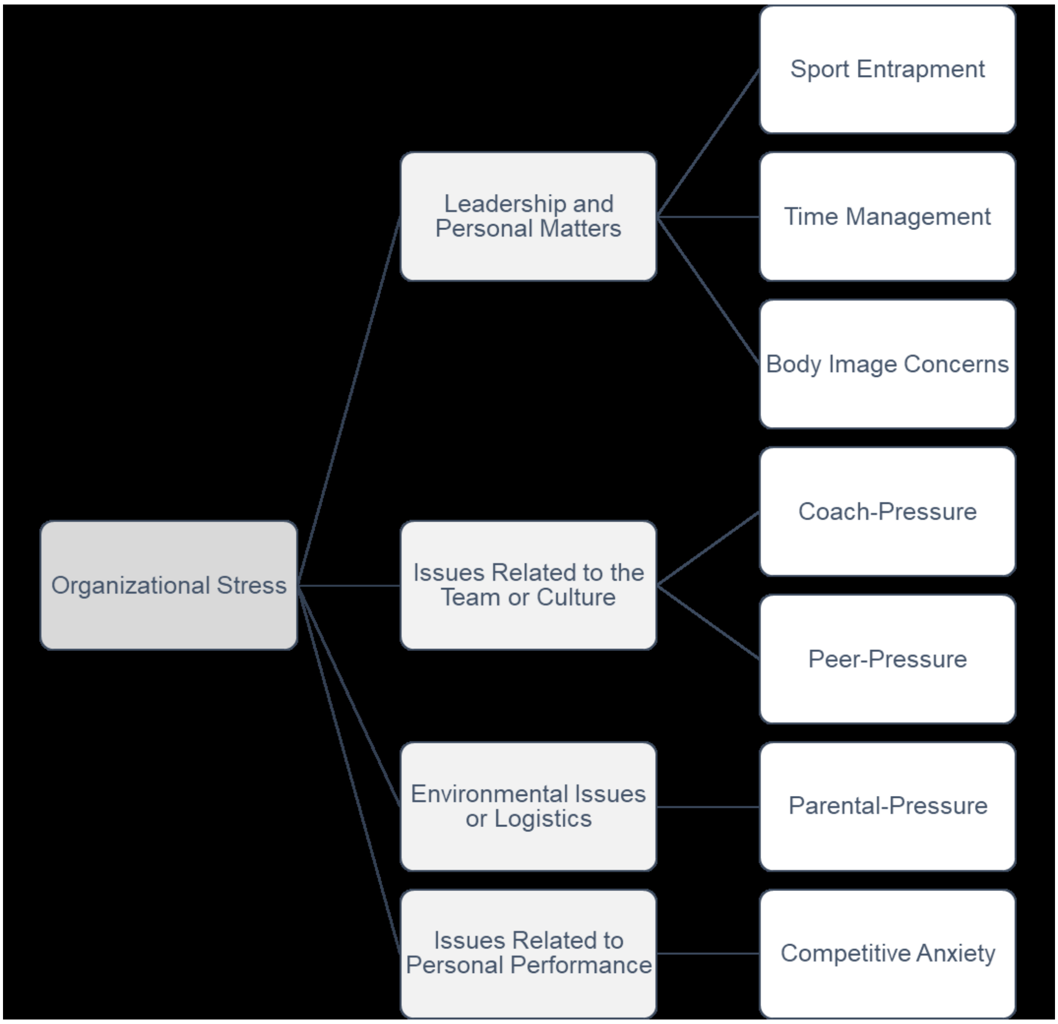

Figure 1. Sources of organizational stress in rhythmic gymnastics.

Leadership and Personal Matters

Sport entrapment. The athletes struggled to balance leisure time with the rigorous training demands of RG. The gymnasts reported feeling entrapped into the sport milieu, as they were unable to attend social gatherings (e.g., parties, sightseeings, and meetings) with their friends because of their sport-related commitments:

Oh let's go shopping on Friday! But I have to say: I cannot. I'm training. (Interview Excerpt – G5)

There was one time I really wanted to go to my friend´s 15 years birthday party…but I couldn't because I had to travel... it's life, right?! (Interview Excerpt – G1)

These things of going to the mall, to the movie theater... these things won't work sometimes because of training. (Interview Excerpt – G3)

Time management. The gymnasts reported having great difficulty balancing their training regime with schoolwork. Daily commitments, such as completing homework on time, were a challenge for the athletes. Missing classes was also a concern for the gymnasts:

I miss classes, content...It is always a concern. It is hard because you have to study and go to training. (Interview Excerpt – G1)

It is difficult because you have to travel to compete and when you come back all of your assignments are late… It is twice as much work! (Interview Excerpt – G2)

It messes with schoolwork because I miss classes and content… so I am always worried because I have to study and go to practice (Interview Excerpt – G4)

Body image concerns. Self-imposed as well as external pressures for the ideal body weight appear to be another source of stress experienced by the athletes. Our analysis suggests that the gymnasts can perceive their body to be inadequate for the practice of RG, which in turn might lead to eating disorders. Puberty changes were also a source of stress, as the physical changes that came with it interfered with the gymnasts' ideal body image.

My body is not good for gymnastics [...] I put my finger down my throat to vomit [...] There is a time the person turns desperate because everyone is talking about it, talking, talking, and talking… then you feel the pressure! (Interview Excerpt – G1)

When the time comes, we become more like teenagers, and the hormones flourish… and your body is more "women-like" … than it is a bit more difficult to be a gymnast. (Interview Excerpt – G2)

Issues Related to the Team or Culture

Coach-pressure. The gymnasts perceived that relating to their coaches was stressful at times because their coaches' showed favoritism to some athletes, as exemplified below.

Every coach has an athlete he likes more, and then he (coach) spends more time training that athlete, and then the other gymnasts get upset… I mean, generally the coach trains everyone and treats everyone the same, but there are times when you can see that he is giving more time to one athlete. (Interview Excerpt – G5)

Peer-pressure. Intra-group conflict generated additional stress during training and competition. Intra-group conflict seemed to arise from gossip and communication problems between the athletes as illustrated below.

There are athletes that when they are with the group they will say one thing… But when they are not in the group they will talk crap about their teammates… and this complicates things! (Interview Excerpt – G6)

You know… its gossip. People talking behind each other's back…I would much rather have us all standing together. (Interview Excerpt – G3)

Environmental Issues or Logistics

Parental-pressure. The athletes also identified parental pressure as a source of stress. Specifically, the gymnasts reported that their parents often expected them to perform at peak level all the time in both training and competition.

If I make a mistake, she (mother) will spend the whole day like this… "you should have trained better… you should have done better" and I am training hard but there are times that you cannot be that good. (Interview Excerpt – G4)

It is because sometimes it feels hard… like she (mother) is pushing me… I need to get that, and that must be done right… (Interview Excerpt – G2)

Issues Related to Personal Performance

Competitive anxiety. The athletes reported feeling anxious before, during, and after training and competition. Overall, they noted that they were afraid of failure, and particularly of making execution mistakes in (overlearned) movement routines.

You want to succeed but then you get stressed with the training or you get mad at yourself because you are not doing it [the routine] right… (Interview Excerpt – G3)

Before [competition] I feel nervous… we think about all the training. As they say, we practice every day, four hours a day, and then we go to a competition, and we get one minute and half to do everything. (Interview Excerpt – G5)

If I am making mistakes, I get nervous, I get sad, I want to cry… I cry. There were times when I would go get water, and then I sat down and started to cry. (Interview Excerpt – G1)

I feel sad when I compete well but get a low score or when I do not compete well and think I could have done better. (Interview Excerpt – G3)

DISCUSSION

We explored sources of organizational stress among young Brazilian rhythmic gymnasts. We adopted a realistic ontological stance and interpretivist epistemological approach; that is, we aimed to understand and theoretically interpret the perceived realities of competitive young Brazilian gymnasts. Our direct categorical analysis was theoretically informed by previous research in organizational stress (Arnold & Fletcher, 2012), and revealed sources related to *leadership and personal matters*, *issues related to the team or culture*, *environmental issues or logistics*, and *issues related to personal performance*.

Leadership and Personal Matters

Sport entrapment was reported by the athletes as a source of personal stress. These findings add to the literature by suggesting that young gymnasts perceive that their social well-being is at odds with the development of a successful athletic career. As such, young athletes, coaches and parents need to be educated that the opposite is true, as athletes under high competitive pressure need to develop relationships outside the sport environment in order to perform well athletically and stay healthy (Kroshus & DeFreese, 2017). Sport entrapment has been related to overtraining and burnout, and thus must be minimized by encouraging young athletes to partake in different social milieus while engaging in purposeful and meaningful recovery activities (Côté, Lidor, & Hackfort, 2009; Raedeke, 1997).

Time management was also found to influence the athletes' personal lives. In addition to committing significant time to training and competition in RG, managing school responsibilities was deemed to be stressful by the young athletes. Noteworthy, adolescent athletes have been found to possess fewer coping (i.e., less adaptive coping strategies and more maladaptive coping strategies) and life skills than adults (Hampel & Petermann, 2006). Accordingly, teaching young athletes the coping skills (e.g., problem and emotion focused) might alleviate their feelings of stress (Hayward et al., 2017; Nicholls & Polman, 2007).

Body image concerns were another source of stress experienced by the athletes. Body image issues are predominant in sports like RG, wherein an ideal body type is oftentimes considered a necessary condition for excellence (Nordin et al., 2003). Moreover, pressures for the perfect body can trigger problems related to eating disorders (Oliveira, Bosi, Vigário, & Vieira, 2003). As such, we reiterate the importance of educating young athletes about healthy dietary behaviors and mindful body acceptance (Kosteli et al., 2014). In addition, coaches must be aware of the cultural aspects associated with the striving for perfect bodies as well as the possible negative consequences of this (Sherman, DeHass, Thompson, & Wilfert, 2005).

Issues Related to the Team or Culture

Coach-pressure was a source of stress for the RG athletes. Specifically, the athletes reported that at times their coaches criticized their performance in public and showed preference for some athletes rather than exhibiting fair treatment to all gymnasts. Given that healthy relationships with coaches are an important factor in expertise development in youth sports (Côté et al., 2009), it is essential to educate coaches on communication skills, such as active listening and types of feedback (e.g., motivational and instructional; see Law et al., 2007). In addition to communication skills, social, educational, and psychological skills are needed to create a positive effect on the quality of the coach-athlete relationship in the context of individual youth sports (Lisinkiene, 2018).

Peer-pressure was also found to generate stress in RG. The gymnasts reported that intra-team conflict, generated by communication issues, was a very stressful component of their sporting experience. These findings add to the literature by suggesting that team processes are important even in individually performed sports. Specifically, our findings suggest that coaches and practitioners should emphasize a task-oriented climate in practice and competition, where success is self-referenced, and the emphasis is on learning and effort, rather than an ego-oriented climate where the emphasis is on competition and comparison to peers (Bortoli, Bertollo, Filho & Robazza, 2014).

Environmental Issues or Logistics

Parental-pressure was highlighted by the athletes as a major stressor in their athletic experience. Athletes feel pressured by their parents in many ways, including pressure to perform at peak level all the time. It has long been known that healthy parental involvement in sports and other domains of human performance is crucial for talent development (Salmela & Moraes, 2003). Thus, parents need to be educated about applied psychological principles, particularly the notion that unrealistic performance expectations can lead to overtraining, burnout, and other clinical psychological conditions (Malina, 2010). Similar to the process of coaches' education, parents need to be educated to form a healthy relationship with their youth athletes, especially since most of them do not have adequate knowledge about the context of competitive sport (Dorsch, King, Tulane, Osai, Dunn, & Carlsen, 2019)

Issues Related to Personal Performance

Competitive anxiety was another source of stress reported by the athletes', as their performances were subjectively evaluated by judges. The subjective assessment of performance before a judge in a competition can indeed trigger competitive anxiety, as the scores received for performance routines are often lower than expected (Tsopani et al., 2011). Our results also revealed that the athletes experienced pre-, during and post-performance pressures. In fact, previous research (Ruiz, Raglin, & Hanin, 2017) purports that both dysfunctional (e.g., stress) and functional (e.g., confidence) affective patterns tend to be experienced differently over distinct time windows. Therefore, our findings suggest that specific psychological routines should be developed to address the stressors that come into play before, during and after gymnastics competitions.

Another important approach regarding not only competitive anxiety, but all RG context and its stressors sources, relies on the notion that athletes should be encouraged to develop coping strategies, but, equally important, all those involved (athletes, parents, coaches, referees) should be instructed to promote a better environment, focusing on reducing the stress sources and creating a healthier and safe environment (Camiré et al., 2012).

LIMITATIONS

This study is not without limitations. Trustworthiness of the findings could have been increased by triangulation of methods (e.g., observations and document analysis) and participants (e.g., interviewing coaches and parents). Accordingly, specific avenues for future research include exploring the sources of organizational stress experienced by coaches and parents with respect to themselves and RG athletes. Although naturalistic generalizability of the findings is possible (see Smith & Sparkes, 2020), multi-site and multi-cultural studies are important to unpack potential country-level idiosyncrasies pertaining to sources of organizational stress in sports (Schinke et al., 2012).

Despite the limitations, this study identified and clarified the key factors behind different stressors in the rhythmic gymnastics' environment. Young female Brazilian RG athletes reported worrying about their bodies, their (in)ability to manage relations, sport and schoolwork, and feelings of sport entrapment. They also reported experiencing competitive anxiety and performance pressure from coaches, parents, and their peers. Considering these findings, we suggest that sport and context specific mental toughness training programs might be more effective than trainings developed for different organizational contexts. Specifically, practitioners need to equip coaches and athletes with a myriad of skills so that they can cope with stressors arising from personal and leadership factors, team issues and culture, environmental factors and logistics, and personal performance. In particular, teaching athletes' pre-performance routines and a task-oriented focus may help with personal performance and environmental stressors, respectively. As an example, visualization techniques can help gymnasts assimilate the actions to be performed during the presentation. Addressing communication issues between athletes and coaches, ensuring that athletes have a social life beyond sports, mindful acceptance of their bodies, and time-management skills can also help to ameliorate stress in RG. These interventions might not only be focused on coping strategies, but on diminishing the stress factors as well.

CONCLUSIONS

In conclusion, the findings of this case study add to the literature by highlighting the complex and multi-dimensional nature of organizational stress in sports, thus revealing that multiple theoretical frameworks and intervention techniques are needed to support and develop healthy athletes in RG.

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JUDGE BIAS IN AESTHETIC GROUP GYMNASTICS

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Abstract

There are several competitions where the objectivity of judges has raised some questions, in particular the style point evaluation. If part of the actual performance can be objectively measured with an instrument and part of the performance is based on subjective evaluation of judges, an error in ranking is possible. There are some sport disciplines, like ski jumping, where both metrics are used (Krumer et al., 2020); however, in gymnastics, the only criteria are judges' subjective evaluation (Bučar et al., 2012; Leskoŝek et al., 2012; Rotthoff, 2014).

Our analysis reveals that biased judging in aesthetic group gymnastics is more than probable in domestic competitions in Finland. The local judge that evaluates their own team is not overestimating the performance in any of its three parts: technical value, artistic value, or execution value. However, it seems that judges strategically underestimate the performance of the most important rival. This underscoring is truncated since the highest and lowest scores are truncated in the case of four judges. The local judge's scoring is usually within the two middle scores, which is taken into account in the final score of a performance.

Our analysis used evaluations of 66 different competitions including 585 performances in a period of 22 months. All competitions were domestic, with domestic teams and domestic judges only. Many competitions had 12 judges: 4 evaluating technical value, 4 artistic value, and 4 execution value. All judges were nominated before the actual competition.

Keywords: *Aesthetic group gymnastics, Finland, Judge bias.*

INTRODUCTION

There have been several competitions in which the objectivity of judges has raised some questions. In particular, the style point evaluation – namely, the objectivity of judges – has been challenged. If part of the actual performance can be objectively measured with an instrument and part of the performance is based on the subjective evaluation of judges, an error in ranking is possible. There are some sport specialties, like ski jumping, where both metrics are used (Krumer et al., 2020); however, in most gymnastics the only criteria are the judges' subjective evaluations (Bučar et al., 2012; Leskoŝek et al., 2012; Rotthoff, 2014).

Reliability in measurement is consistent when, under identical conditions, the same results are achieved. Laboratory testing falls into this category. However, achieving identical performances in sports can be challenging as athletes may not perform identically in repeated attempts, often due to factors such as muscle fatigue.

Objectivity is defined as obtaining the same result from different authorities evaluating the same performance. There are several reasons why judges may fail to be objective. For instance, judges may display favoritism towards their own ethnic group, resulting in fewer fouls being called when their race matches that of the refereeing officials in the NBA (Price & Wolfers, 2010). Similarily, they might call more penalties on soccer players with a different mother tongue (Faltings et al., 2019). Judges may award more style points to their compatriots in ski jumping (Balmer et al., 2010; Krumer et al., 2020; Zitzewitz, 2006) , boxing (Balmer et al., 2007), gymnastics (Balmer et al., 2011) or figure skating (Findlay & Ste-Marie, 2004; Zitzewitz, 2014). Corruption is also a potential issue (Moriconi & de Cima, 2021; Zitzewitz, 2014). Furthermore, experience plays a role in judging. More experienced judges tend to be better than novices at perceptually anticipating upcoming gymnastic elements based on advance information (Ste-Marie, 1999). Soccer referees can also be influenced by home team spectators' noise, leading to fewer penalties being awared to the home team (Boyko et al., 2007).

Ranking in group gymnastics is based on the technical value of both obligatory and non-obligatory movements, the artistic value of the performance, and the execution value of the performance. Consequently, there are three judge groups involved in each competition. The judging process typically divides scores into components: a difficulty score which evaluates the complexity of each movement executed by a gymnast, and an execution score, which assesses the performance of each movement performed by the group during their routine in the competition.

The ranking in aesthetic group gymnastics (AGG) is based solely on the aesthetic criteria of the participating teams. AGG evolved from traditional Finnish women's gymnastics and shares some similarities with rhythmic gymnastics. An AGG competition program is a fusion of artistry and athleticism, set to music, and it encompasses various elements such as body movements, balances, jumps, and combinations. Beyond the obligatory difficulty elements, the entire performance is unified by a continuous, flowing movement and the program's overall atmosphere or theme, which is conveyed through the language of movement, the music selection, and the artistic elements woven into the routine. The entire performance is elevated by the performers' capacity for empathy and expression.

The jury panel is typically selected approximately one to two hours prior to the competition. In most cases, each participating team is obligated to provide one judge for the competition. However, the availability of authorized judges is often limited, and these judges are typically coaches affiliated with one of the competing teams. Consequently, there exists the potential for judges to render biased rulings.

The objective of this study is to evaluate potential bias within judge panels based on a sample of various group gymnastics competitions held in Finland. The range of competition varies from local and rather small competitions to Finnish championship competitions where almost all existing groups are represented. Additionally, there are a few important competitions that sigbnificantly impact the selection of the Finnish national team. The bias exhibited by judges is quantified by either awarding higher scores to the home team compared to other judges' assessments (referred to as over-grading) or assigning lower scores to other teams, typically the primary rivals, in contrast to other judges' evaluations (known as under-grading). The study aims to determine whether over-grading or under-grading bias exists in Finnish group gymnastics competitions. Furthermore, it seeks to identify potential strategies to mitigate or reduce such bias in future competitions.

Our analysis looks at scores assigned to teams by various judges, including the possibility of a coach judging their own team. Specifically, we examine whether the coach serving as a judge tends to award higher scores to their own team compared to the scores given by other judges, who are likely associated with different teams. To investigate this potential bias, we conduct paired-sample t-tests to assess the disparity between the scores provided by the team's own judge and those assigned by the other judges (referred to as over-grading). Additionally, we perform similar paired-sample t-tests to identify any instances of under-grading by judges associated with rival teams.

METHODS

Depending on the competition series, an AGG competition team typically consists of 6 to 12 gymnasts who perform a routine lasting approximately 2 to 3 minutes. The specific requirements for the routine, such as the number of body movements, balances, jumps, and combinations, can vary depending on the series.

The competition takes place in a designated area measuring 13 x 13 meters, and teams are expected to utilize the space creatively throughout their program. AGG competitions are organized into different age and level categories:

Children's series are available for 8 to 10-year-olds, 10 to 12-year-olds, and 12 to 14-year-olds. Gymnasts under the age of 12 compete within their respective age groups, either in the 8- to 10-year-olds or 10- to 12-year-olds series.

AGG gymnasts aged 12 and above have the option to compete at three different series levels: the Finnish Championships, the Racing Series, and the Hobby Series. Teams can choose the level that suits them best.

The national competitions within the Finnish Championship series hold significant prestige. All series feature age groups for children (12- to 14-year-olds), juniors (14- to 16-year-olds), and women (over 16 years old). Additionally, there are competition series for gymnasts in the 12–14, 14–16, 16–20, and over-18 (women) age categories.

The Hobby Series is open to participants in age groups 12–14, 14–16, and over 16.

In all series except the 8–10 series, the jury will be composed of three different jury panels. One panel of judges assesses the technical value of the program (TV = technical value). For example, in the 10- to 12-year-old series, this jury observes whether all required skill parts are included in the competition program (body movements, balances, jumps, hand movement sets, step sets and jumps, acrobatic movements, mobility movements). In all age groups (10–12, 12–14, 14–16, and over 16 years old) of 10–12, the maximum TV score is 6.0 with 0.1 increments. The task of the second jury is to assess the artistic value of the program (AV

= artistic value). AV points are affected, for example, by team gymnastics technique, the synchronicity of gymnasts, the composition and originality of the program, and the unity of the group. The maximum AV score is 4.0 with 0.1 increments. The third panel of judges evaluates the execution (EXE = execution). This jury makes deductions for observed errors, such as incomplete stretches, poor posture, falls, and loss of balance. The maximum performance score is 10.0 with 0.1 increments. In addition, in each criterion (technical, artistic and execution), the judges can award a bonus if the performance is extremely good. A deduction is also possible if any gymnast is outside the designated area, or the costume is in breach with the rules. A typical reduction might take place if the gymnastic slipper falls off the leg. The slipper does not cover the heel. The maximum number of points in all series is 20. In the Finnish Championship series (highest level), the maximum of technical points is 6, of artistic points 4, and of performance 10. In the competition (medium level) and hobby (lowest level) series, the maximum technical and artistic points are 5. The 8-to 10-year-old series has two different judging panels: (1) composition; and (2) performance and expressiveness.

If there are four judges evaluating, for example, technical value, the extreme points, lowest and highest, are truncated, and the average of the two remaining is the score given to a team. In the case of three judges, no truncation is made and the final score is the average of three evaluations. It is important to note that all judges are making their evaluations simultaneously. Below are two examples of evaluations from four judges when a team performed really well. It is assumed that one judge represents their own team (judge #1) and one represents the most important rival team (judge #4). The two remaining judges (#2 and #3) are independent. Suppose that the team's own judge gives the highest possible points, and in scenario A, the rival judge does the same. In this case the final score is 5.95.

Table 1:
Technical value points given by four judges when the rival judge values the performance as extremely good.

Scenario A	Judge #1 (own)	Judge #2 (indep.)	Judge #3 (indep.)	Judge #4 (rival)
	6	5.9	5.9	6
Highest and lowest truncated	truncated	truncated	5.9	6
Final				5.95

Scenario B shows a case where the team's own judge gives the maximum points, and the rival judge gives a slightly lower point value. Both of these are truncated, and the final score in Scenario B is 5.9, a lower final score than in scenario A.

Table 2:
Technical value points given by four judges when the rival judge values the performance as rather good.

Scenario B	Judge #1 (own)	Judge #2 (indep.)	Judge #3 (indep.)	Judge #4 (rival)
	6	5.9	5.9	5.8
Highest and lowest truncated	truncated	5.9	5.9	truncated
Final		5.9		

In Scenario B, the rival judge uses strategic voting in order to lower the final score of the team (the team with its own judge in the panel). Scenario B in comparison with Scenario A shows that the strategy of Judge #4 is to give the most important rival fewer points (lower enough) since this results in a lower final score for the rival. Since the composition of the judge panels is randomised for each competition, the game is played only once; however, it is possible that the teams will remember the strategic voting bias, and during the next competition the judges may use a tit-for-tat tactics. This strategy is not studied in this paper.

RESULTS

The data used cover all competitions in the Finnish Championship series (highest level) between 2 November 2019 and 25 September 2011, including 66 competitions and 585 performances of 31 different gymnastic associations and 152 judges. Most gymnastic associations have teams in all three age series: 12- to 14-year-old, 14- to 16-year-old and over 16-year-old categories. The data source is public and available from www.kisanet.fi. Some descriptive statistics of the technical values awarded are shown below in Table 3. All judge points have been collected from these public websites. In addition, since the judges names are also public, the affiliations or home teams of the judges have been collected. If the coach of team has been also one of the judges, there is a possibility to over-grade one's own team and under-grade a rival team.

Based on Table 3, the average technical value is higher in the senior (over 16) category, and it seems that only the best teams have continued to the senior level. The number of performances (110) and evaluations (431) is only half the number of performances and evaluations in the juniors' (14- to 16-year-old) and children's (12- to 14-year-old) categories.

Judges gave their own teams average points. There is no significant difference between their own assessment and the middle assessment by the other three judges. The highest points awarded to other teams have been significantly higher than those given to their own team in the children's (t-test -3.582) and juniors' (t-test -3.914) categories. The lowest points given have been significantly lower than those awarded by the team's own judge. In the case of four judges, the highest and lowest points given are truncated in the final evaluation, which is the average of the two middle point values. Thus, the technical value evaluation of the team's own judge is usually included in the final score.

Table 3:
Technical value, descriptive statistics, all competitions at the highest level (Finnish Championship rules) between 2.11.2019 and 25.9.2021

Technical value max 6.0	All age series	12- to 14-year-olds #perf. 244	14- to 16-year-olds #perf. 231	16-year-olds+ #perf. 110
Average (std)	5.19 (0.65) n = 2252	5.18 (0.55) n = 920	4.98 (0.72) n = 901	5.67 (0.37) n = 431
Final score with truncation (std)	5.19 (0.63) n = 585	5.20 (0.50) n = 244	4.95 (0.71) n = 231	5.69 (0.34) n = 110

Table 4:
Technical value awarded by the team's own judge and other judges at the highest level between 2.11.2019 and 25.9.2021

Technical value	All age series	12	14	16
Team's own judge	5.265 (0.683) n = 95	5.165 (0.543) n = 31	5.138 (0.746) n = 45	5.732 (0.541) n = 19
The highest of the other three judges	5.448 (0.561)	5.445 (0.379)	5.298 (0.651)	5.811 (0.416)
Paired sample t-test (own vs. highest)	-5.39***	-3.582***	-3.914***	-1.662
Middle of the other three judges	5.160 (0.994)	5.194 (0.462)	4.916 (1.277)	5.684 (0.614)
Paired sample t-test (own vs. middle)	1.338	-0.387	1.420	1.634
The lowest of the other three judges	4.734 (1.498)	4.439 (1.590)	4.571 (1.578)	5.600 (0.642)
Paired sample t-test (own vs. lowest)	4.277***	2.715*	3.088**	3.371**

Table 5:
Artistic value, descriptive statistics

Artistic value max 4.0	All age series	12- to 14-year-olds #perf. 244	14- to 16-year-olds #perf. 231	16-year-olds+ #perf. 110
Average (std)	3.10 (0.48) n = 2243	2.99 (0.42) n = 920	3.03 (0.49) n = 901	3.52 (0.37) n = 431
Final score with truncation (std)	3.11 (0.45) n = 585	3.11 (0.37) n = 244	3.03 (0.47) n = 231	3.50 (0.36) n = 110

Artistic value is highest in the senior category, which is reasonable considering that seniors have more experience than younger gymnasts. Furthermore, there are fewer teams and performances than in juniors' or children's series. The final score, excluding the highest and lowest points that are truncated, is higher in the children's series.

Table 4:
Artistic value awarded by the team's own judge and other judges at the highest level between 2.11.2019 and 25.9.2021

Artistic value	All age series	12	14	16
Team's own judge	3.258 (0.451) n = 97	3.184 (0.403) n = 45	3.190 (0.511)) n = 29	3.487 (0.396) n = 23
The highest of the other three judges	3.325 (0.429)	3.231 (0.401)	3.283 (0.449)	3.561 (0.382)
Paired sample t-test (own vs. highest)	-3.328***	-1.773(*)	-1.823(*)	-3.364**
Middle of the other three judges	3.139 (0.475)	3.022 (0.417)	3.110 (0.498)	3.404 (0.469)
Paired sample t-test (own vs. middle)	5.450***	4.951***	1.771(*)	2.646**
The lowest of the other three judges	2.580 (1.222)	2.344 (1.224)	2.459 (1.341)	3.196 (0.836)
Paired sample t-test (own vs. lowest)	6.478***	5.281***	3.446**	2.034(*)

The artistic value awarded by tean's own judges is the second highest evaluation in most cases, and is therefore included in the final score. The highest value given in all age categories is higher than that of the team's own judge. The difference is significant in the senior category. Moreover, there is evidence that the lowest point value awarded is substantially lower than the points given by the team's own judge. The result indicates the possibility of strategic voting by judges from rival associations.

The execution value counts for half of the points given to a performance and, therefore, is the most important. The final scores for each part [t(echnical), a(rtistic) and e(xecution)] are positively correlated: $\rho_{ta} = 0.828$, $\rho_{te}= 0.820$ and $\rho_{ae} = 0.869$. Table 7 presents some descriptive statistics of the execution value given. The points increase with age: seniors have a substantially higher average (8.9) score than juniors (8.0) or children (7.8). The evaluation (Table 8) lies between the highest and the lowest.

The team's own judge evaluated technical value in 95 out of 585 competitions., whereas the number for artistic value is 97 and execution value 107. The share of competitions with a team's own judge is slightly higher than 50%. The highest share is in the senior category, i.e., 58%.

There is some evidence of bias, however. Since the lowest points awarded in each section seem to be significantly lower than those awarded by the team's own judge, the strategic underscoring is plausible.

Table 5:
Execution value, descriptive statistics

Execution value max 10.0	All age series	12- to 14-year-olds #perf. 244	14- to 16-year-olds #perf. 231	16-year-olds+ #perf. 110
Average (std)	8.098 (0.798) n = 2243	7.846 (0.728) n = 920	8.025 (0.776) n = 901	8.876 (0.451) n = 431
Final score with truncation (std)	8.094 (0.759) n = 585	7.850 (0.660) n = 244	8.019 (0.744) n = 231	8.891 (0.428) n = 110

Table 6:
Execution value awarded by teams' own judgse and other judges at the highest level between 2.11.2019 and 25.9.2021

Execution value	All age series	12	14	16
Team's own judge	8.373 (0.708) n = 107	8.020 (0.593) n = 41	8.486 (0.670) n = 44	8.805 (0.691) n = 22
The highest of the other three judges	8.546 (0.652)	8.283 (0.563)	8.609 (0.648)	8.909 (0.633)
Paired sample t-test (own vs. highest)	-5.768***	-4.416***	-3.351**	-1.994(*)
Middle of the other three judges	8.328 (0.702)	8.029 (0.571)	8.407 (0.731)	8.727 (0.648)
Paired sample t-test (own vs. middle)	1.723(*)	0.089	2.093*	1.882(*)
The lowest of the other three judges	7.885 (1.562)	7.549 (1.358)	7.818(1.917)	8.645 (0.663)
Paired sample t-test (own vs. lowest)	3.612***	2.190*	2.587*	3.332**

Recently, in Finnish aesthetic group gymnastics, two teams have consistently outperformed all others. One is based in the Helsinki region (Espoo), and the other hails from Tampere. Both have won several World Cup and World Championships competitions. In international competitions, there are typically two combined events, and the winner is the team with the highest cumulative score from the preliminary competition (usually held on Saturday) and the final competition (held on Sunday). International regulations stipulate that only the top two teams from each country can advance to the finals. Teams from Espoo (E) and Tampere (T) have most often secured their places in the final competition. The following analysis utilizes the points awarded in domestic competitions in comparison to the other leading team in Finland.

The results in Table 9 indicate that judges from the other top team seem to undervalue the rival's performance. This is especially notable in the execution points.

Table 7:
Pairwise comparison of rival judge's evaluation for the top two teams

	TV n = 13	AV n = 24	EXE n = 44		TV n = 18	AV n = 3	EXE n = 4
Points to Espoo awarded by Tampere judge	5.43 (0.65)	3.46 (0.44)	8.55 (0.65)	Points to Tampere awarded by Espoo judge	5.86 (0.17)	3.70 (0.10)	9.12 (0.09)
The highest of the other three judges	5.61 (0.48)	3.53 (0.37)	8.79 (0.58)	The highest of the other three judges	5.93 (0.13)	3.83 (0.05)	9.27 (0.28)
Paired sample t-test (rival vs. highest)	-2.71*	-2.00$^{(*)}$	-5.87***	Paired sample t-test (rival vs. highest)	-2.24*	-2.00	-1.13
Middle of the other three judges	5.49 (0.63)	3.31 (0.49)	8.62 (0.56)	Middle of the other three judges	5.88 (0.16)	3.73 (0.05)	9.17 (0.22)
Paired sample t-test (rival vs. middle)	-0.97	3.71***	-2.13*	Paired sample t-test (rival vs. middle)	-0.83	-0.50	-0.480
The lowest of the other three judges	5.41 (0.70)	3.20 (0.51)	8.50 (0.60)	The lowest of the other three judges	5.81 (0.23)	3.66 (0.05)	9.05 (0.26)
Paired sample t-test (rival vs. lowest)	0.35	5.92***	1.36	Paired sample t-test (rival vs. lowest)	1.37	1.00	0.54

DISCUSSION

The analysis reveals that biased judging in aesthetic group gymnastics is more than probable in domestic competitions in Finland. The team's own judge that evaluates their own team is not overestimating the performance in any of the three parts: technical value, artistic value, or execution value. However, it seems that the judges of the top teams strategically underestimate the performance of the most important rival. This underscoring is truncated from the final score, since the highest and lowest scores are truncated in the case of four judges. The team's own judge scoring usually is within the two most middle scores, which is taken into account in the final score given to a performance. The national gymnastic association should monitor bias in judging and if necessary, impose a fine to the home team of the particular judge and a temporary moratorium.

The analysis used evaluations of 66 different competitions with 585 performances in a period of 22 months. All competitions were domestic, with only domestic teams and domestic judges. Many of the competitions had 12 judges: 4 evaluating technical value, 4 artistic value, and 4 execution value. All judges were drawn prior to the actual competition. Since there is a shortage of judges, all teams must register one judge for each competition in which their team is performing. If the team cannot register any judge, the team must pay a penalty payment to the organizer of the competition.

CONCLUSIONS

Regrettably, biased judging appears to be a prevalent issue in entirely domestic aesthetic group gymnastics competitions. These competitions mandate the presence of over ten judges, with each participating team financially penalized for failing to provide one judge, often selected from the coaching staff. Remarkably, judges do not exhibit a tendency to overestimate their own team's performance. The scores provided by the team's own judge are neither the highest nor the lowest which would be omitted from the final score calculation.

However, there is evidence suggesting the practice of strategic underscoring when evaluating the most prominent rival team. This strategic underscoring potentially allows the judge to lower the final score of the rival team. Addressing this issue warrants immediate attention and action by the judge committee of the gymnastic federation.

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Appendix: Averages of all scores in Senior's competitions

Technical value	Judge #1 (own)	Judge #2 (highest)	Judge #3 (middle)	Judge #4 (lowest)
Seniors (16+) Highest and lowest truncated	5.732	5.811 truncated	5.684	5.600 truncated
Final			5.708	

Artistic value	Judge #1 (own)	Judge #2 (highest)	Judge #3 (middle)	Judge #4 (lowest)
Seniors (16+) Highest and lowest truncated	3.487	3.561 truncated	3.404	3.196 truncated
Final			3.445	

Execution	Judge #1 (own)	Judge #2 (highest)	Judge #3 (middle)	Judge #4 (lowest)
Seniors (16+) Highest and lowest truncated	8.805	8.909 truncated	8.727	8.645 truncated
Final			8.766	

Execution	Judge #1 (rival)	Judge #2 (highest)	Judge #3 (middle)	Judge #4 (lowest)
Seniors (16+) Highest and lowest truncated	8.55	8.79 truncated	8.62 (8.63) = aver. of three others	8.50 truncated
Final			8.58	

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SHORT HISTORICAL NOTES XXVIII

Anton Gajdoš, Bratislava, Slovakia

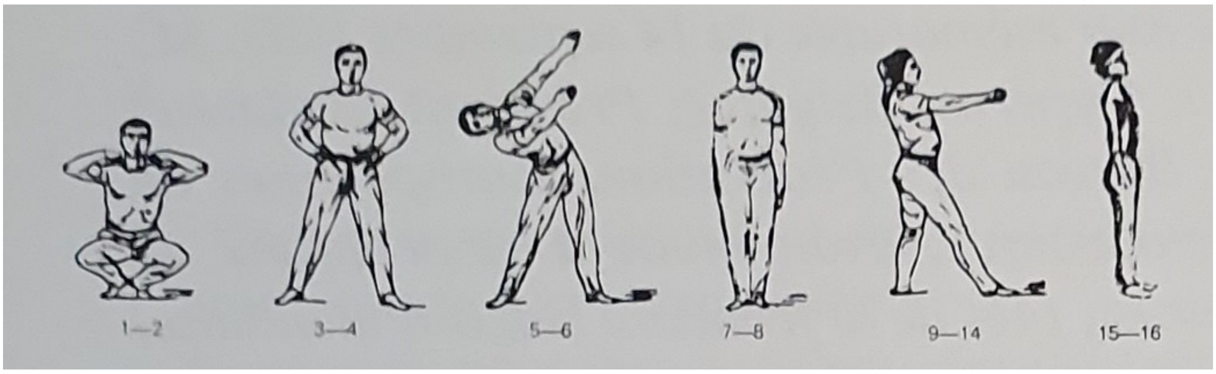
Ph.D. Anton Gajdoš born on 1.6.1940 in Dubriniči (today Ukraine) lives most of his life in Bratislava (ex TCH, nowadays SVK). He comes from gymnastics family (his brother Pavel have world championship medals) and he devoted his life to gymnastics. His last achievement is establishment of Narodna encyklopedia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

1st World Championship 1903 in Antwerpen

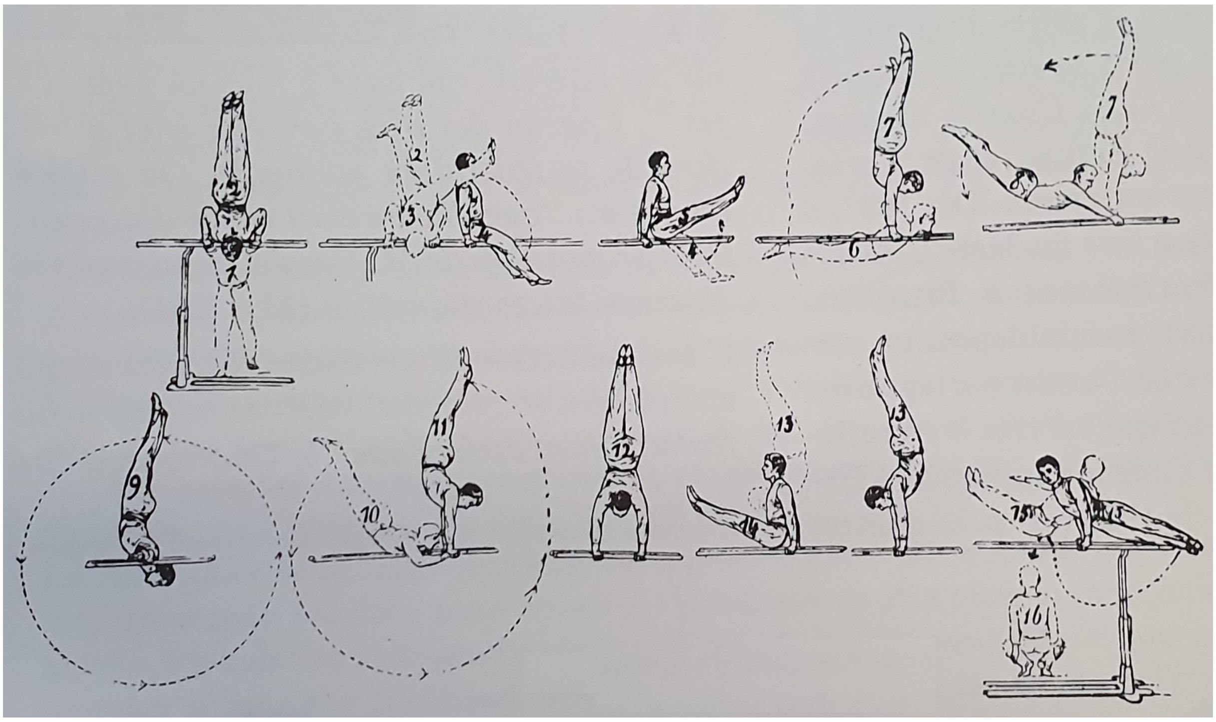
Antwerpen hosted already 3 World Championships in artistic gymnastics. The first was also the first ever organized by European Gymnastics Union (just by name, included also federation of Canada and federation of Egypt) World Championship in 1903, the second in 2013 and the last one 2023.

The first championship was organized just for men. They competed in four types of exercises in 21 discipline:

- 6 compulsory floor exercises, performed as a team, but evaluated each gymnast individually, 5 points for execution and 2 points for section compartment
- 12 exercises on apparatus 5 points for execution and 1 point for entrance and 1 point for leaving apparatus:
  - Two compulsory and optional exercise on rings, parallel bars and horizontal bar,
  - One compulsory and one optional exercise on pommel horse,
  - One compulsory vault
- 2 track and field disciplines:
  - Sprint 150 meters – 10 points – 18 seconds
  - High jump – 10 points – 175centimeters
- Weight lifting – 40 kg 20 times for 10 points



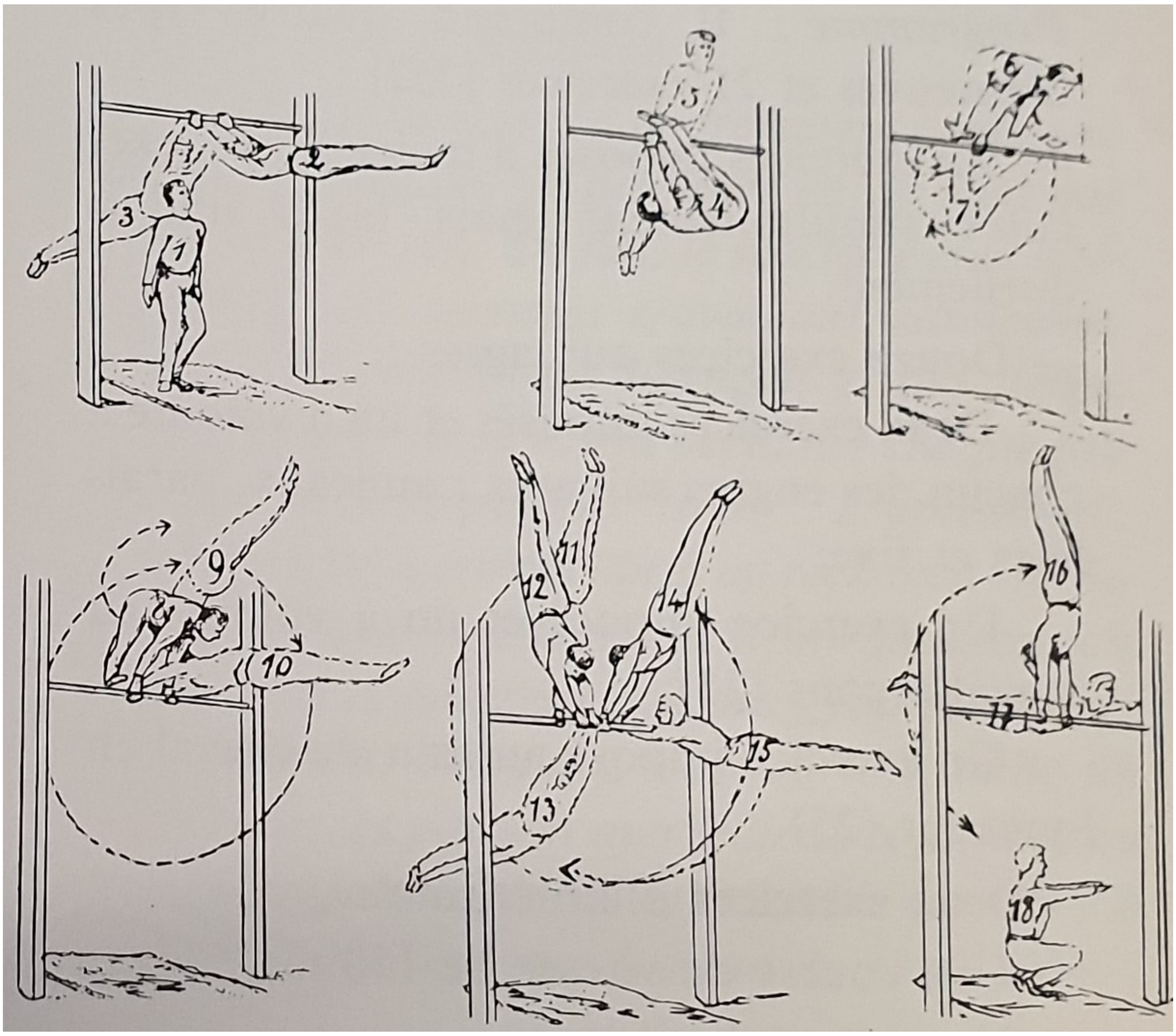
Example of Preliminary floor exercise compartment


The second compulsory exercise

RESULTS:

1. France
2. Belgium
3. Luxemburg
4. Netherland

1. Martinez (France)
2. -3. Lux (France) Wierinckx (Belgium)



The second compulsory exercise

Slovenski izvlečki / Slovene Abstracts

Michal Babela

ZGODOVINA TELOVADBE NA SLOVAŠKEM OZEMLJU OD 1918 DO 1980

Telovadba se na ozemlju Slovaške izvaja že več kot stoletje. V tem obdobju so slovaški telovadci dosegli pomembne tekmovalne uspehe. Ta zapis se osredotoča na nastanek in razvoj telovadbe na ozemlju Slovaške od začetka 20. stoletja do zgodnjih 80. let 20. stoletja, pri čemer obravnava glavne razloge in dejavnike, ki so vplivali na nastanek, razvoj in usmeritev telovadbe na ozemlju Slovaške v tem obdobju. Uporabljene so bile običajne zgodovinske raziskovalne metode. Glavni poudarek je bil na zbiranju gradiva povezanega s področjem. Poiskani so bili temeljni viri, vključno z dnevniki, časopisi, knjigami, govori, zgodovinskimi zapisi in elektronskimi podatki. Nato so bila ta dejstva razvrščena in njihovi odnosi preučeni z uporabo primerjalne metode. V članku so predstavljeni tudi najuspešnejši telovadci, rojeni na ozemlju Slovaške, ki so med letoma 1918 in 1980 dosegli pomembne tekmovalne uspehe na mednarodni ravni. Osnovno merilo za uvrstitev slovaških telovadcev med uspešne tekmovalce je bila njihova udeležba na vrhunskih mednarodnih telovadnih tekmovanjih, z uvrstitvijo v finala v mnogoboju in posameznih telovadnih orodjih največ do 10. mesta. Podatki o pomembnih dosežkih slovaških telovadcev so v priloženih preglednicah, v katerih so navedeni največji dosežki slovaških telovadcev na olimpijskih igrah, svetovnih prvenstvih in evropskih prvenstvih.

Ključne besede: zgodovina, Slovaška, orodna telovadba, rezultati.

Yaiza Taboada-Iglesias, Diego Alonso-Fernández, Xoana Reguera-López-de-la-Osa, Águeda Gutiérrez-Sánchez

TELESNA SESTAVA IN NJENA POVEZANOST S ŠPORTNIMI POŠKODBAMI PRI MLADIH AKROBATKAH

Tveganje za poškodbe je povezano z vrhunskim športom. Obstajajo dokazi, da lahko sestava telesa vpliva na tveganje poškodb. Namen te raziskave je bil razčleniti pojav poškodb in ugotoviti povezavo telesne sestave s pojavom, vrsto in resnostjo poškodb pri akrobatkah. V vzorec je bilo vključenih 92 akrobatk, starih od 9 do 20 let (13,66 ± 2,66 leta), 33 gornjih (11,06 in 1,41 starosti) in 59 spodnjih (15,11 in 2,00 leta) akrobatk. Izvedene so bile meritve telesne sestave (odstotek maščobe, odstotek mišične mase in vsota 6 kožnih gub) ter indeks telesne mase (ITM) in določena njihova razvrstitev na podhranjenost, normalno telesno maso in prekomerno. Podatki o poškodbah so bili izbrani z vprašalnikom za samoizpolnjevanje ob koncu tekmovalnega obdobja, kjer so zapisali, ali so utrpeli poškodbe, vrsto poškodbe (sklep, vez, kita ali kost) in njeno jakost (lahka, zmerna ali huda). Izvedena je bila opisna, primerjalna in vzročna razčlenitev proučevanih spremenljivk in med skupinami. Rezultati pridobljeni v tej raziskavi, kažejo na višji odstotek nepoškodovanih, a tudi visok odstotek poškodovanih, pri čemer so najpogostejše poškodbe vezi. Kar zadeva razmerje s telesno sestavo in ITM, pomembnih razmerij v pojavnosti, vrsti ali resnosti poškodb, ki so jih utrpeli, ni bilo. Zdi se, da vpliva samo na poškodbe tetiv spodnjih akrobatk, pri čemer imajo poškodovane višji ITM, odstotek maščobe in vsoto šestih kožnih gub.

Ključne besede: telovadba, telesne značilnosti, poškodbe, akrobatika.

Emre Bağcı

RAZČLENITEV POVEZAVE MED STASOM TELOVADCA IN OSVOJENIMI ODLIČJI NA ORODJIH PRI ORODNI TELOVADBI

Za uspeh so potrebne določene telesne značilnosti. Namen te raziskave je bil ugotoviti, ali obstaja povezava med višino telovadcev, ki so osvojili odličje na svetovnih prvenstvih in olimpijskih igrah v orodni telovadbi, ter orodjem, na katerem so jih osvojili. Tekmovanja v orodni telovadbi za moške na svetovnih prvenstvih in olimpijskih igrah potekajo na šestih orodjih za posameznike: parterju, konju z ročaji, krogih, preskoku, bradlji in drogu. Vsako orodje sledi posebnim pravilom za ocenjevanje sestav. Akrobacije v zraku prevladujejo na parterju in preskoku, medtem ko je opora pomembna na konju z ročaji in bradlji, prvine v vesi pa so značilne za kroge in drog. Medtem ko telesna višina telovadca vpliva na vse oblike telovadbe, ostaja vprašanje: kdo se lahko povzpne na vrh. V okviru raziskave so bili preučeni rezultati med leti od 2009 do 2021. Uporabljeni so bili podatki s treh olimpijskih iger (2012, 2016 in 2020) in devetih svetovnih prvenstev (2009, 2010, 2011, 2013, 2014, 2015, 2017, 2018 in 2019). Ocenjene so bile višine (251 nizov podatkov) telovadcev, ki so osvojili odličja na teh tekmovanjih. Medtem ko je bil najnižji telovadec, ki je osvojil odličje, visok 150 cm (na parterju in konju z ročaji), najvišji pa 183 cm (na parterju in na bradlji), je bila povprečna višina telovadca z osvojenim odličjem 164,67 cm (± 6,12). Obstaja statistično značilna razlika med višinami telovadcev, ki so osvajali odličja na orodjih ($p<0,05$).

Ključne besede: telovadci, telesna višina, odličje.

Karmen Šibanc, Maja Pajek, Ivan Čuk, Igor Pušnik

TEMPERATURNE RAZLIKE DLANI PO STATIČNI IN DINAMIČNI OBREMENITVI V OPORI NA BRADLJI

V znanosti o športu in telesni vadbi se termografija v veliki meri uporablja za ocenjevanje tekmovalne uspešnosti, za preučevanje površinskih žilnih sprememb, ki jih povzroča vadba, in za spremljanje poškodb. Primanjkuje raziskav in literature o temperaturah dlani po različnih obremenitvah in naše vprašanje je bilo, kako se razlikuje temperatura dlani po statični in dinamični obremenitvi na bradlji, saj je pojavnost tako raznolika (tekmovalna in razvedrilna dejavnost, telesna vzgoja, rehabilitacija). S kakovostno termovizijsko kamero je bilo izmerjenih osemintrideset študentov Fakultete za šport Univerze v Ljubljani. Temperatura dlani je bila izmerjena pred obremenitvijo, takoj po obremenitvi in vsakih 30 sekund v obdobju 5 minut po obremenitvi. Vsaka roka je bila razdeljena na devet različnih območij (ROI). Izračunani so bili povprečje (XA), standardni odklon (SD), najvišje in najnižje temperature ter število slikovnih pik. Temperatura dlani se je takoj po obremenitvi znižala, nato pa začela naraščati. Po 5 minutah so bile vrednosti temperature višje kot pred obremenitvijo, po kolebih (dinamični obremenitvi) pa so bile vrednosti temperature višje kot po opori (statični obremenitvi). Različne obremenitve torej različno vplivajo na temperaturo roke.

Ključne besede: temperatura dlani, termalno slikanje, bradlja, opora, koleb v opori.

Masaharu Matsushima

RAZMERJE MED ČASOM GIBANJA NA MREŽI VELIKE PROŽNE PONJAVE NAVZDOL IN NAVZGOR

Čas leta pri tekmovanjih na prožni ponjavi je odvisen od gibanja pri skokih, ki se izvajajo na mreži ponjave, ki jih lahko razdelimo na del navzdol in del navzgor. Ta dva dela gibanja imata različne značilnosti. Zato je bil cilj te raziskave raziskati temeljne podatke o dolžini navpičnega odklona, času, hitrosti in sili, vključeni v navpično gibanje na mreži ponjave. Raziskava je vključevala deset akrobatov na ponjavi, vključno z udeleženci Vse japonskega prvenstva in člani japonskega državnega moštva. Akrobatom so izvedli 15 zaporednih skokov na ponjavi, začenši iz stoje, s ciljem doseči največjo višino in ohraniti ravno pot na sredini mreže ponjave. Ugotovitve so pokazale, da so bile vse izmerjene vrednosti bistveno višje v delu navzdol v primerjavi z delom navzgor. Zanimivo je, da je bilo ugotovljeno, da je višina skoka med dolgotrajnim letom pretežno določena z dejanji v spodnjem delu skoka na ponjavi, ne pa v delu navzgor. Posledično je treba del navzdol izvesti kot dejavno skakanje.

Ključne besede: Skoki na veliki prožni ponjavi, čas obremenitev mreže, navzdol, navzgor.

Dimitros C. Milosis in Theophanis A. Siatras

UČINKOVITOST RAZLIČNIH TEHNIK POSTAVITVE STOJE NA ROKAH PRI NADZORU RAVNOTEŽJA IN RAZLIKE V SPOLU

Namen raziskave je bil dvojen: (a) preučiti vpliv različnih postavitev in uporabe prstov na kakovost, nadzor in splošno učinkovitost delovanja stoje na rokah in (b) raziskati morebitne razlike med spoloma v zvezi s temi dejavniki. V raziskavi je sodelovalo enaintrideset mladih tekmovalnih telovadcev (15 moških; starost: 12,60 ± 2,08 in 16 žensk; starost: 13,31 ± 2,21). Prenosna naprava za oceno položaja telesa je bila uporabljena za beleženje površine roke (cm^2), največjega pritiska (kPa), CoP (središče največjega pritiska roke) površine nihanja (mm^2), CoP premega premika razdalje (mm) in CoP hitrosti. Izpeljani podatki so bili razčlenjeni v »Foot Checker«-ju, različica 4.0. Korelacijski koeficient znotraj razreda in koeficient variacije sta podprla zanesljivost meritev. Enosmerna MANOVA je pokazala boljši nadzor ravnotežja za vse telovadce za stojo na rokah s ploskimi dlanmi ter združenimi in popolnoma iztegnjenimi prsti, ki ji je sledila tehnika s ploskimi dlanmi in široko odprtimi in popolnoma iztegnjenimi prsti ter širokimi ploskimi dlanmi in odprtimi in upognjenimi prsti. Rezultati enosmerne MANOVE niso pokazali razlik med moškimi in ženskami glede starosti, časa vadbe, telesne mase, višine in indeksa telesne mase. Z nadzorom nad učinki starosti, časa vadbe, osebnimi lastnostmi in območjem roke za oporo so imele ženske boljši nadzor ravnotežja v primerjavi z moškimi na podlagi razlik v območju nihanja CoP, premiku preme razdalje CoP in hitrosti CoP. Kljub omejitvam raziskave ugotovitve prispevajo k obstoječi literaturi o tehnikah nadzora ravnotežja v stojah na rokah v povezavi z razlikami med spoloma. Študija daje priporočila za učinkovitejše usposabljanje vaditeljev in predlaga možnosti za prihodnje raziskave.

Ključne besede: stoja na rokah, nadzor ravnotežja, orodna telovadba, moški, ženske.

Solmaz Nabizadeh Morsalfard, Mohamed Hosein Nasermeli and Behnaz Ganji Namin

PRIMERJAVA OBIČAJNE METODE UČENJA STOJE NA ROKAH IN S POMOČJO POSEBNE NAPRAVE TER NJIHOV VPLIV NA KAKOVOST IZVEDBE STOJE NA ROKAH

Ta raziskava je bila izvedena z namenom primerjave običajne vadbe stoje na rokah in vadbe stoje na rokah z uporabo posebne naprave med telovadkami začetnicami, starimi od 8 do 10 let. Da bi to dosegli, je v osmih tednih 30 uvrščenih telovadk namensko izbranih ter naključno razporejenih v dve skupini: v eni je bila uporabljena pomoč za učenje z napravo, ki so jo izdelali raziskovalci (n=15), v drugi pa je bila uporabljena običajna metoda (n=15). Po zaključku vadbe so bile opravljene različne meritve, vključno s trajanjem vzdrževanja ravnotežja, kakovostjo ravnotežja po strokovni oceni, obsegom gibljivosti v zapestju, komolcu, ramenskem in gleženjskem sklepu ter oceno bolečine v zapestju, predelu komolcev, ramen in spodnjega dela hrbta. Podatki so bili razčlenjeni z neodvisnimi t-testi, MANOVA in Mann-Whitneyjevim testom, s stopnjo značilnosti $p \geq 0,05$, podatki so bili obdelani z SPSS 22. Rezultati so pokazali, da je uporaba naprave za vadbo ravnotežja privedla do znatnega izboljšanja kakovosti ravnotežja z vidika sodnikov, pa tudi do opaznega zmanjšanja bolečin v predelu ramen, hrbta in zapestja v primerjavi z običajno vadbeno metodo. Poleg tega ni bilo bistvenih razlik med običajno metodo in uporabo naprave, ko smo upoštevali dejavnike, kot so kakovost delovanja ravnotežja, merjena z odstopanjem od navpične črte v različnih telesnih sklepih, trajanje vzdrževanja ravnotežja, obseg gibanja v zapestju, komolcu, rami, gležnju in bolečinah v komolcu in kolenu.

Ključne besede: stoja na rokah, naprava za učenje, telovadba, kakovost vadbe, bolečina.

Ani Agopyan, Berfin Serdil Ors

KAZALNIKI USPEŠNOSTI RITMIČARK, NOSILK ODLIČIJ NA OLIMPIJSKIH IGRAH 2020

Namen raziskave je bil razčleniti seštevke ocen orodja v rezultatu mnogoboja in določiti ključne kazalnike uspešnosti, po katerih se med 10 finalistkami v ritmiki na olimpijskih igrah 2020 v Tokiu razlikujejo dobitnice odličij od ostalih finalistk. V vzorcu smo ločili dobitnice odličij (n=3) in ostale (n=7). Ocena na vsakem orodju (obroč/žoga/kiji/trak) je imela sedem delov[težavnosti s telesom (DB), težavnosti z orodjem (DA), skupna D ocena, umetniška izvedba (EA), tehnična izvedba (ET), skupna E ocena, skupni rezultat (TS) orodja in skupno končno oceno (TFS-vsota štirih ocen orodij)]. Za izračun razlik so bili uporabljeni Mann–Whitneyjevi testi U in Cohenov izračun velikosti učinka d (ES). Naslednje spremenljivke so bile določene za razlikovanje TFS ritmičark, ki so osvojile odličje, in ritmičark brez: velik učinek z žogo-DA/D skupno/EA/E skupno/TS (ES=1,550–1,879), kiji-DA/D skupno /EA/TS (ES=0,316–2,080), obročem-DA/D skupno/TS (ES=1,897–2,316), trak-EA (ES=1,879) in z nizkim učinkom kiji-AD(ES=0,316). Obroč-DA in Obroč-D-TS (ES=2,316, $p<0,05$) imata največji vpliv, medtem ko vsi rezultati DB in ET ($p>0,05$) nimajo vpliva na TFS. Vpliv posameznega dela ocene, na rezultat z olimpijskim odličjem se razlikuje glede na orodje. Kot ključni pokazatelji uspešnosti pri doseganju visoke končne ocene in zagotovitev olimpijskega odličja se je pokazaIa ocena za težavnost (D) (tako v mogoboju kot na posameznih orodjih) in ocena umetniške vrednosti. Vaditelji bi morali pri načrtovanju sestave stremeti k čim višji težavnostni vrednosti sestave, zlasti težavnosti dela z orodjem in se ob tem osredotočiti na izboljšanje umetniške vrednosti in brezhibni tehnični izvedbi.

Ključne besede: težavnost z orodjem, težavnost s telesom, olimpijska odličja

Eduardo Macedo Penna, Edson Filho, Lívia Maria Neves Bentes, Renato Melo Ferreira, in Daniel Alvarez Pires

VIRI ORGANIZACIJSKEGA STRESA PRI MLADIH RITMIČARKAH: OPISNA RAZČLENITEV

Cilj raziskave je bil preučiti vire organizacijskega stresa med brazilskimi mladimi ritmičarkami. Pol vodene pogovore so izvedli s šestimi športnicami, starimi približno 15 let (M = 14,50; SD = 1,76) s povprečno približno sedemletnimi izkušnjami v športu (M = 6,83; SD = 3,25). Za razčlenitev neobdelanih podatkov je bila uporabljena razčlenitev iz splošnega na posamezno. Razčlenitev je pokazala, da so ujetost v šport, upravljanje časa in pomisleki glede telesne podobe nekateri od stresnih dejavnikov, ki jih doživljajo ritmičarke. Pritisk vaditelja, pritisk vrstnikov in pritisk staršev so dodatni viri stresa, o katerih poročajo športniki. Nazadnje so športniki poročali o tekmovalnem strahu pred, med in po tekmovanju. Naše ugotovitve skupaj kažejo, da so ritmičarke poročale o številnih stresorjih, povezanih s športom. Da bi preprečili te pritiske, morajo vaditelji športnike opremiti z različnimi veščinami obvladovanja, da bi spodbujali dobro počutje in povečali vrhunsko učinkovitost v športu.

Ključne besede: organizacijski stres, telovadba, medkulturna raziskava

Seppo Suominen

PRISTRANSKOST SOJENJA V LEPOTNI SKUPINSKI TELOVADBI

Obstaja več tekmovanj, kjer je objektivnost sodnikov sprožila nekaj vprašanj, zlasti ocenjevanje skladnosti. Če je del dejanske uspešnosti mogoče objektivno izmeriti z napravami, del uspešnosti pa temelji na subjektivni oceni sodnikov, je možna napaka pri razvrstitvi. Obstajajo nekatere športne discipline, kot so smučarski skoki, kjer se uporabljata obe metriki (Krumer et al., 2020); v telovadbi pa je edino merilo ocena sodnikov (Bučar et al., 2012; Leskošek et al., 2012; Rotthoff, 2014). Razčlenitev razkriva, da je pristransko sojenje v lepotni skupinski telovadbi več kot verjetno na domačih tekmovanjih na Finskem. Domači sodnik, ki ocenjuje lastno vrsto, ne precenjuje uspešnosti v nobenem od njenih treh delov: tehnične vrednosti, umetniške vrednosti ali vrednosti izvedbe. Vendar se zdi, da sodniki strateško podcenjujejo predstavo najpomembnejšega tekmeca. To podcenjevanje je manjše, ker se najvišji in najnižji rezultat od štirih sodnikov ne upošteva. Točkovanje domačega sodnika je običajno znotraj dveh srednjih točk, kar se upošteva pri končni oceni nastopa. V razčlenitvi so bili uporabljene ocene 66 različnih tekmovanj, vključno s 585 nastopi v obdobju 22 mesecev. Vsa tekmovanja so bila domača, samo z domačimi ekipami in domačimi sodniki. Številna tekmovanja so imela 12 sodnikov: 4 so ocenjevali tehnično vrednost, 4 umetniško vrednost in 4 izvedbo. Vsi sodniki so bili imenovani pred tekmovanjem.

Ključne besede: lepotna skupinska telovadba, Finska, pristranskost sojenja

To the Editors:

Once again, I have prepared a post-World Championship analysis of the many problems related to the current World Championship regulations. My analyses this year and last year reveal that the current system is beset with unacceptable problems that negatively affect all countries. A return to the 2005-2021 system with a mid-cycle Open Team World Championship seems the easiest and most palatable solution.

***Note** that this is from a PowerPoint presentation and cannot include commentary, nor can it show the colours, transitions and other aspects of a presentation. The PDF of the presentation as well as the two open letters that I wrote in 2022 are available on request.*

Dear President Watanabe, dear FIG Authorities, dear member Federations,

I was recently invited to make a Zoom presentation regarding the World Championship system. I wrote to you twice during 2022 but the length and tone were much criticized, and the important content was ignored. I am attaching relevant slides from my Zoom presentation for your information. I have again done and am providing the analysis for all to review. What happens for the future is in your hands. I hope that my analysis and observations will provide the necessary clarity for decisions going forward that will benefit the entire gymnastics world.

A Myriad of Problems with the Current Regulations for Artistic Gymnastics World Championships

Virtual Presentation
to the
International Freiburg Gymnastics Congress
October 14, 2023

Hardy Fink
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Introduction

For the past two years, I have tried to alert the FIG authorities and the member federations that the current World Championship format negatively and permanently impacts the majority of federations and their gymnasts. These are the open letters of 2022.

April 18, 2022 – No more Open Team World Championships – a critical look
November 22, 2022 – FIG's Assault on World Championship Participation

It impacts and damages Federations now and for the future:
Financially
Developmentally
Aspirationally

I will explain how the new system is wrongly justified, terribly flawed, massively unfair, and beset with negative impacts and unintended consequences – quite contrary to the "promises".

I will argue that the gymnastics world needs and should demand an "Open Team World Championship" at least once every cycle. The most reasonable solution is to return to the system in place from 2005-2021.

Some Historical Background

<table>
<tr><td>1979-2003</td><td>Open access Team & AA WC --- pre-OG year for all Olympic qualification</td></tr>
<tr><td colspan="2">Here is what was: The 2005-2021 WC System – a WC every non-Olympic year
It was a hard-fought compromise solution that worked well for 16 years.</td></tr>
<tr><td>Post-Olympic WC
Mid-cycle WC
&
Pre-Olympic WC</td><td>Open access CII & CIII, 4W & 6M per country, 3 per event
Open access for all federations - CI, CII & CIII
▪ Top 24 teams from mid-cycle Worlds
▪ 3W & 3M AA (or specialists) for all other countries</td></tr>
<tr><td colspan="2">Here, the decision in 2019 for '22 & '23; and in 2022 for '25, '26 & '27 WC</td></tr>
<tr><td colspan="2">Establishment of Continental Team & AA quotas to attend mid-cycle & pre-Olympic WC</td></tr>
<tr><td>Post-Olympic WC
Mid-cycle WC
&
Pre-Olympic WC</td><td>Open access CII & CIII, 3W & 3M per country, 2 per apparatus
▪ 24 M & W Teams from Continental qualification based on quotas
▪ 41 M & 50 W AA from Continental qualification based on quotas
▪ 8 specialists on each apparatus (=80) based on World Cup results</td></tr>
</table>

Note: CIa = compulsory; CIb = optional (now CI); CII = AA final; CIII = Apparatus final; CIV = Team final

The rationale for the current WC system

Here, the words of FIG President Morinari Watanabe, to 2018 FIG Congress and/or Council press release of May 2019. *(the Council controls Technical Regulations)*

I believe that each statement is either false or misleading or contrary to logic.

1. *"In future, we will have more gymnasts from Africa and Oceania. We cannot continue with the current system of World Championships. We must take countermeasures."* In fact, the "countermeasures" have reduced chances for Africa and Oceania. 30 African and 9 Oceania federations have 1 team allocation, and 2 AA (4W for Africa). Many more have attended in the past and will want to in the future.
2. *"The new format will come into force at the 2022 and 2023 Worlds, which will limit the number of participants… This will allow a reduction in the overall duration of the World Championships to 11 days, compared to 15 at the 2018 event, with two training days and two competition days less."* Liverpool revealed that the saving is only 1 competition and 1 training day over a 4-year period because pre-Olympic WC were already 24 teams with 3-days. Competition organization is related to number of gymnasts on the most populated apparatus, not the total number in attendance. It is the 6-days of finals that make World Championships long, not the 4-days of qualification.

3. *"Every national federation, even the smallest, must have a chance to host a World Championships."* This is pure fantasy. It will and can never happen.
4. *"The format changes that we have adopted will help reduce the length and the costs, help make the competition more thrilling as well as enhance the value of the continental championships."* As Liverpool revealed, the time saving is 1 competition day once every four years!!!! The costs for mid-cycle WC participation are slightly lowered but two Continental qualifications massively increase costs and obstacles for all federations. A rational financial decision for poorer federations is to totally ignore the mid-cycle qualification and WC – so much for enhancement; and to focus on the pre-Olympic qualification where the top 8-teams are not obligated to attend – so much for enhancement. Interestingly, in 2023, only Japan WAG chose the option to not enhance the Continental Championships by not attending. It is always thrilling because it is a World Championship. "More thrilling" is the purpose of Finals, not qualification.

The Travesty of Continental Quotas

- This was determined in 2019, without advance notice, based on 2018 results.
  - Due to cost, only 17 non-European teams participated in 2018.
  - Would more have attended had they known this would determine their future opportunities for at least 9 years?
- Quotas were based only on 2018 participation numbers without reference to other relevant factors.
- Many teams better than those qualified are forced to stay at home, because of the quotas.
- In 2023, 7 M&W teams qualified that had not been among the top 24 in the past; and 22 that had been among the top 24 (mid-cycle '06, '10, '14, '18) did not.
- Many legitimately good teams & gymnasts can no longer appear at a WC.
- This was not a discussion item at the FIG Congress where such massive decisions have always been debated.

<u>The Quotas are permanent</u>

- There is no mechanism for change; Would EG or any CU give up spots?
- There is no longer a mechanism for a world ranking.
- There is no process by which a Continent could successfully appeal.

The Travesty of Continental Quotas - cont'd

The whole system is Eurocentric.

It unfairly favours those with economic and geographic privilege,
and in effect, it punishes the rest.

EG	Team quotas for rest of World				
13			**11**		
	Total	**OGU**	**UAG**	**PAGU**	**AGU**
MAG	11	1	1	4	5
WAG	11	1	1	5	4

EG	AA quotas for rest of World				
23+1	16 MAG & 25 WAG				
	Total	OGU	UAG	PAGU	AGU
MAG	16	2	2	6	6
WAG	25	2	4	11	8

- Why the huge numerical AA advantage to Europe vs the rest of the World? Most place near the very bottom at WC – about 17W & 13M from Europe below 60th; similar for rest of world.
- Why such a disparity in AA quotas, when almost none (2 of 89 this year) qualify for AA Final?
- Why not base it on membership numbers? – i.e. for Federations with no team, guarantee of 1.

The Travesty of Continental Quotas – cont'd

There are other relevant factors that should have been considered – success, members, numbers attempting to qualify, etc.

MAG Medals – EG vs World with 2018 reference					
2018 World	2018 EG	2022 World	2022 EG	2023 World	2023 EG
13	11	15	9	16	8

Team quotas M – 1.6 EG teams/medal vs. 0.7 teams/medal for world

WAG Medals – EG vs World with 2018 reference					
2018 World	2018 EG	2022 World	2022 EG	2023 World	2023 EG
15	3	13	5	17	1

Team quotas W – 13 EG teams/medal vs. 0.65 teams/medal for world

FIG member federations					
Total	EG	OGU	UAG	PAGU	AGU
160	50	9	30	31	40

Team quotas – 26% of EG federations vs. 10% for rest of world

Teams & AA trying to qualify in Continent - 2023				
	EG teams	World teams	EG AA	World AA
MAG	27	38	77	138
WAG	27	35	95	123

Team quotas – 48% of teams for EG vs. ≈30% for rest of world

- How can EG with 13 teams & 24 AA be reconciled with 11 teams & 16M/25W AA for the rest?
- How should the 30 federations of Africa react with 1 team & 2M/4W gymnasts forever?
- Many countries have recently been enticed to join FIG. Why are they excluded in advance?

The Travesty of Continental Quotas – cont'd

- There is no satisfactory or fair way to establish Continent based quotas for 24 teams in an ever- changing gymnastics world. Only an open WC can provide a ranking to be used to qualify for the next.
- Permanent quotas can not be acceptable when we know that even two years can be a lifetime in gymnastics.
- There is no process for changing the quotas because there is no such thing as a ranking list for those not within the existing quotas.
- Can a ranking based on Continental scores be used? **NO!** Judging scores, especially for MAG, are not at all comparable across Continental Championships.
  - 2022 - TUR 3 ⇒ 11; NZL 21 ⇒ X; FIN 24 ⇒ X; **CAN 27 ⇒ 10**; COL 32 ⇒ 23
  - 2023 - TUR 5 ⇒ 10; KAZ 7 ⇒ 18; NZL 24 ⇒ X; **CAN 31 ⇒ 4**; BRA 26 ⇒ 13
  - 2023 – For PAGU men, only USA would have qualified by these scores.

The Unequal Costs of Continental Qualification

The entire new system from quotas to qualification is Eurocentric. It provides massively unfair and unequal financial, resource and time burdens on non-European federations

Europe	Other Continental Unions
Mostly connected by train	International, even intra-country, train impossible
At destination, train connected to airport	Nearly zero such train-airport connections
Often close enough for team to travel by mini-bus; flights are mostly direct flights	Driving not possible, must fly each person in the delegation; often multiple flight connections
Travel flight time rarely exceeds 4 hours	Travel time often exceeds 24 hours
Many budget airlines	Budget airlines do not exist
Mostly visa free travel	Frequent need to buy visas for delegation
Very little jet lag	Extensive jet-lag = extra hotel days to acclimatize
Relatively low cost to qualify	Enormous cost to qualify
Relatively little additional gymnast stress	Much more stress & interrupted training for gymnasts
Reference: Lisbon-St.Petersburg 3500km	*Reference: Vancouver-Beunos Aires; 11000km; Tokyo-Jordan 9500km; Cairo to Capetown 7300km*

- For Canada to qualify in BRA 2022 cost $60000; and again in 2023 COL. I estimate that, on the average, it cost at least $20000 to try to qualify x 50 teams = $1million each time. You can do your own calculation.

Everything costs more, is more complicated, and takes longer.

The Unequal Costs of Continental Qualification – cont'd

What are the predictable consequences?

- Of about 60 federations that have traditionally attended with teams, perhaps as many as 30 will stop team gymnastics. New federations will never do so and perhaps also not AA gymnastics. Easiest access is Wcup.
- Without a true ranking or chance to show improvement, many will lose NOC or government funding.
- Local media of all kinds, and thus sponsors, will be less interested.
- Reduction in coaches and judges, clubs and gymnasts.
- Loss of opportunities for judge advancement.
- Enormous cost of money, resources and time for non-Europeans.
- Greater stress on gymnasts – travel, jet-lag, interrupted and sub-optimal training, additional peaking cycle. Is this athlete centered?
- Lost freedom for federations to determine how or if to use Continental Championships and how to allocate national team budgets.

NOTE:

- A 24-team WC with Continental qualification was held in Dortmund in 1994.
- The costs and other problems were so great that it was decided never to do it again. Until now!

The sham of World Cup qualification

- Most believe that the top 8 specialists from the Wcup circuit of 4 competitions (Doha, Cottbus, Cairo, Baku) will qualify for Worlds.
- It is not the top 8; it is the remaining 8 once team & AA qualifiers are removed.

The reality:

- Almost no non-European countries can afford to attend. More so because of the need to provide a judge or be penalized. The 80 specialist spots were allocated to 51 gymnasts in 2022 and 56 in 2023. 34 and 40 were from Europe. For PAGU, the most distant from the Wcups, it was 0 specialists in 2022 and 3 in 2023.
- Top countries with teams don't need to attend and mostly do not bother.
- Almost no one attends 3 or 4 Wcups; 36 of the qualified 80 specialists attended only 1 Wcup; only 4 of 80 gymnasts attended 4 Wcups.
- Gymnasts with zero points can qualify; in 2023, 14 qualified with 0-points placing as low as 39th in a single Wcup. This after not being among the 46 that had at least 1-point – *!!!not in the top 46; and then only 39th in one Wcup, but still qualified!!!*
- Except for a few men from countries with no teams, almost all qualified specialists rank far down and even last place at World Championships.

- This cannot be anyone's idea of a specialist.
- One became an "accidental AA gymnast" by qualifying on 4 apparatus (even with 0-points) and qualified as an AA gymnast for the OG replacing one who had specifically qualified as an AA gymnast for Worlds.

It is not "world"; it is not a "series" if 1-Wcup is OK; it is not "specialist" if 0-points is OK

70 years of changing WC participation

- There have been frequent changes (reductions) in participation numbers over the decades. When AA and Team finals were added, competition days increased.
- When team size was reduced, it often led to the possibility of more countries with teams so that there are more teams but not necessarily greater numbers.
- Since 1997, 4-qualifying days for open WC has always been enough.

Year	Change in numbers
1950-1978	Open access every 4-years mid-cycle - CIa & CIb - Team size 8-6-6
1954	Team size 7-6-5
1979-1995	Open access every 2 years – CIa & CIb – team size 7-6-5
1997-2003	Open access every 2-years – compulsories eliminated – team size 6-5-4
2005-2021	Post-OG = CII & CIII; mid-cycle = Open access; pre-OG = top 24 – team 6-5-4
2018	Team size 5-4-3 *(This reduced Men numbers per apparatus by ≈40; Women by ≈20)*

It is important to understand that the number of gymnasts registered for a World Championship do not affect the competition scheduling. The critical factor is the number of gymnasts on the most populated apparatus because that will determine the number of needed subdivisions.

The shrinking World Championships

Mid-cycle World Championship - competitors per apparatus										
	V	**UB**	**BB**	**FX**	**FX**	**PH**	**R**	**V**	**PB**	**HB**
2006 Aarhus (*6-5-4*)	189	194	193	188	227	230	228	230	228	227
2010 Rotterdam	185	187	188	183	244	246	243	244	246	245
2014 Nanning	212	213	216	209	252	254	244	252	253	248
2018 Doha *(5-4-3)*	194	191	198	191	200	202	194	195	189	197
The Mid-cycle & pre-Olympic World Championships are now the same *(24T; 5-4-3)*										
2022 Liverpool	144	145	147	148	132	138	128	133	139	138
2023 Antwerp	152	153	152	151	140	140	137	141	140	141

NOTE:

- Men, who always had more teams (avg 48) than women (avg 36) lost about 50% of participating teams and numbers; WAG lost only 33% because the pre-determined number is 24 teams for each.
- MAG lost about 100 gymnasts per apparatus; WAG lost about 50.

The reduction to 24 teams in the mid-cycle World Championship is unnecessary

- The rationale was that only 2 instead of 4 competition days would be necessary. Liverpool revealed that the necessary 10 WAG & 6 MAG subdivisions require three days. The pre-Olympic WC were already down to 24 teams and also require 3-days.
- This saves only 1 competition day, once in a 4-year period, and dramatically proves my point. This “solution” to a mostly non-existent problem has created many real and serious problems. And it has damaged federations financially, developmentally and aspirationally forever.
- 4-days of qualifying competition, once every 4-years, is not unreasonable for two disciplines and in advance of six days of finals competition.
- 4-days of competition can accommodate 14 WAG and 10 MAG subdivisions or as many as 288 per apparatus with subdivision adjustments. 288 has never been reached in our history.
- A little off topic, but interesting in this context, is that the only thing that has continually increased is the number and cost of judges and juries. It takes about 120 judges now to evaluate a world championship. That has more than doubled since pre-1990.

2024 Olympic Qualification

FIG President Morinari Watanabe again:

- *We need a qualification system which everybody can easily understand. Being simple is the best. For the 2024 Paris Olympic Games, we will aim to create a simple qualification system.*
- *It was also crucial for us to implement a qualification system for Paris 2024 that everybody can understand while being fair to the best athletes.*

- It is true that this is much simpler than the 2016 Olympic qualification system.
- But it is 3-year process, with 7 criteria and remains almost impossible for media, and even experts, to understand.
- It involves 29 competitions to complete the full process (15 Continental Championships, 12 World Cups, and 2 World Championships).
- Are 29 competitions necessary? Must it be so very expensive and stressful and prolonged for federations? It was done with 1 or 2 competitions in the past.
  - I still like the pre-2004 system of an Open Team pre-Olympic WC from which all Olympians will qualify under equal conditions for all.
  - But the 2005-2021 WC system might be easiest to return to. An Open Team mid-cycle WC to qualify the top 24 teams to the pre-Olympic WC from which all Olympians will qualify. Only two OG qualifying steps! Simple, understandable, equal conditions for all, cheaper for federations.

A 3-year expensive & convoluted OG qualification process

The new WC system which began in early 2022 is intricately linked to an Olympic qualification that requires 29 competitions for the whole process.

7 criteria		To qualify for WC	OG qualified
1	2022 WC	▪ Continental Team qualification based on quotas	▪ Top 3 teams from team finals
2-5	2023 WC	▪ Continental Team & AA qualification based on quotas ▪ Top 8 teams from 2022 are exempt ▪ 8 specialist per apparatus from the 4 World Cup events	▪ Nine teams: 4-12 from qualification ▪ Teams 13-15 – 1 gymnast ▪ 8M & 14W AA not on qualified team ▪ 1 specialist per apparatus not on team or AA
6	2024 WCup		▪ 2 specialists on each apparatus
7	2024 Continental		▪ 1AA gymnast per continent
---	2024		▪ Host country & Universality spots

- Criteria 6 & 7 are especially harmful and could have been settled in 2023.
- The unequal extra cost, stress and travel cannot be justified and detracts from the equal possibility of focusing on OG preparation following 2023 WC.

Some of the Olympic & WC qualification "quirks"

- Countries not qualified with a team can and did qualify a "team" of 5 gymnasts.
- The top 3-teams from 2022 WC qualified by Team Final results. This differs from Olympic rules and for all other WC & OG qualification. They do not have to attend the pre-Olympic WC.
- The 1st qualified specialist is not often the World Champion. It is whoever remains after team and AA gymnasts are removed. For 2024, we have 1st qualified specialists with rankings of 23rd, 27th and 30th.
- The 2nd and 3rd specialist on each apparatus will likely be someone ranked as low as 40th at the World Championships or did not compete at all. The original concept was that all WC medalists would be guaranteed an Olympic spot.
- Specialist and AA qualified gymnasts are guaranteed by name, but not if they are part of a team; not even if they are World Champion.
- An "accidental AA gymnast" can qualify on all apparatus (even with 0-points) and qualify as an AA gymnast for the OG replacing one who had specifically qualified for WC as an AA gymnast.
- A wise option for many with financial difficulties is to completely ignore the 2022 World Championships and its qualification process.
- A gymnast can compete at Continental Championships in 2024 and qualify for OG, without having attended anything else in 2022 or 2023.
- Unlikely, but a specialist can theoretically compete on one apparatus in one World Cup in 2024 and qualify for OG without having attended anything else.

The illogical post-Olympic WC participation numbers

This is a specialist and AA World Championship

Federations should be able to contest each apparatus if they have the gymnasts.
That is why the 4W & 6M, 3 per apparatus was decided 20 years ago.
The 3W & 3M, 2 per apparatus decision is inexplicable, unjustifiable, and wrong.

- The 3+3, 2 per apparatus is not logical or necessary. There is no justification.
- The qualification has always been able to be run in 2-days. Moreover, two days of Team finals are not needed and therefore it is already 2-days shorter.
- The other two WC are biased in favour of geographically and economically privileged federations, but this WC is biased against the strongest federations and the best gymnasts. Recall the promise of fairness to the best gymnasts.
- The consequences: If a FED has 1AA gymnast, it can have only 1 specialist; if 2 AA, then no specialists; if two specialists on one apparatus, then no AA.
- Only 2-per federation is acceptable for finals, not for qualification before finals.
- Historically, only a few federations attended with 6+4. The average has been 60% of maximum: 2.5W and 3.5M = 6. This is the same total as the new 3+3 but without the negative consequences.
- Men are again disadvantaged as opportunities are cut by 50% vs 25% for WAG.

The illogical post-Olympic WC participation numbers - cont'd

- The numbers per apparatus have always been relatively low compared with team world championships.
- Qualification is always 2-days; and 2-days are saved because no team finals.
- There was no good reason to cut the numbers that will now be lower than 2021.

Post-Olympic World Championship for specialists and all-around gymnasts
Number of competitors per apparatus
(Delegation maximum 4 WAG & 6 MAG, maximum 3 per apparatus)

	V	UB	BB	FX	FX	PH	R	V	PB	HB
2005 Melbourne	68	76	79	74	85	91	93	90	87	91
2009 London	107	112	118	113	133	132	126	122	127	127
2013 Antwerp	106	102	111	105	137	149	136	122	142	135
2017 Montreal	103	106	119	111	124	132	113	106	123	124
2021 Kitakyushu	80	82	94	82	102	109	89	98	96	91

The illogical post-Olympic WC participation numbers - cont'd

How is this still a World Championship when dozens of potential medalists are left at home? This cannot be permitted to happen.

- How does a Federation decide which of 4 or 6 events and/or AA to contest?
- Over the previous post-Olympic WC, there have been dozens of examples where 5 or 6 men and 4 women have won different medals.
  - *2013 JPN 1st &2nd AA, 1st PH, 1st FX; - all different gymnasts*
  - *2017 CHN 1st & 2nd AA, 1st PB, 3rd R; - all different gymnasts*
  - *2021 CHN 5 different medalists & JPN 4 different medalists.*
  - *Similarly for WAG: 2013 USA 1st & 2nd AA & another 1st V.*
  - *There are dozens of examples of finalists in AA and apparatus for many FEDs*
- How does a Federation decide which medals or which world champions to sacrifice? Many best gymnasts and best countries are deprived of WC participation. This is unacceptable.

This flawed decision must be reversed before it is put in effect in 2025. There is time to change it. There is no excuse to keep it.

The advantages of attending World Championships

I believe strongly that there is a need for at least one Open Team World Championship each cycle.
I believe that the FIG authorities should commit to provide it and the federations should demand it.

I remember when Canada always placed near the bottom, but nothing was more important than participating in World Championships. It was the motivator behind everything the federation did. Other countries have told me the same. It motivated gymnasts, clubs, coaches, judges, leaders and secured government funding and sponsorships. It helped develop and grow the sport in the country.

The developing and the new federations are excluded in advance and deprived of all aspiration or motivation to advance towards WC. This is a massive disincentive for everything and everyone in Federations that wish future WC participation.

The extra 1-day required for an Open Team World Championship is not a negative. It is an enhancement, a motivation, a benefit, a stimulus for development for countries and the world.

What will we have?

Exclusion and unequal costs & conditions based on mostly non-existent problems
or
Inclusion: for motivation and development of world-wide gymnastics.

What is the issue? Why this system?

It is, in effect, to save 1 competition day in 4 years!
(And, perhaps, for a flawed promise to enhance Continental & Wcup events).

But what are the real costs to the world of this 1-day reduction?

What can be done; and by when.

There is not much time to make changes for the next Olympic cycle.

- The 2025 post-Olympic WC can be changed (reverted) immediately, because it does not add competition or training days for the organizers, and it is not part of Olympic qualification.
- Federations can petition their elected representatives immediately.
- The FIG Executive & authorities could decide to propose change immediately.
- The Council could vote in May 2024. The organizers for 2026 would need to agree to add 1 competition and 1 training day. It is not a problem for 2027.
- Federations are not permitted to make proposals at the 2024 FIG Congress, but the EC can do so.
- The Council could vote in May 2025, but probably too late for 2026 & 2027.
- It could also vote in 2026 as could the Congress but that is too late to affect 2026 and 2027 for Olympic qualification.
- **It must be done in 2024**, otherwise there can probably be no change before 2029. That would mean, the next possible Open Team WC will be in 2030, 12 years after the last full World Championship in 2018. 12 years is a lifetime of irreversible damage to the gymnastics world and to an entire generation of gymnasts and to previously WC aspiring federations that can’t begin again.

Flavio Bessi

XVII Freiburg International Gymnastics Congress: An outstandig continuing education programme for coaches with top speakers and renowned scientists

The Department of Sport and Sport Science at the University of Freiburg hosts a world meeting of gymnastics enthusiasts and experts

Freiburg, Germany - October 20, 2023 - The picturesque city of Freiburg in southwestern Germany recently became the epicenter of the gymnastics world as it played host to the Freiburg International Gymnastics Congress. This prestigious event, held at the Department of Sport and Sports Science of the University of Freiburg for the 17th time, brought together gymnasts, coaches and sports scientists from different countries to exchange cutting-edge knowledge and ideas.

The Freiburg International Gymnastics Congress, held from October 14 to October 15, was once more an exceptional experience, drawing participants and attendees from all over Germany, but also from different countries. Coaches of all levels, researchers and gymnasts gathered on the beautiful university campus at the foot of the Black Forest to partake in a program that combined insightful presentations, and hands-on workshops.

The list of the renowned speakers and scientists gives an idea of the standard of this event:

- Yurii Akhmerov UKR
- Almir Atiković, BIH
- Marco Antonio Bortoleto, BRA
- Flavio Bessi, GER
- Eric Boucharin FRA
- Ivan Čuk, SLO
- Lina Fay GER
- Katja Ferger GER
- Hardy Fink CAN
- Axel Fries GER
- Monèm Jemni, GBR
- Ursula Koch GER
- Leticia Lima, BRA
- Robin Link GER
- Michel Marina, ESP
- Falk Naundorf GER
- Jonas Rohleder GER
- Ghazal Seilsepour GER
- Claudia Seitz GER
- Sabine Storz GER
- Michael Vid GER
- Melanie Voss GER

Their groundbreaking either research or experience contributes to develop the way we understand gymnastics.

Attendees had the opportunity to participate in practical workshops led by gymnastics coaches and specialists. These workshops covered a wide range of topics, from basics on different apparatus to advanced gymnastics skills. Moreover, the main organiser and responsible of Artistic Gymnastics at the Department of Sport and Sport Science at the University of Freiburg, Flavio Bessi, facilitated an atmosphere of knowledge exchange and scientific exploration. Several parallel sessions ran throughout the event, allowing scientists and researchers to present their latest findings and engage in in-depth discussions. Topics spanned from biomechanics guidelines for difficult vaults to the new education system of the FIG were presented.

Two particularly engaging sessions featured Marco Bortoleto, president of the Education Commission of the FIG, and Hardy Fink, former Director of the FIG Coach Academy, a pioneer in coach education, shared insights on current topics.

Global Collaborations and Networking

The Freiburg International Gymnastics Congress served as a platform for building global connections within the gymnastics community. Coaches, athletes, and scientists had the opportunity to network and forge collaborations, with the goal of advancing the sport and promoting its inclusivity and accessibility worldwide.

As the congress concluded, it left an indelible mark on all those who participated. Attendees departed with a renewed passion for gymnastics, armed with the latest research and practical knowledge to elevate their gymnastics careers, be it as athletes, coaches, or scientists.

The success of the Freiburg International Gymnastics Congress reaffirmed the power of such gatherings in propelling the gymnastics world forward. The city and the University of Freiburg founded in 1457, with their rich history and stunning landscapes, provided a fitting backdrop for this remarkable event. With the inspiration and knowledge gained, the gymnastics community looks forward to scaling new heights and achieving even greater feats in the years to come.

(photo Jonas Rohleder)

INVITATION FOR PARTICIPATION IN A STUDY

It is not only about the athlete, but also about the surroundings…!

Participants needed for an international study on the impact of surrounding factors (family, job, training site, judges, …) on sports performance. If you are interested, please check out the following link:

https://www.umfrageonline.com/c/iycvfkqe

Please email any questions to:

j.weber_@hotmail.de

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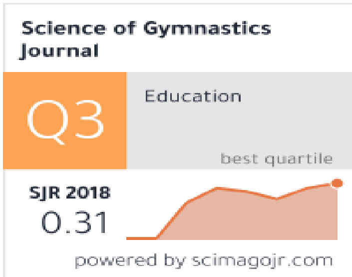

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