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Science of Gymnastics Journal (ScGYM®)

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

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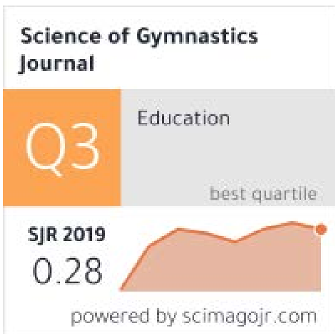

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CONTENTS

EDITORIAL

Dear friends,

we are all waiting for OG to start in Tokyo. We expect the Games to be another step into the third milenium gymnastics. Nikita Nagorny with the triple salto backward piked on floor and Simone Biles with double piked Yurchenko on vault have already made such a step and on OG they will show it to the world audience.

With the June issue, we have added a DOI number to each article, as our university and sports faculty are authorized to generate DOI. With the unique DOI number your articles will be more visible in various publishing apps.

We strongly recommend all authors to use Grammarly or Instatext (you can find them through any search program on www) before sending the text to the editor. Both tools are free and can improve your text.

The first article should support idea of »Mens sana in corpore sano«, but with the knowledge that a totalitarian regime has ordered it, shaded a bit.

And again, authors from different countries have contributed their knowledge and we are proud that the knowledge is spread.

Anton Gajdoš has prepared 21 short historical notes until today and introduced a short reminder on OG in Tokyo 1964.

Two exceptional gymnastics friends passed away from February. Istvan Bercy from Hungary (he was judge at 8 Olympic Games) and Jože Senica from Slovenia (he was judge at Barcelona OG, and coached Miroslav Cerar few years) went among the stars. Our condolences to family and friends.

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

I wish you an enjoyable read and many ideas for new research projects and articles,

Ivan Čuk
Editor-in-Chief

THE SPARTAKIADE AS A PHENOMENON IN THE SOCIO-CULTURAL AND SPORTS DIMENSION IN THE TERRITORY OF CZECHOSLOVAKIA

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Abstract
The aim of the article is to provide a description of the emergence and genesis of the Spartakiade in the territory of former Czechoslovakia. In the article, we focused on the origin and development of mass sport in Czechoslovakia since 1918, on the emergence and genesis of the Spartakiade and the definition of the term "Spartakiade". In this paper, we also present a chronological name list and a brief course of individual Spartakiades that were held in the territory of Czechoslovakia within the period 1955 – 1985.

Keywords: *history, physical culture, nation.*

INTRODUCTION

In the period 1955 – 1985, various group sports exercises were held in Europe, as well as in the world, as outdoor sports activities in the open air. Among these group events, mass physical exercises including different age categories of gymnasts have a very important place in former Czechoslovakia in that period. They were called *the Spartakiade.* They were organized to honor the tradition of mass sports events of the first republic, a communist-oriented sports organization called *Federácia robotníckych telocvičných jednôt* (*The Federation of Workers' Gymnastics Units*) that held very similar mass sports events under the same name. These mass performances were called *Nationwide Spartakiades* and later renamed to *sCzechoslovak Spartakiades*. In this paper, we present the general characteristics of these Spartakiades and briefly describe their structure and significance.

We have used standard methods of historical research. We have focused on collecting material related to the issue, searching for primary sources such as diaries, newspapers, books, speeches, historical data, electronic data. The established facts and their relations were categorized and studied on the basis of comparative method. This manuscript is based on our findings.

Mass sports performances in Czechoslovakia

The development of mass gymnastics in former Czechoslovakia after the establishment of the Czechoslovak Republic in 1918 goes back to the period when other *Sokol organizations (Units)* were gradually founded, including in Slovakia (Beňušková, 2012).

The Sokol movement, known as *the Sokol (the Falcon)*, was founded by *Dr. Miroslav Tyrš* and *Dr. Jindřich Fügner* in Prague on 16 February 1862. A part of the program of the cultural and social education movement was the regular organization of the *Všesokolské Slety (Pan-Sokol Slets)* that were attended by large numbers of Sokol members (Sak, 2012).

Figure 1. Public mass exercising of the Sokol members at Střelecký Ostrov, 18.6. 1882. Drawn by A. Liebscher. Source: Československá obec sokolská. Dr. Miroslav Tyrš 1832–1932. K stým narozeninám zakladatele Sokolstva. Československo: Praha III, Tyršův dům

In addition to the Czech gymnasts, there were also gymnasts from Slovakia who regularly participated in the Pan-Sokol Slets in Prague, specifically in years 1920, 1926, 1932, and 1938. In the period 1919 – 1937, the number of Sokol members in Slovakia increased from 12,385 to 49,625 members. More members meant greater participation in mass gymnastic events (Beňušková, 2012).

Pan-Sokol Slets were social events characterized by public exercises with international participation. International participation was based on the idea of *Pan-Slavic reciprocity and patriotism*[1] (Mauerhart, 1930). Therefore, it is possible to talk about the beginnings of mass physical education exercises. In addition to public exercises, the Slets also included various accompanying events, most often marching in traditional costumes (Martínkova, Klír & Swierczeková, 2013).

I. Pan-Sokol Slet was held *18-19 June 1882* at the Střelecký ostrov in Prague. 700 men from 79 Sokol units performed exercises under the leadership of their chief Dr. Miroslav Tyrš (Gajdoš, Provaznikova, Bednar & Banjak, 2012). A total of 1,572 costumed Sokol members with 57 flags, enthusiastically greeted by patriotic Praguers, marched through the streets of Prague (Česká obec sokolská, 2017).

At the Střelecký ostrov, Sokol members performed original collective mass gymnastics exercises and a 40-member team demonstrated exercises with gymnastic apparatus. The parade and the public exercises were very well received by the public and this led to a significant expansion of the Sokol organization in the territory of Bohemia and abroad (Sokol Strašnice, 2016).

Thanks to the success and popularity of this mass event, others *Pan-Sokol Slets* were held in *1891, 1895, 1901, 1907, 1912, 1920, 1926 and 1932* (Česká obec sokolská, 2017).

Very important was *the tenth Pan-Sokol Slet in 1938* that was held at a time

[1] Pan-Slavism, a 19th-century movement that recognized a common ethnic background among the various Slav peoples of eastern and east-central Europe and sought to unite those peoples for the achievement of common cultural and political goals. The Pan-Slav movement originally was formed in the first half of the 19*th* century by West and South Slav intellectuals, scholars, and poets, whose peoples were at that time also developing their sense of national identity. The Pan-Slavists engaged in studying folk songs, folklore, and peasant vernaculars of the Slav peoples, in demonstrating the similarities among them, and in trying to stimulate a sense of Slav unity. As such activities were conducted mainly in Prague, that city became the first Pan-Slav center for studying Slav antiquities and philology. (Encyclopedia Britannica, 2020).

of a growing fascist threat. In addition to its high-quality sports level, the determination to defend democratic principles and the Czechoslovak Republic were on full display at this Slet. In addition, it was preceded by the state funeral of Tomáš Garrigue Masaryk[2] (he died on the 14 September 1937) that was held in the spirit of a demonstration against the rising Nazism (Strachová, 2020, p.105). The success of this event was due to a mass floor exercise called "Oath to the Republic" that was performed by more than 29,000 gymnasts and an original aesthetically impressive dance vortex in a circular exercise called "Rej" performed by 30,000 women as the first major organized choreography. All parades had a manifestation character. This *Pan-Sokol Slet* became an encouragement to the Czechoslovak nation before the Munich Agreement was declared. It lasted 5 weeks and included 348,086 gymnasts with 2,300,000 spectators (Sokol Strašnice, 2016). On the basis of the number of tickets sold, Strachová estimates there were about 2,500,000 spectators (Strachová, 2020, pp. 1-2). In terms of organization and number of participants, we can unambiguously describe the Pan-Sokol Slet as a mass sports event.

During the World War II, organizing Pan-Sokol Slets was banned throughout the temporarily disintegrated Czechoslovakia[3] since the Sokol movement promoted ideas of freedom and democratic principles. During the period of the totalitarian regime, the Sokolovna (Sokol House), playgrounds (training grounds) and other Sokol facilities were purposefully liquidated (Sokolská únia Slovenska, n.d.).

In 1945, after the World War II, the Sokol movement was reactivated in liberated Czechoslovakia. (Gajdoš, Provaznikova, Bednar & Banjak, 2012).

Figure 2. Jiří František Chaloupecký – a Czech social democrat, a railway worker, the founder of the left-wing Federation of FRTJ (Workers' Gymnastics Units) and the initiator of the I. robotnícka spartakiáda (I. Workers' Spartakiade) in Prague in 1921.
Source: Wikipedia.org. Retrieved from https://cs.wikipedia.org/wiki/Ji%C5%99%C3%AD_Franti%C5%A1ek_Chaloupeck%C3%BD

However, from February 1948 onward, communist totalitarian ideology and the government of a single political party called Komunistická strana Československa – KSČ (The Communist Party of Czechoslovakia) prevailed, even though other political parties existed and participated marginally in the government. From the political point of view, it was a process of transition from a pluralist democracy to a totalitarian democracy. This change affected all areas of social life, including sports life. Political events were reflected in the last, *XI. Pan-Sokol Slet* in 1948 that was organized immediately after the end of the World War II. The Slet was held after political events in February 1948. As a part of it, a relay-race was held in the autumn 1947. The race consisted of 11 routes leading from the border to

[2] T. G. Masaryk co-founded Czechoslovakia together with Milan Rastislav Štefánik and Edvard Beneš and served as its first president, and so he is called by some Czechs the "President Liberator" (Preclík, 2019).
[3] The Protectorate of Bohemia and Moravia was established in the territory of the Czech and an independent state called the Slovak Republic was established in the territory of the Slovakia (Oborný, 2020).

Prague and was attended by about 46,000 runners. A floor exercise called "We will remain faithful" was performed to commemorate the members of the Sokol tortured and killed during the World War II. A modern exercise composition with cones was performed by women and it was so successful that it had to be repeated. Another unique performance included 2,500 campers. A total of 500,000 gymnasts performed mass exercises at the Slet. The communist regime considered the event appropriate propaganda, but the Sokol members were pro-democratic and therefore during the youth parade they demonstrated against the totalitarian communist regime. After this parade, more than 11,000 members were expelled from the Sokol by communist action committees (Česká obec sokolská, 2017).

Subsequently, the Sokol was integrated into the system of unified physical education and ceased to carry out its independent activities for the next 41 years. Thus, the Sokol was forced to stop organizing Pan-Sokol Slets (Kozáková, p. 47).

During the communist regime (1948-1989), very similar mass events were held under the name *Spartakiade* (Život, 2017).

The History of Spartakiades

The author of the name "*Spartakiáda" ("Spartakiade")* is Jiří František Chaloupecký[4]. The author of the term was inspired by the historical figure of *Spartacus*. Spartacus was a gladiator who led an uprising of Roman slaves (gladiators) against their exploiters, tyrants. Later, Spartacus led his army to war against the Roman troops (Morkes, 2010).

This concept was based on revolutionary ideas that combine the progress of revolutionary traditions with physical education. The concept was to acquire an international character with easy transposition and application to foreign languages (Šimanová, 2013).

The first mention of the name *"Spartakiade"* in the context of physical education comes from 1921 when the *FRTJ* (*Federation of Workers' Physical Education Units*) was established in Czechoslovakia. In this year, the FRTJ held a public exercise performance in Prague, in the city part called Manín, under the name *I. robotnícka spartakiáda* (*I. Workers' Spartakiade)* (Šimanová, 2013, pp. 13-14).

The FRTJ was a direct branch of the KSČ (The Communist Party of Czechoslovakia) and did not identify with an apolitical principle of physical education associations. For this reason, it was persecuted. Therefore, the second *Workers' Spartakiade*, which was to take place in 1928, was banned (Grexa, 2018, p. 32).

Six years after the last, XI. Pan-Sokol Slet in 1948, a mass physical education event was held under the name *I. Krajská spartakiáda DŠO Slávia (I. Regional Spartakiade Voluntary Sports organization*[5] *Slávia*) in Pilsen on 12 May 1954. The gymnastic level of a great number of gymnasts was displayed at this event. The event comprised public exercises and the main part were floor exercises. After the Regional Spartakiade in Pilsen, gymnasts from Moravia and Slovakia performed floor exercises. Women's floor exercises with cones and men's exercises with poles and fencing with bayonets were the most popular.

Regional Spartakiades comprised two parts: *Junior Days* and *Senior Days*. These Spartakiades were held in Slovakia in six

[4] Jiří František Chaloupecký was a Czech social democrat, a railway worker, the founder of the left-wing Federation of FRTJ (Workers' Gymnastics Units), and the initiator of the *I. robotnícka spartakiáda (I. Workers' Spartakiade)* in Prague in 1921 (Internetová encyklopedie dějin Brna, 2018).

[5] The Voluntary Sports Organization (DSO) was a designation for sports clubs used in Czechoslovakia in the 1950s. After the communist coup in February 1948, physical education was united, so all existing sports associations and organizations with all their property had to join the Sokol. In 1952, another reorganization took place - on December 12, Act No. 71/1952 Coll. on the organization of physical education and sport was adopted according to which the State Committee for Physical Education and Sport (SVTVS) was established as a tool for the central management of all sports activities in the country. All existing divisions were included in voluntary sports organizations, newly created after the Soviet model. The DSO system was a part of the Revolutionary Trade Union Movement (ROH) (Slovenská numizmatická spoločnosť, n.d.).

regional settlements: Prešov, Bratislava, Nitra, Žilina, Banská Bystrica and Košice. A total of 27,410 gymnasts performed at the Regional Spartakiades at *Senior Days* held in Slovakia and 41,333 gymnasts performed at *Junior Days*, i.e., a total of 68,743 Slovak practitioners actively participated in Regional Spartakiades in 1954. A total of 68,743 Slovak gymnasts were selected to take part in the *I. Nationwide Spartakiade*. Junior Days and Senior Days had a high attendance of 120,000 spectators.

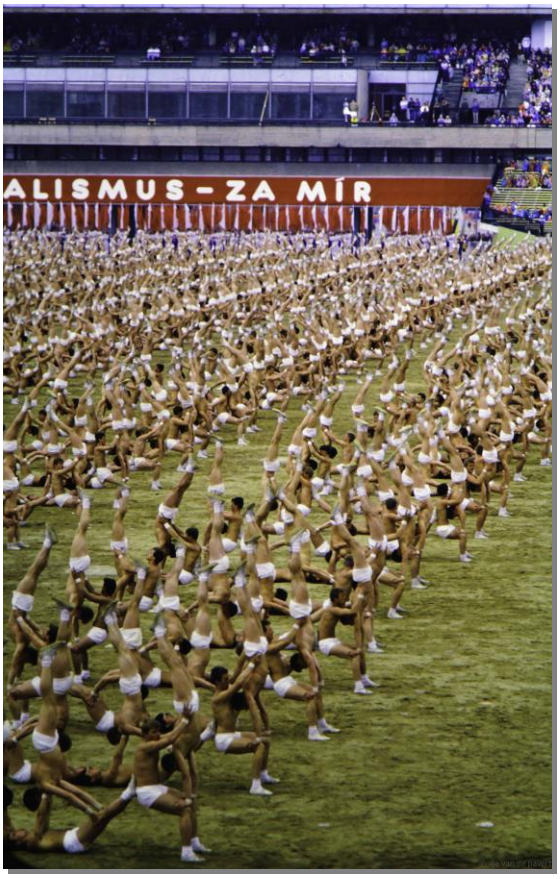

Figure 3. Czechoslovak Spartakiade 1985, Strahov stadium in Prague. Czechoslovak People's Army performed collective gymnastics composition with musical accompaniment. Source: Ilja Van de Pavert (1985). *Personal photo from Spartakiade 1985.* Československá republika, Praha. Retrieved from https://www.flickr.com/photos/ilvic/albums/72157625792004861

In addition to Regional Spartakiades, *District Spartakiades* were also held. *The District Spartakiades* were full-featured trainings for gymnasts and worked as a selection process for participation in *Nationwide Spartakiades*. In 1955, a total of 94 District Spartakiades were held in the territory of Slovakia with 174,234 performing gymnasts (137,217 youth and 37,017 adults) and 323,700 spectators (Kšiňan & Kováčik, 1955).

Therefore, Regional Spartakiades and District Spartakiades can be understood as an important part of the preparations and the organizational process for the largest mass sports event in the history of Czechoslovakia called *the Nationwide Spartakiade*.

In 1955, in preparation for the *I. Nationwide Spartakiade,* 311 District Spartakiades were held with a total of 755,000 gymnasts and 23 Regional Spartakiades with 390,684 gymnasts. (Perútka, 1975). The number of spectators at the District and Regional Spartakiades totalled 1,298,000 spectators (Dobrovodský, 1966, p. 7.)

All Spartakiades comprised 3 main sections: *mass sports performances*, *sports competitions,* and *tourist events* (Swierczeková, 2007).

The program also included a *Festival of Folk Art Creativity* and *Večery Družby* (*Friendship Evenings*), small cultural and sports performances with international participation at the Strahov Sports Stadium in Prague. There were participants from the Soviet Union, China, Mongolia, Hungary, Poland, Bulgaria and Romania. (Šterc, 1975, p. 51).

Dr. Jaroslav Šterc (1975) states the basic concept of the *Nationalwide Spartakiade* in points:

1. *Spartakiades are nationwide, and they are held every 5 years in honor of the liberation of Czechoslovakia by the Soviet Army during World War II.*

2. *Spartakiades have the character of a popular manifestation.*

3. *The Spartakiade is a common action of the whole physical education movement and all its sections, i.e. Základná a rekreačná telovýchova – ZRTV (Basic and recreational physical education), sports and tourism.*

4. *The main program of each Spartakiade will be mass sports performances.*

5. *The Spartakiade is not just a central event and must involve both republics (the Czech and the Slovak people), all regions, districts and cities at the same time.*

The phenomenon of mass exercises at Spartakiades in the period from 1955 to 1985 was, in a sense, a manifestation of the continuity of great and common gymnastic exercises of almost entire age spectrum. From the personnel, organizational, but also ideological point of view, the Spartakiades followed up the tradition of the Sokol Slets that were inspired by the German Turnerschaft (Roubal, 2016).

A total of six Spartakiades were held on the territory of former Czechoslovakia between 1955 and 1985 (Swierczeková, 2007).

The I. Nationwide Spartakiade started on 23 June and finished on 5 July 1955 in Prague at the Strahov Stadium (Metro, 2015). The Nationwide Spartakiade was the culmination of the celebrations of the 10th anniversary of the liberation of Czechoslovakia by the Soviet Army (Mucha, 1956). The budget for the I. Nationwide Spartakiade was 64 million Czechoslovak crowns with an expected profit of 26.5 million (Mikulecká, 2009, p. 48).

The slogan *"Ready to work and defend the homeland!"* dominated the Strahov stadium, and the editorial of the daily paper Rudé právo (The Red Law) stated: *"The Spartakiade will show the whole world that our people are guarding the peace and tranquility of their homeland and they are determined to protect the security and inviolability of the Republic"*, that was thematically reflected in the content of the Spartakiade's main program.

The preparation of the composition itself took about two years. The training started in autumn, i.e., at the time of the year when the program had to be ready - compositions, music, methodology, trainers. The compositions were spatially and physically drawn, then broken down and planned as smaller formations that complemented each other over a large space. The complete choreography and visual effects that were achieved by seemingly insignificant movements were manifested only when several groups performed their exercises together. Many schools were not equipped with gyms during the preparations, so gymnasts practiced in makeshift conditions. In winter, girls practiced "in the hall" and boys "in the hallway." In summer, the preparations moved to school playgrounds. Gymnasts also practiced exercises on playgrounds or in open areas provided with temporary markings made with preserve lids. (Bordášová, 2010, p. 19).

The main program of the Spartakiade, i.e., a mass sports performance, took place at the Strahov Stadium in Prague covering an area of 63,000 m² (approximately nine soccer fields) where thousands of gymnasts performed individual compositions in the same uniform outfits and shoes. Typical were white canvas shoes with elastic band popularly called *"jarmilky"*. In the stadium area, special marks were systematically placed on a square matrix that represented orientation points for the gymnasts. From here comes the Czech proverb *„Zpět na značky!" ("Back to the marks!")* signaling a start of something from scratch again (Doležalová, 2018).

Another modification of the same proverb was *„Na značky!", ("On your marks!")* as a signal to take a specific position as a starting position for the next action in the communication between members of each group (Oborný, 2020)

Figure 4. Czechoslovak Spartakiade 1985, Strahov stadium in Prague. Czechoslovak People's Army performed collective gymnastics composition with musical accompaniment. Source: Ilja Van de Pavert (1985). Personal photo from Spartakiade 1985. Československá republika, Praha. Retrieved from https://www.flickr.com/photos/ilvic/albums/72157625792004861

Gymnasts were choreographed in square units. One square unit usually consisted of 36 gymnasts. By moving the individual gymnasts inside the unit or moving the units around, formations were created that could be observed by spectators from the elevated seats of the grandstands and from a bird's eye view. The gymnasts themselves did not see these formations (Jezzina, 2018). From the experience and memories of many gymnasts performing at Spartakiades, we learn that they were mostly pleasantly surprised by the impressiveness of the compositions performed at the Strahov stadium. (Oborný, 2020). These compositions were visually very attractive for the spectators. (Jezzina, 2018). It should be emphasized that the authors of compositions sought to bring the ancient Greek idea of 'Kalokagathia' into practice. The impressiveness of Spartakiade compositions evoked uplifting feelings in most spectators (Oborný, 2020).

The mass performances also included musical accompaniment that contributed to the success and attractiveness of Spartakiades. It started with a counting exercise, that is, simple rhythms and setting the tempo during public performances (exercises) already present during the I. Pan-Sokol Slet in 1882. Musical accompaniment became an inseparable part of all Spartakiades. At the *I. Nationwide Spartakiade*, the gymnasts exercised to live music (Šterc, 1975). Some songs, especially by and for children and young people, became musical hits. These musical scores could also be purchased on gramophone records in specialized music shops. All Spartakiades were also recorded and archived on film. (Oborný, 2020).

An overview of the mass compositions performed in the main program of the Spartakiade 1955

Junior Days. *The youngest school children (5-7 years)* practiced a composition to a musical score called "Zlatá brána" ("Golden Gate"). The composition was practiced twice by 6,888 children (Šterc, 1975, pp. 48-49). It was only children from Prague and its immediate surroundings who performed in this age category at the Strahov Stadium as it would be organizationally demanding to provide accommodation for so many children and their parents for a few days away from home. (Oborný, 2020).

Younger school students (8-11 years) performed a composition to music that involved a special hand apparatus – dices. The composition was practiced by 24,192 students.

Older school students (12-14 years) - a total of 64,800 students practiced a floor exercise.

Youth common formation. A total of 40,000 gymnasts created the letters "ČSR-SSSR" at the Strahov stadium.

School teenagers – Girls (9th-10th grade). A total of 46,080 girls practiced an exercise with ribbons.

School teenagers – Boys (9th-10th grade). A total of 48,000 boys practiced a floor exercise.

Juveniles of ROH included 30,400 gymnasts.

Juveniles DSO Sokol included 30,400 gymnasts.

Juveniles from state labour reserves included 19,200 gymnasts.

A total of 333,468 gymnasts performed Spartakiade compositions during the Junior Days over 4 days (Šterc, 1975, pp. 48-49).

Senior Days. The program for Senior Days started with a folklore performance called "*Veselica krojovaných skupín" ("Festivity of costumed groups")*. 6,000 dancers from 500 folklore ensembles from different regions of Czechoslovakia participated. (Harasimowicz, 2017, pp. 107-108)

Women from concerns and offices (ROH). A total of 32,640 women performed a gymnastic exercise with one cone.

Men from concerns and offices (ROH). A total of 32,076 men performed a floor exercise.

Men and women from villages (DSO Sokol) - 31,720 gymnasts performed a composition including practicing a floor exercise.

Physical education schools and SŠD. Students at the *Institute of Physical Education and Sport*, *pedagogical schools*, *Tyrš Institute of Physical Education and Sport* and *students of the Sports Schools for Adolescents* performed a joint composition that included 4,800 gymnasts. (Mucha, 1956).

Performances by the Armed Forces of Czechoslovakia were held on a special day called The *Armed Forces Day*. They were very popular. An interesting composition was performed by soldiers on parallel bars and with rifles. At the end of the program, there was a mass jump of paratroopers to the stadium area (Jancura, 2015).

Additionally, the soldiers' program also included a group demonstration of the liberation of Czechoslovakia by the Soviet Army, exercises with children, exercises on beams, floor exercises and exercises on parallel bars (Šterc, 1975).

The first performance by the Armed Forces in 1955 was accompanied by 15,000 pigeons that circled over the Strahov Stadium for three minutes. *Zväzarm Day* was also a part of the main Spartakiade program. Members of Zväzarm[6] brought in hundreds motorcycles and tractors in and formed circular assemblies.

During the final performance, aerolites in swarms flew over the stadium. The pilots created the word "MIER" ("PEACE") and the letters "I. CS" in the sky in honor of the *I. Nationwide Spartakiade* (Vtedy, 2015).

At the *I. Nationwide Spartakiade*, a total of 567,506 gymnasts performed 29 group compositions (Plní elánu, 2020). It was watched by 1,800,000 spectators (Šterc, 1975, pp. 50-51).

In addition to the main program, various sports competitions and tourist events were held in Czechoslovakia during the event. For example, the famous Armenian gymnast Albert Azarjan performed an exercise on still rings and the Soviet gymnast Ludmila Yegorova performed an exercise on parallel bars in the gymnastics competitions. Emil Zátopek, a phenomenal Czechoslovak long-distance runner, also participated in

[6] Zväzarm - abbreviation for *Union for Cooperation with the Army*. The Union dealt primarily with military training, especially of the young male population in Czechoslovakia. Zväzarm performed some tasks of state defense. The Union covered military sports and technical hobby activities, as well as aviation, cynology, aeromodelling, motoring, orienteering, skydiving, diving, etc. (Retrománia, 2019).

athletic competitions (Česká televize, 2011).

From the perspective of program compositions and exercises, it can be noted that the event was held in the spirit of liberating ideas, the promotion of unity, the cohesion of the Czechoslovak nation and the demonstration of military readiness and defense of the nation. Thus, the *I. Nationwide Spartakiade* was a full-fledged successor to the Pan-Sokol Slets.

This Spartakiade, as well as the others, had strong political undertones. From the political perspective, the advantages of "socialist" general physical education and sport were promoted. However, the political aspect of the Spartakiades is not the goal of this article, so we will not deal with this more deeply. Roubal (2020) asked several research questions in a comprehensive evaluation of the Czechoslovak Spartakiades: *"To what extent did the Spartakiades from 1955 to 1985 follow the tradition of Pan-Sokol Slets, whether and to what extent was participation spontaneous and voluntary and were Spartakiades generally popular among gymnasts?"* These questions were in principle answered in the affirmative. Thus, the sports, cultural and social effects events were prevalent.

The II. Nationwide Spartakiade was held from 23 June to 3 July in 1960 (Šterc, 1975, p. 53).

It was held in honor of the 15th anniversary of the liberation of Czechoslovakia by the Soviet Army. The Spartakiade reflected the peaceful message of coexistence with other nations and according to the then official terminology, the Spartakiade was an expression of the political and moral unity of the Czechoslovak people (Oktábec & Novák, 1960).

The main organiser was ČSTV (The Czechoslovak Association of Physical Education) (Swierczeková, 2007).

Preparations began in September 1958 and were divided into two cycles. The first half of the compositions were performed at *District Spartakiades* in 1959 and rehearsals with music were held in March 1960. A total of 290 District Spartakiades were held with 1,149,879 gymnasts and they were watched by 1,937,000 spectators. A total of 47 Regional and County Spartakiades were held with the attendance of 847,923 gymnasts and participation of 1,024,670 spectators. Compared to the I. Nationwide Spartakiade, 457,259 more gymnasts took part in the preparations which was also reflected in greater participation in the main program (Oktábec & Novák, 1960).

The preparations were mainly focused on the creation and practice of new concepts of gymnast’s arrivals in the stadium and departures from it. There was some pressure to develop more difficult compositions, especially in spatial orientation (Šindelářová, 2011, p. 65).

The II. Nationwide Spartakiade begun on the 23 June 1960 with a cannon shot at the Strahov Stadium, followed by mass performances. (Šterc, 1975, p. 53). The main program consisted of 19 group compositions (Oktábec & Novák, 1960).

An overview of the group compositions performed in the main program of the Spartakiade 1960

Junior Days. *The youngest school children (6-8 years)* performed their composition to music called “Pohádka” (“Fairy-tale”). Children practiced a group exercise with a special hand apparatus called “Májka” (“Waver”).

Younger school students (8-11 years) performed their composition to a music score called “Radostná jar” (“Joyful Spring”).

Older students – Girls (12-14 years) performed their composition to a music score called “Červené míčky” (“Red Balls” and with rubbery red balls.

Older students – Boys (12-14 years) performed their composition to music called „Buď připraven k práci a obraně vlasti!“ (“Be ready to work and defend your homeland!”).

School teenagers – Girls performed their composition to music called „Radostné mládí“ („Joyful Infancy) and with white rhythmic gymnastics hoops.

School teenagers – Boys performed their floor exercise to music called „Mládí – krása – síla“ (“Youth - beauty – strength”).

Adult juveniles performed their group gymnastic exercises to music called „Zapalte ohně na horách!“ (“Light the fires in the mountains!“).

Apprentice juveniles. A total of 14,120 gymnasts performed their composition to music called „Do nových zítřků“ (“To the new tomorrows“).

Senior Days. *Folk artistic creativity*. At the beginning of the Senior Days program, a total of 6,000 artists presented a musical composition called „Píseň rodné země“ ("Song of the Homeland").

Women performed two compositions: the first composition was called „Rozsévačka“ (“Seeder“) and included 15,360 women performing a floor exercise. The second composition was called „Za mír, přátelství a spolupráci“ (“For peace, friendship and cooperation”). A total of 3,456 women participated in the mass gymnastic exercise with cones.

Men performed two compositions: in the first one, called „Za vítězstvím“ (For the Victory“), a total of 15,000 men practiced a floor exercise using short bars. The second one included 3,000 men performing an exercise with medicine-balls. (Šterc, 1975).

The *performance of soldiers* was also admirable. Soldiers performed a demanding acrobatic exercise on 160 springboard tables (also called ‘rib tables’ - tables with a covered area for somersaults) with jumping boards. The composition was called „Odvahou ke kázni, obratnosti a vytrvalosti“ ("With Courage to Discipline, Dexterity and Endurance”).

The Spartakiade program ended with a composition to music called „Život vítězí nad smrtí” ("Life Wins Over Death") that was performed by a total of 29,000 women.

Figure 5. Czechoslovak Spartakiade 1985, Strahov stadium in Prague. Czechoslovak People's Army performed collective gymnastics composition with musical accompaniment. Source: Ilja Van de Pavert (1985). Personal photo from Spartakiade 1985. Československá republika, Praha. Retrieved from https://www.flickr.com/photos/ilvic/albums/72157625792004861.

During the Spartakiade, a parade was held with attendance of 180,000 gymnasts from Czechoslovakia and foreign countries.

An interesting part of the *II. Nationwide Spartakiade* was an innovation in sound technology. Music for group performances was reproduced with magneto phones and radio. The sound system consisted of 112 terrestrial speakers and 3,500 speakers located around the stadium (Oktábec & Novák, 1960, p. 40).

A total of 349,662 adult gymnasts and 371,947 young gymnasts took part in the collective performances in the main program. The total number of gymnasts was 721,603, watched by 2,023,000 spectators. (Oktábec & Novák, 1960, pp. 16-21). A total of 68,129 Slovak gymnasts performed in the main program (Slovenský zväz rekreačnej telesnej výchovy a športu, n.d.)

In addition to mass exercises, there were also *Večery Družby* (*Friendship Evenings*) held during the event, where 410 gymnasts from the Union of Soviet Socialist Republics (the USSR), Hungary, Bulgaria, the People's Republic of China, the German Democratic Republic, Poland and France performed gymnastics and dance exercises (Oktábec & Novák, 1960, p. 24).

As an accompanying feature of the Spartakiade, there was also a comprehensive program of cultural events including plays, film shows, concerts, operas, exhibitions, performances by people's arts dance and song ensembles, etc. (Oktábec & Novák, 1960).

The program also included sports competitions. There were championship competitions at the district level and international championships in skiing, gymnastics, ice hockey, sports gymnastics, swimming, light athletic, etc. Climbing events in the High Tatras (mountains in the Slovak Republic) and tourist events in Krkonoše (mountains in the Czech Republic) were held (Šindelářová, 2011, p. 66). A total of 3,059,035 athletes competed in all sports contests (Oktábec & Novák, 1960).

The high organizational level was appreciated by several participating high-ranking foreign officials. Apparently, the II. Nationwide Spartakiade in 1960 was well managed organizationally, as evidenced by positive reports in the press and on the radio and television. Thus, this Spartakiade became the quality model for the organization of the next one (Oktábec & Novák, 1960).

However, there were also some negative aspects. For example, university students were forced to perform at the event. Therefore, a year earlier (in 1959), the only regular multi-sport university competition registered a significant drop in participants because they had to practice Spartakiade compositions (Bobrík & Seman, 2010, p. 68). Spartakiades, as a model of the functioning mass physical education in Czechoslovakia, required a sufficient number of active practitioners. Therefore, new members were recruited in the period before the organization of the Spartakiades, especially in university physical education units and sports clubs, (Bobrík & Seman, 2012, p. 33) in order to not only create a high membership base camp but also to have enough people who could be easily forced to perform.

The III. Nationwide Spartakiade was held from 1 to 4 July 1965 (Dobrovodský, 1966). As the previous one, this too was held to commemorate the 20th anniversary of the liberation of Czechoslovakia by the Soviet Army. The slogan was: *„Ve jménu zdraví, síly a krásy za šťastný život v míru, za víťezství komunismu*!“ *("In the name of health, strength and beauty for a happy life in peace, for the victory of communism!")* (Šterc, 1975). The slogan makes us think that the Spartakiade was held in the spirit of Kalokagathia, but also in the spirit of strengthening the communist ideology.

The preparations were completed by gymnasts in 1,485 public performances of units and schools at 424 Parish and District Spartakiades (Dobrovodský, 1966). A total of 1,365,514 gymnasts took part in them (Novák, 1966). For the first time, an exercise with parents and preschool children was included at the District Spartakiades. These exercises took place at the national level and the title of the collective composition was „Na sluníčku“ ("In the sun") (Česká televize, n.d.).

A significant change occurred in the design concept of the main program. Two cycles, Junior Days and Senior Days, were replaced by a single cycle lasting 4 days. The number of compositions was reduced to 12 and *continuous Program Afternoons* with a representative slogan were created. *The Program Afternoons* were designed around two program thematic concepts (Šterc, 1975). The first concept, „Zpěv míru“ ("Song of Peace"), took place 1-3 July 1965 and the second program concept, „Vítězství patří nám“ ("Victory belongs to us"), was held between 2-4 July 1965. In eight groups compositions for each concept, about 90,000 gymnasts practiced at the stadium (Dobrovodský, 1966).

An overview of the mass compositions performed in the main program of the Spartakiade 1965

Younger school students (8-11 years) performed a composition called „Učit se hrou" ("Learn through Game"). Girls practiced dance exercises and boys an exercise with crates (boxes). A total of 13,440 boys and 13,440 girls performed.

Older students – Boys (12-14 years) performed a composition called „Jeden za všechny" ("One for All"). It included 12,000 boys practicing a gymnastics exercise.

Older students – Girls (12-14 years) performed a composition called „Má země je kvetoucí louka" ("My country is a flowering meadow"). 16,000 girls performed an exercise with two flowers with a ribbon.

School teenagers – Boys performed a composition called „Přes překážky"("Over the obstacles"). They used 1,260 benches in their exercise.

School teenagers – Girls performed a composition called „Jaro země mé" ("My country's spring"). A total of 14,484 girls practiced a floor exercise.

Apprentice juveniles. A total of 14,120 gymnasts performed a composition called „Svou práci přetváříme svět" ("We are transforming the world with our work") and 12,000 boys and girls practiced a composition using a short jump rope. (Šterc, 1975). The dance performance was delivered to the musical rhythm of cha-cha-cha (Česká televize, n.d.).

Men performed a composition called „Jednotně vpřed" ("Unanimously go ahead" and included 14,104 men performing gymnastics exercises in 2 groups.

Women performed two compositions called „Zpěv míru" ("Singing of Peace") and „Pohybem ke kráse" ("By movement to beauty"). A total of 16,000 women performed the compositions based on a modern concept of gymnastics and choreography.

Figure 6. Czechoslovak Spartakiade 1985, Strahov stadium in Prague. Women performed the original aesthetically impressive dance vortex in a circular exercise called "Rej". Source: Ilja Van de Pavert (1985). Personal photo from Spartakiade 1985. Československá republika, Praha. Retrieved from https://www.flickr.com/photos/ilvic/albums/72157625792004861

One of the most attractive mass compositions was the performance of the *Czechoslovak Army* called "Vítězství patří nám" ("Victory belongs to us"), where 16,000 soldiers entered the stadium in armored transporters (Šterc, 1975).

This Spartakiade also included sports competitions and tourist events that were attended by 2,200,000 athletes and tourists. It introduced a multi-competency badge (PPOV) competition in categories: best district, best team and best athlete (Šindelářová, 2011, p.69).

The benefit of the Spartakiade was the organization of the *National Spartakiade for deaf, blind and physically handicapped athletes* that was held in parallel with the main event at the Strahov Stadium (Česká televize, n.d.).

Friendship Evenings were held in a sports hall in Prague for the first time. Gymnastic exercises were practiced by gymnasts from Bulgaria, Finland, France, Yugoslavia and Cuba (Šindelářová, 2011, p.69).

At *III. Nationwide Spartakiade in 1965*, a total of 356,120 gymnasts took part in the main program in front of 730,000 viewers (Šterc, 1975, p. 59). A total of 27,757 gymnasts from Slovakia participated (Slovenský zväz rekreačnej telesnej výchovy a športu, n.d.).

Even though there was a decrease in the number of gymnasts and compositions and there were some changes in the design of the program, it is not possible to evaluate *III. Nationwide Spartakiade* as unsuccessful, as it introduced an innovation that worked and was applied to future Spartakiades.

Five years later, in 1970, the *IV. Nationwide Spartakiade* was planned; however, the highest political authorities decided to cancel the event. The main reason was fear of demonstrations because of August 1968 when occupying troops of the Soviet Union and its allies had entered the territory of Czechoslovakia. The political leadership expected demonstrations against the occupation and the political regime that could probably be organized at a planned mass sports event such as the Spartakiade. Thus, there were also concerns for the safety of gymnasts. (Školské, 2015).

In 1975, the official name 'The Nationwide Spartakiade' was changed to *Czechoslovak Spartakiade* (Doležalová, 2018).

The Czechoslovak Spartakiade 1975 was held from 23 June to 1 July (YouTube, 2015).

It was traditionally held as a celebration of the 30th anniversary of the liberation of Czechoslovakia by the Soviet Army. The slogan this time was: „Pod vedením Komunistické strany Československa za další rozvoj socialistické tělesné výchovy" ("Under the leadership of the Communist Party of Czechoslovakia for the further development of socialist physical education") (Chválny, 1976).

More than 1,460,000 gymnasts performed at Local, Parish and District Spartakiades during the preparation stage. A total of 180,000 gymnasts performed in *two Program Afternoons* at the Strahov Stadium. The main program comprised 16 compositions (https://www.maria-online.us/go.php?x=1). A total of 27,757 gymnasts from Slovakia took part in this mass event (Slovenský zväz rekreačnej telesnej výchovy a športu, n.d.).

The Program Afternoons were conceived around two program thematic concepts that were repeated twice, following the model from the Spartakiade in 1965 (Šindelářová, 2011).

An overview of the mass compositions performed in the main program of the Spartakiade 1975

Parents with children (3-5 years) performed a composition with a musical accompaniment. Children from Prague and its immediate surroundings practiced exercises at the Strahov stadium. Three-year-old children were the youngest gymnasts in the history of Czechoslovakia who took part in a mass sports event.

The youngest school children (6-8 years) performed a composition with concrete building blocks.

Younger school students - Boys (9-11 years) - 7,000 boys performed a composition using red and white flying discs.

Younger school students - Girls (9-11 years)- 14,000 girls performed a dance composition.

Older students (12-14 years) – 11,500 boys performed a composition using sticks and balls.

Apprentice juveniles - 14,000 boys and girls performed a composition to music using non-traditional instruments similar to a Swedish vaulting box.

School teenagers – Girls performed a composition called „Zpíváme slunci" ("We sing to the Sun"). A total of 7,000 girls practiced exercises with gymnastic elements.

Men (17-75 years) performed a brisk and practical group composition aimed at preventing obesity.

Women practiced group exercises with cones and blue ribbons to a well-known musical composition 'Vltava' composed by world-famous artist Bedřich Smetana.

The performance of the Army began with a flight of fighters over the stadium and continued with admirable gymnastic mass compositions demanding physical fitness and spatial orientation (YouTube, 2015).

Gymnasts from ten, mostly socialist, countries took part in the international event *Večery Družby (Friendship Evenings)* (Wikipedia, 2020).

Sports competitions experienced a great boom. A total of 3,890,475 athletes participated in winter and summer Spartakiade sports competitions (Šindelářová, 2011, p.72). An interesting sporting event was *the Spartakiade Relay of Dukla Prague* attended by 820,660 runners, some from other countries. Tourists participated in an event called *"Ohňové posolstvo" ("Fire Message")* including almost 250,000 tourists (Wikipedia, 2020).

At the end of the Spartakiade, there was a parade with120,000 participants marching through Prague. It was watched by 700,000 spectators (Březina, 1996).

Despite unfavorable weather - there was constant rain during the mass performances on the first day of the main program, the *Czechoslovak Spartakiade in 1975* surpassed all previous mass physical education events in terms of its aesthetic value, performance, organization, care, technical parameters at the stadium and participants' involvement in the procession around Prague (Perútka, 1980, p. 222).

Other sports events held elsewhere were often dedicated to Spartakiades. For example, in 1975 the oldest national road race in Slovakia called "Devín – Bratislava" was dedicated not only to the 30th anniversary of the liberation of Czechoslovakia, but also to the Czechoslovak Spartakiade. (Bobrík & Seman, 2017, p. 43).

The Czechoslovak Spartakiade in 1980 was held from 26 to 29 June. It was held in honor of the 35th anniversary of liberation by the Soviet Army. A total of fifteen compositions were presented in *four Program Afternoons*. The compositions were modern in terms of music and physical movement. The originality of spatial solutions and a higher difficulty level of exercises provided a proof of increasing effectiveness of the physical education process in Czechoslovakia.

The gymnastic compositions by *the Czechoslovak Army* and women were repeated in both *Program Afternoons*. The highest number of gymnasts participating in one composition was 13,824.

A total of 1,265,320 gymnasts took part in the Regional and Parish Spartakiades and a total of 702,732 gymnasts took part in the District Spartakiades (Chválny, 1981, pp.161-162).

A total of 189,000 gymnasts performed at Strahov during the main Spartakiade program. The main program was watched by 2,340,000 spectators. The event cost 673,000,000 Czechoslovak crowns, i.e., about 220,000,000 euros (Kern, 2015). A total of 34,652 Slovak gymnasts participated in the main program (Slovenský zväz rekreačnej telesnej výchovy a športu, n.d.).

An overview of the mass compositions performed in the main program of the Spartakiade 1980

I. Program Afternoon (26 June – 28 June)

Opening I. – a total of 2,944 high school students performed a dance composition called *„Oslava života"(*"Celebration of Life").

The youngest school children (5-7 years) performed a composition by ČSTV and the Ministry of Education; 840 children with 192 trainers participated. The aim of the composition was to lead children to an all-round movement development through simple gymnastic exercises.

School teenagers – Boys (15-18 years) performed mass composition by ČSTV and the Ministry of Education; 6,912 boys presented a mass gymnastic exercise in pairs and trios. The composition had lots of difficult elements.

Younger school students – Girls (8-11 years) performed a collective composition by ČSTV and the Ministry of Education. 13,824 girls practiced a mass exercise using non-traditional tools – red wooden frames.

Apprentice Youth (15-18 years) performed a collective composition by ČSTV and the Ministry of Education; 6,912 girls practiced gymnastic exercise using metal bars and orange ribbons and 6,912 boys exercised with chrome bars.

10,368 *women* performed a collective composition by ČSTV and the Ministry of Education. The composition was focused on the rhythm, movement alterations and spatial perception.

Older students – Boys (12-14 years) – 9,216 students performed a collective composition by ČSTV and the Ministry of Education.

The Czechoslovak People's Army performed a mass composition organized by Ministry of National Defense. A total of 13,824 soldiers were involved in the first and second *Program Afternoon*. The soldiers performed demanding gymnastic exercises with acrobatic elements, e.g., ejection from "live " trampolines into bent high squadrons.

The Ending I. – a total of 15,018 gymnasts performed a group composition forming the symbol of the XXII. Olympic Games.

II. ***Program Afternoon (27 June - 29 June)***

Opening II. – A total of 1,944 women performed a collective composition with red battalions as part of a coin technique and 1,728 men performed sports gymnastics.

Parents with children (3-4 years) performed a collective composition by ČSTV and the Ministry of Education, including 2,450 children with mothers and fathers. They practiced exercises in pairs and more emphasis was put on the elements of basic gymnastics for parents.

Women performed the same collective composition as in the I. Program Afternoon.

Younger school students – Boys (8-11 years) performed a collective composition by ČSTV and the Ministry of Education. 13,824 boys practiced a mass exercise using balls, skipping ropes and rings also known as “Hula Hoops”.

Zväzarm and schools – The collective composition of ČSTV and the Ministry of Education was intended primarily for future high school graduates aged 16 and over. A total of 6,144 boys practiced a mass gymnastic exercise using an original metal gymnastic apparatus called “semicircles”.

Universities - A group composition was performed by 5,760 male and 5,760 female students. The performance had a dance character with the use of aesthetic elements of "jazz gymnastics" and folklore motives.

Older students - Girls (12-14 years) – 13,824 female students performed a collective composition by ČSTV and the Ministry of Education. The exercise was focused on basic and modern gymnastics.

6,912 Men performed a collective composition by ČSTV and the Ministry of Education. It was a dynamic composition with a fitness test performed by 18-year-olds as well as 80-year-old men.

School female teenagers and women – 5,760 female gymnasts performed a collective composition by ČSTV and the Ministry of Education. The exercises included fitness gymnastics using special mattresses.

School teenagers – Girls (15-18 years) performed a collective composition by ČSTV and the Ministry of Education. 13,824 girls practiced a mass exercise using white skipping ropes with foam tassels.

The Czechoslovak People's Army performed the same composition as in the I. Program Afternoon (Chválny, 1981).

Figure 7. Czechoslovak Spartakiade 1985, Strahov stadium in Prague. Women performed the original dance composition with scarves.Source: Ilja Van de Pavert (1985). Personal photo from Spartakiade 1985. Československá republika, Praha. Retrieved from https://www.flickr.com/photos/ilvic/albums/72157625792004861.

In addition to the main program, *Večery Družby (Friendship Evenings*) with international participation were traditionally held in the Prague Sports Hall. The event was attended by gymnasts from ten countries. The program was repeated four times and was watched by more than 50,000 spectators.

A total of 4,232,840 athletes took part in the sports competitions during the Spartakiade. As part of sports competitions, the *Spartakiade Cup of Talents in Skiing and Sledding* was held in the winter season. The *Talent Cup of the Chairman of the Central Committee of the ČSTV, Youth Sports Games, Apprenticeship Olympiads, Youth Agricultural Olympiad*, etc., were held in the summer as part of sports competitions (Film Europe Media Company, n.d.).

More than 3,100,000 tourists took part in 2,320 tourist events called *"Fire Message"* (Chválny, 1981, pp. 161-162).

The entire Spartakiade was recorded and archived on film by renowned Czech cinematographers and directors, so it is still possible to view the audio-visual digitized recording of the main program (https://www.fdb.cz/film/ceskoslovenska-Spartakiadea-1980/30795).

The Czechoslovak Spartakiade in 1985 was held from 27 to 30 June (Demetrovič, 1985).

It was held to commemorate the 40th anniversary of the national liberation and liberation by the Soviet Army. The program reflected the pride and love of the working people and youth for their socialist homeland (Súkup, 1985, p.2). The ceremonial parade through Prague was attended by 176,400 gymnasts and watched by 90,000 spectators (Demetrovič, 1985, p. 184).

Preparations for the Spartakiade began with the traditional ritual "*Fire Message"*, organized by the Tourism Association. A total of 3,242 fire wafers were lit throughput the Czechoslovak Republic (Demetrovič, 1985, p. 47).

A total of 2,186,905 gymnasts performed at Local, Parish and District Spartakiades that were viewed by almost 3,917,611 spectators (Demetrovič, 1985, p.188).

The Spartakiade compositions were organized by ČSTV - ZRTV and again included a large number of practicing gymnasts. The exercises were performed by 5-year-old children to adults. They were mainly floor exercises.

The large base of gymnasts came from primary schools (younger and older students), apprentice schools (school teenagers, juveniles) and universities. Spartakiade preparations in schools were incorporated in compulsory physical education lessons. Both basic service soldiers and younger professional soldiers were selected for the military compositions, 13,824 men in total (Doležalová, 2018).

The main program at the Strahov Stadium was divided into *two Program Afternoons*; each Program Afternoon had two repeats. During the main program, a total of 172,496 gymnasts performed mass exercises in fifteen compositions; it was watched by 940,000 spectators (Demetrovič, 1985, pp. 188-189). A total of 36,433 gymnasts from Slovakia participated in ten performances (Slovenský zväz rekreačnej telesnej výchovy a športu, n.d.).

An overview of the mass compositions performed in the main program of the Spartakiade 1985

I. Program Afternoon (27 June – 29 June)

Opening I. – A total of 648 gymnasts performed in the opening ceremony.

Women I. – 13,824 women performed a group composition with small hoops and ribbons; its title was „Listy ratolesti“ (“Leaves of a branch“).

Parents with children - 2,336 practicing pairs performed a group composition called „Prvé dotyky“ („First touches“).

Older students – Boys (11-14 years) performed a collective composition called „Lano života“ (“Rope of life“). A total of 10,368 boys performed the mass exercise with ropes.

Younger school students – Girls (8-11 years) 10,752 girls performed a collective composition called „Kto je kamarát“(“Who is a friend“) using a ribbon with rings at both ends.

The Czechoslovak People's Army performed a collective composition called „Mať to štastie“(“To have luck“). There were 13,824 soldiers in each of the four performances executing demanding disciplinary gymnastics and acrobatic exercises.

School teenagers – 13,824 girls performed collective composition „Najkrajší vek“ (“The most beautiful age“) using ribbons on a short pole.

Universities – A collective composition called „Mladosť a krása“ (“Youth and beauty“) was performed by 5,148 university students. Male students did an exercise with over-balls and female students with a ball in the net.

School teenagers – 6,912 boys performed a collective composition „Zajtra muži“ (“Men tomorrow“) with two benches.

Apprentice Youth – 13,824 boys and girls performed a composition called „Dynamická, veselá“ (“Dynamic, cheerful“) using skipping ropes (Súkup, 1985, p. 8).

Figure 8. Czechoslovak Spartakiade 1985, Strahov stadium in Prague. Boys practiced mass gymnastic exercise using the original gymnastic apparatus called the “semicircles” made from metal. Source: Ilja Van de Pavert (1985). Personal photo from Spartakiade 1985. Československá republika, Praha. Retrieved from https://www.flickr.com/photos/ilvic/albums/72157625792004861.

II.Program Afternoon (28 – 30 June)

Zväzarm performed a collective composition called „Áno i nie“ (“Yes and no“). There were 6,144 gymnasts performing gymnastic geometric exercises using heavy metal semicircles.

The youngest school children (5-7 years) 5,760 children performed a collective composition called „Leťme s drakmi“ (“Let's fly with dragons“) using an original pedagogical toy that consisted of 5 foam cubes joined into one unit depicting a dragon.

Younger school students - Boys (8-11 years) performed a composition „Les tenistov“ (“Forest of tennis players“). There were 10,752 boys exercising with tennis rackets and moss balls.

Older students – Girls (11-14 years) – 13,824 girls performed a composition called “Usmiate púčiky” (“Smiling buds”).

Women II – 13,824 women performed a collective composition „Listy ratolesti“ (“Leaves of a branch”) using scarves.

Men performed a collective composition „Od 18 do 80 rokov“ (“From 18 to 80 years“). A total of 8,640 men executed demanding acrobatic exercises.

School female teenagers and women – 6,912 gymnasts performed a collective composition with cones.

The Czechoslovak People's Army performed the same collective composition as in the I. Program Afternoon.

The last and final Spartakiade composition was performed by 16,000 gymnasts (Súkup, 1985).

The Spartakiade in 1985 received a positive response, as evidenced by the statement of a participant and then chairman of the International Olympic Committee, Juan Antonio Samaranch, who said*: "The Spartakiade is one of the most important sporting events I have ever seen. I have seen many mass sports performances in other countries, but in my life never like the one here in Prague. I think that such gymnastic events as the Spartakiade can also contribute to the development of elite sport. Congratulations on organizing the Spartakiade* (Demetrovič, 1985). *"Your physical education performances are a clear example for other countries"* (Súkup, 1985, p.27).

In addition to Czechoslovak gymnasts, delegations from eight countries (Bulgarian People's Republic, Finland, France, Cuba, the Hungarian People's Republic, the German Democratic Republic, the Polish People's Republic, the USSR) performed gymnastic exercises in 35 collective compositions at *Večery Družby (Friendship Evenings)*. About 70,000 spectators attended this traditional gymnastic event (Demetrovič, 1985, p. 184). An interesting, modern gymnastic performance was presented by German gymnasts. Romanian gymnasts successfully performed gymnastic exercises using a new, non-traditional tool – connecting hemispheres filled with silk scarves. Slovak gymnast from the Faculty of Physical Education and Sports in Bratislava, led by Hedviga Šimoneková, Emilie Fialová and Anton Gajdoš, performed an attractive folk dance and an interesting gymnastic composition with skipping ropes (Súkup, 1985, p. 25).

Figure 9. Czechoslovak Spartakiade 1985, Strahov stadium in Prague. Girls performed collective conposition with musical accompaniment called „Najkrajší vek“ („The most beautiful age“).Source: Ilja Van de Pavert (1985). Personal photo from Spartakiade 1985. Československá republika, Praha. Retrieved from https://www.flickr.com/photos/ilvic/albums/72157625792004861.

A total of 9,089,243 athletes took part in more than 12,000 sports competitions in various sports events. In an event for tourists called „Za jeden den kolem celé ČSSR“ ("In one day around the whole Czechoslovakia") participants completed a total of 48 hiking marches throughout Czechoslovakia in one day (Demetrovič, 1985, p. 185).

Immediately after the end of the Spartakiade, preparations for the Spartakiade in 1990 started, as evidenced by mass preparations in 1988 and 1989 including thousands of gymnasts (Kern, 2015). However, due to the political, economic, cultural and ideological changes that began in November 1989, the planned Czechoslovak Spartakiade did not take place in 1990 (Oborný, 2020).

After the fall of communism, the festival of ideological physical education - Spartakiade - was replaced by the *Prague Sports Games* that were held at a much smaller stadium. The number of gymnasts and spectators was lower and there were fewer events and categories (Kern, 2015).

Since 1985 the idea of Spartakiade has not been revived. The only mass exercises on a large training ground since 1985 were due to the revival of Sokol Slets in 1994, 2000, 2005, 2012 and 2018. These Sokol Slets were held at the transnational level, but never had such a high participation of gymnasts as Spartakiades (Česká obec sokolská, 2020).

CONCLUSION

Spartakiades, as a successor of Pan-Sokol Slets, that were held in Czechoslovakia in the period 1955 - 1985, were certainly a phenomenon in the physical education culture and sports. To this day there has not been a comparable event that would involve such a large number of gymnasts in group performances. There were 552,000 gymnasts in 1955 and 172,496 performing at the last Spartakiade in 1985. Spartakiades were mass sports performances with a well-thought-out organizational structure, systematic, regular preparation and with a precise execution of compositions. The composition content was divided into gender and age categories from 5 to 80-year-olds. Chorographically, there were floor exercises, different types of gymnastics and dance exercises using various non-traditional instruments and tools. Very attractive were performances given by the Czechoslovak Army as soldiers performed demanding gymnastic and acrobatic exercises. The goal was to create unique thematic formations that the spectators seated in the elevated parts of the stadium could admire. The Spartakiade compositions were the result of several years and months of preparation and drills and they symbolized ideological messages, most often the message of unity, cooperation and maintaining peace. As part of each Spartakiade, various cultural, social and sports competitions with international participation were held. Thus, we can unequivocally confirm that Spartakiades represented the development of physical education culture for the masses with an emphasis on the socio-cultural-physical development of the individual.

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USE OF OBJECTIVE METHODS TO DETERMINE THE HOLDING TIME OF HOLD ELEMENTS ON STILL RINGS

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Abstract
The duration of holding elements represents a critical factor for judging routines on the still rings in artistic gymnastics. Athletes can be penalized with non-recognition of an element if the hold time is too short. Dynamometric and kinematic measuring methods offer the possibility to provide support to judges in evaluating the duration of the hold time. In this study a dynamometric method with two different variants (dms10 and dms5) as well as a kinematic method (kms) based on a trained neural network were presented and examined with regard to their agreement with judges' evaluations when determining the hold time. To check the agreement, a) the percentage agreement and b) the interrater reliability were calculated using Cohen's kappa (k). The two dynamometric methods showed a percentage agreement of 83.5% (dms10) and 51.7% (dms5) with the hold time evaluation by judges. The percentage agreement of the kms was 38.8%. The interrater reliability showed for the dms10 a moderate (k = 0.58) and for the dms5 a fair (k = 0.23) agreement, while the kms showed a poor (k = 0.02) match. The results supported dms10 for its possible use as a practicable and reliable method to assist judges in evaluating hold times on the still rings. Dms5 and kms (in the current development stage) were not suitable as means of judges' support.

Keywords: *men's artistic gymnastics, still rings, judging, hold time, measurement systems.*

INTRODUCTION

Competition results in artistic gymnastics are determined by judges who evaluate routines according to clearly defined rules. Despite there being objective rules on how to evaluate a gymnastics routine, such evaluations are prone to mistakes (Leskošek, Čuk, Karácsony, Pajek, & Bučar, 2010). Making use of technical measuring systems could help to minimize these errors and thus make these evaluations more objective. In order to increase the use of measuring systems in gymnastics, researchers have developed various solutions using engineering and computer science (Fujihara, Gervais, & Irwin, 2019, Omorczyk, Nosiadek, Ambroży, & Nosiadek, 2015; Veličković, Paunović, Madić, Vukašinović, & Kolar, 2016). Some of these ideas are already being utilized in other competitions. For example, in trampoline gymnastics, time of flight (ToF) is a scored part of the competition and can be accurately measured by using a laser-based light curtain. Since the 2017-2020 Olympic cycle, determination of the take-off and take-on position of a jump (horizontal displacement) has become important. As a result, a measuring system that can determine both ToF and position is now in use (Ferger & Hackbarth, 2017). The impact scores of different horizontal displacement calculations on competition has also been investigated (Ferger, Helm, & Zentgraf, 2020).

In October 2017, the Fédération Internationale de Gymnastique (FIG) announced that it would partner with Fujitsu to develop a practical judging support system for gymnastics competitions. By using a 3-D-laser-sensor technique and artificial intelligence, the movements of gymnasts were recorded and automatically analyzed to detect elements and recognize the difficulty score (D-score) (Fujitsu Limited, 2018, Fujitsu Limited, 2019). At the Artistic Gymnastics World Championships 2019, the judging was supported by this system.

Since 2014, a dynamometric measuring system has been used at European Gymnastics Federation competitions in order to determine the hold times of strength elements on still rings (Aarts & Pluk, 2016a). The objective of this system is to help judges to more objectively estimate hold times. In this system, still rings are equipped with specially prepared force elements allowing the vertical forces on the ring cables to be measured.

The hold times are calculated in a combination of displaying objective data together with subjective data. The exact start and end time of a hold is given by a Hold Time judge. A graphical user interface assists the judging in evaluating hold times in still rings routines.

Consequently, a high level of attention must therefore be devoted to hold times during the training of athletes in order to obtain good competition scores. In summary, it can be stated that the use of objective measurement methods to support judges is gaining ground.

According to current FIG regulations, routines on still rings have to be composed from elements of 1) kip and swing elements & swings through or to handstand; 2) strength elements and hold elements; 3) swings to strength hold elements, and 4) dismounts, to receive full evaluation of the element groups (FIG, 2017). Most of these elements end in a holding position. A count of all elements on still rings that end in a holding position from the current Code of Points (CdP) reveals they make 67% of the total elements that can be realized on this apparatus (FIG, 2017). Furthermore, these elements are the only ones with a difficulty greater than or equal to a D-score of 0.5 points, except for the "O'Neil" element and the six dismount elements (FIG, 2017).

A look at competition data from the World Championship still ring finals between 2017 and 2019 reveals 35.3% of the element part in the D-score comes from group 2 (strength elements and hold elements), and 27.0% from group 3 (swings to strength hold elements). This shows how important these elements are for a successful routine. With this in mind, it’s clearly essential to have a means of accurately determining hold times on still rings. Aarts and Pluk (2016b) confirm the importance of correct hold time determination due to the marginal differences exhibited between final scores in the 2014 and 2015 European Championships ring final. When evaluating elements, judges are required to assess the duration of the holding position, which must be held for at least two seconds for full acceptance. If a holding position is held for less than two seconds, the gymnast loses 0.3 points for this element. If there is no visible stoppage, the element will not be recognized by the difficulty judges and 0.5 points will be deducted by the execution judges (FIG, 2017). But there is no exact definition in the CdP how long a visible stop has to be. By using objective methods, a more accurate system of deductions (small, medium or large) can be utilized. However, before using technical systems in competition and training, potential measuring systems need to be evaluated in order to confirm their accuracy. There is no “gold standard” for the evaluation of hold time; for this reason the evaluation should be conducted by qualified judges (keeping in mind that judges do not always agree with each other).

The aim of this study was to investigate two measuring systems which have been developed to evaluate hold time. The two systems to be assessed are a dynamometric method and a kinematic method (which uses a trained neural network to estimate hold times in video frames). The quality of these measuring systems will be examined and compared to the corresponding decisions made by judges.

METHODS

For the data analysis, 14 still ring routines from the German Championships all-around final 2018 were used. The routines were performed by eleven German national team squad gymnasts and three non-squad gymnasts. Their age, height and body mass were 25.6 ± 2.9 years, 170.0 ± 0.062 m and 65.2 ± 4.9 kg. The body masses of the athletes were measured using the dynamometric measurement system over 0.5 seconds while in the still hanging starting position with vertical arms and legs at the beginning of the routine. The still rings routines had an average difficulty (D-score) of 5.10 ± 0.75 points. For the analysis of the hold time, 85 hold elements (also including handstands) were performed by 14 gymnasts in their routines.

Dynamometric measurement system

A dynamometric measurement system (dms), based on prepared force elements and a synchronized video camera (Basler BIP 640c, 50 Hz frame rate, 640 x 480 px), was utilized to determine hold time using dynamometry. As a compromise for the different hold elements (cross – front view; planche – side view), the camera position was about 45° (Fig. 2). Force sensors were placed in the screw connection of each cable of the rings. They were directly connected to the suspension of a FIG-certified ring apparatus by SPIETH (Fig. 1).

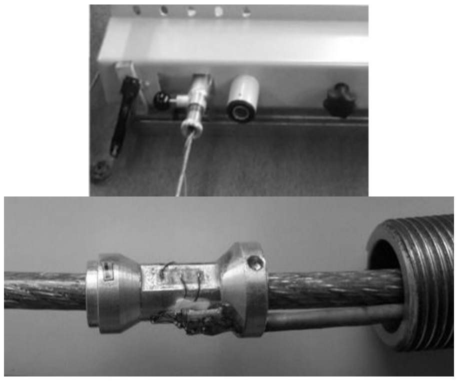

Figure 1. Position of the force sensors.

The prototype sensors consist of a bending body with strain gauges (350 Ohm). The vertical forces exerted by the gymnast were recorded at a sampling frequency of 200 Hz simultaneously with a 50 Hz reference video and stored in a measuring computer. With the help of computer software, the sum signal of the vertical forces of both left and right rings was analyzed relative to the body weight (bw) of the athlete. When conducting an automatic detection of the holding elements and the hold times, forces were detected between a wide range of a) 0.9 - 1.1 bw (±10 %; dms10) and a small range b) 0.95 - 1.05 bw (±5 %; dms5) (Fig. 2). It must be noted that due to the geometric relationship between the length of the ring cables and the gymnast’s arm spans, more force of each cable is measured for the element cross. Gymnasts with arm spans of 1.45 m achieve 1.2% and athletes with arm spans of 1.70 m even 1.9% more force in the cables. This error range is considerably lower than our two defined ranges (±10 %; ±5 %).

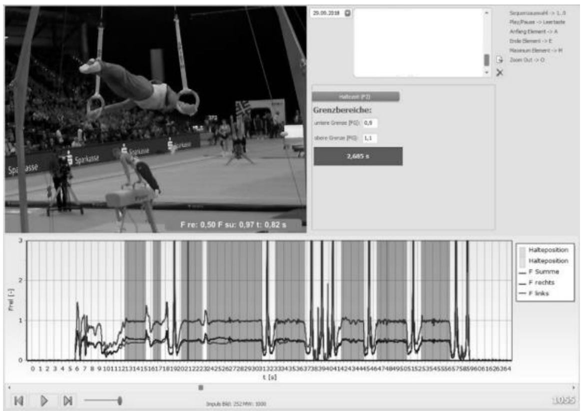

Figure 2. Example of automatic determination of the hold time (marked parts of the force-time curve) and synchronized video.

A kinematic measurement system (kms) based on OpenPose and self-programmed software was the second method used for determining hold time. Open source software OpenPose (https://github.com/CMU-Perceptual-Computing-Lab/openpose) is a trained neural network for human pose estimation in images and videos. It returns 18 body points with x and y coordinates (Cao, Hidalgo, Simon, Wei, & Sheikh, 2018). In order to avoid false negative detections, the body points below the knees (10 and 13) and from the head (14 - 17) were not considered in the evaluation of the hold times. These points were less relevant for the evaluation, plus they were more prone to errors in detection than other body points (Winter, 2019).

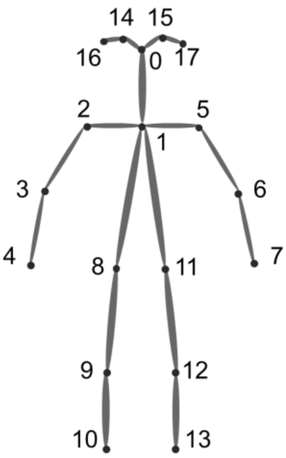

Figure 3. OpenPose body points.

The videos recorded using the dynamometric measurement system (50 Hz, Basler Bip640c), were also used for these data analyses. The x- and y-coordinates of the body points (Fig. 3) were evaluated by a specially developed software program. This program compares the x- and y-coordinates of successive frames. A holding position between two (or more) frames was detected if the difference between the x and y coordinates forming 60% of the body points was less than a defined margin of 1.5% (Winter, 2019). For a video size of 640 x 480 px the change would be a maximum of 9.6 x 7.2 px. The hold time results from counting successive frames where a holding position is detected (Winter, 2019). Using this information, the program could calculate the total hold time of the element.

For an expert comparison of these three methods, five judges (FIG brevet level; four of them category 2) evaluated the routines. They watched each routine at its original video speed and decided if the time for holding positions was accepted without deduction, with 0.3 points deduction or not accepted at all. Only hold times were the focus; holding positions were not evaluated. To compare the judges' evaluations with the other measuring methods, the majority result by the five judges was used.

In this study, all measured hold times (dms10, dms5 and kms) were classified into three judging categories. Because there is no definition of a visible stop for element recognition in the CdP, we define it as being a minimum of 0.5 seconds. Detected hold times from 0.50 to 1.99s were categorized with 0.3 points deduction and hold times ≥ 2.0s without deduction. A comparison was made between the judges' evaluations and the three measurement methods (dms10, dms5, kms). Furthermore, judges' individual evaluations were compared to their majority evaluations. In order to check both the agreement of a) the three measuring methods with the majority evaluation of the judges, and b) the agreement of the individual judge's evaluations with their majority evaluations, percentage agreements were calculated. In addition, the interrater reliability using Cohen kappa (k-value) for both a) and b) was determined to analyze the agreement. The levels for k-value were rated as either 'poor' (<0.00), 'slight' (0.00 - 0.20), 'fair' (0.21 - 0.40), 'moderate' (0.41 - 0.60), 'substantial' (0.61 - 0.80) or 'almost perfect' (0.81 - 1.00) (Landis & Koch, 1977).

RESULTS

Analysis of the various methods showed the judges on the whole and the dms10 made no deductions for hold time in the majority of the elements they evaluated. When assessing hold time using the kms (45.9%) and dms5 (51.9 %), the majority of the elements were given a deduction of 0.3 points (Table 1).

Examining the agreement between judges reveals that all five judges (100%) estimated the hold time as equal for 33 elements (Table 2). This represents 39% of the elements. Four out of five judges (80%) agreed on the hold time for an additional 31 elements (36%).

Table 1
Distribution of element evaluations across the various measurement systems.

	judges		dms10		dms5		kms	
Total number of Elements	85							
not accepted	4	4.7 %	2	2.4 %	14	16.5 %	13	15.3 %
0.3 points deduction	25	29.4 %	17	20.0 %	39	45.9 %	44	51.8 %
without deduction	56	65.9 %	66	77.6 %	32	37.6 %	28	32.9 %

Table 2
Percentage agreement between the judges.

judge assignment	elements	percentage value
100% equality (all 5 jugdes`)	33	39%
80% equality (4 to 1 jugdes`)	31	36%
60% equality (3 to 2 or 3 to 1 to 1)	21	25%

Table 3
Percentage agreement and the Cohen kappa (k-value) for the single judges with the majority.

	judge 1	judge 2	judge 3	judge 4	judge 5
total agreement with judges' majority[elements]	51	56	44	54	25
total percentage agreement [%]	60.0	65.9	51.8	63.5	29.4
k-value	0.05 'slight'	0.14 'slight'	-0.05 'poor'	0.12 'slight'	-0.11 'poor'

Table 4
Percentage agreement of the dynamometric and kinematic measurement systems with the judges' majority evaluations in determining hold times.

	dms10	dms5	kms
total agreement with judge majority [elements]	71	45	33
total percentage agreement [%]	83.5	52.9	38.8
fully recognized [%]	87.9	90.6	82.1
0.3 reduction [%]	64.7	28.2	22.7
non-recognized [%]	100.0	28.6	0

Table 5
Interrater reliability between the dynamometric and kinematic measurement systems, and the judges' majority evaluations in determining hold times.

	dms10	dms5	kms
k-value	0.58 'moderate'	0.24 'fair'	0.02 'slight'

The calculation of k-value for how an individual judge's evaluation compares to the majority evaluation of the judges resulted in values of -0.11 to 0.14. The agreement between the individual judge's evaluation and the majority evaluation is therefore rated as 'poor' to 'slight' with regards to k-value (Table 3).

The analysis showed that 71 of the total 85 elements detected using dms10 were in agreement with the majority judges' evaluations. In ten of the fourteen elements without agreement the dms10 showed longer hold times compared to the judges' evaluations. For example the judges evaluated eight elements with 0.3 points deduction while the dms10 evaluated these elements without deduction. When using dms5, 44 of 85 hold positions were shown to agree with the judges. The percentage agreements of the two dynamometric variants were therefore 83.5% (dms10) and 51.7% (dms5) when compared to the judges' evaluations. A total of 33 of the 85 elements recorded with the kms were in agreement with the judges. This corresponds to a percentage agreement of 38.8%. Dividing the elements into individual categories (fully recognized, 0.3 points deduction and not recognized) the measurement systems showed a high percentage of agreement with the judges' evaluations for the fully recognized elements (Table 4). For the non-recognized elements, dms5 and kms had a low percentage agreement with the judges' evaluations. In contrast, dms10 was 100% identical to the judges' evaluations in the category "non-recognized elements".

For the 33 elements which all 5 judges evaluated equally, a similar percentage agreement for the measuring systems is shown. The total percentage agreement for dms10 is 78.8%, for dms5 60.6% and for kms 24.2%.

The determination of k-value showed the level of agreement with the majority of the judges' hold time evaluations: it was moderate for dms10 (k = 0.58) and fair for dms5 (k = 0.23) (Table 5). For the kms (k = 0.02), there was a slight agreement with the judges' evaluations.

DISCUSION

The use of objective, scientifically evaluated and practicable methods to assess the quality of gymnastics elements is of interest to athletes, coaches and scientists alike. The international gymnastics federations UEG and FIG as well as local organizing committees and media and spectators are also interested in a fair competition for all gymnasts.

Therefore, a dynamometric and a kinematic method were presented in this study as a way of providing support to judges when it comes to evaluating still ring hold times. It investigated how well the dynamometric and kinematic systems agreed with the judges' evaluations of hold times. The results of the study show that for the dynamometric measuring system (dms10), 71 of the 85 hold time evaluations matched those of the judges. However, since the percentage of agreement did not take random agreement into account, Cohen's Kappa was additionally calculated to indicate the agreement of the methods (McHugh, 2012). Based on the calculated k-value (0.58), the result is a 'moderate' agreement between the two measuring methods. By comparison, if one compares the hold time evaluations of individual judges to their majority evaluations, the result shows only a 54.1% mean percentage agreement and a 'low' to 'slight' k-value. The dynamometric system with a 10.0% range of body weight (dms10) was therefore shown to have the highest concordance with the majority of the judges - higher than individual judges themselves.

These results contrast with the experiences of Aarts and Pluk (2016b) who concluded that a fully automatic evaluation of hold time based on force measurements would not be accurate enough. A possible explanation for these different results could be the range of force values that were accepted as hold times, or the comparison with the judges' observations instead of the comparison with the Smart Rings system made by Aarts and Pluk (2016b). The dms5 method, which had a smaller range of force values (0.95 - 1.05 times of the body weight), resulted in a fair agreement with the judges' evaluations. These results support the view of Aarts and Pluk (2016b). Nevertheless, even with the dms5 method, a greater agreement with the judges' majority evaluation is observed when compared to the evaluations of individual judges. A weakness in the dms method must be explained. A constant force in the defined bw can be determined, if the gymnast performs at a constant velocity through the holding position. At constant velocity the acceleration is zero and thus the force is equal to the body mass (cf. $F=m \cdot a$). This weakness in the dms method could be the reason why dms10 evaluates fourteen elements without agreement with the judges, in most cases with a longer hold time. The kms method, which uses human pose estimation through trained neural networks to detect human key points in images and takes an algorithmic approach for calculating hold times, resulted only in a 38.8% agreement with the judges' evaluations. The k-value of 0.02 confirms that the agreements between the kms method and the judges' majority evaluations were only 'slight'. One reason for this poor correlation can be found in the deficiency of the trained neural network. Since the algorithm is highly dependent on the quality of the neural network output, improving the network would increase the quality of the method itself. Such an optimization could be realized through specific training of the neural network on sports related images or an optimized camera perspective of the input videos (Winter, 2019). Gymnastics elements on rings, especially positions like head down/ feet up, were not yet used for training the neural network. Another reason for the 'slight' agreement was that the kms method is based on only 50 Hz video with a resolution of 640 x 480 px. In further studies, video material in higher resolution and/or higher frame rate should be used.

Due to the high significance of hold times in competitions, it's important they are accurately examined during training.

Athletes can therefore be given important information about their performance level in the strength holding elements. For example, a short underrun of the hold time (< 0.5s) would probably be caused by an insufficiently pronounced sense of time, while large underruns (> 0.5s) are likely due to weaknesses in strength levels. There were many possibilities to determine the duration of holding elements with video methods in training. Unfortunately, these methods did not work automatically, making it difficult for coaches to use them as a stand-alone system. Therefore, to effectively check the hold time during a training session, a semi-automatic system should be used whereby both the coach and the athlete receive direct feedback on how long the corresponding elements have been held. The dms10 method meets this requirement and is therefore suited for training. For competition requirements however, the demonstrated 16.5% disagreement with the judges' majority evaluations means this method is considered unacceptable.

CONCLUSION

Reliable measurement systems can help to minimize errors made by judges when evaluating a gymnastics routine. The correct determination of hold time on still rings is one area that is prone to judges' errors . Technical measurement systems can also be used as immediate feedback systems in training. In this study, two measuring systems with the capability to determine hold time (two dynamometric system variants and a kinematic system) were examined by comparing them with judges' evaluations. The results support the use of the dynamometric method (dms10) as a reliable measurement system for the determination of hold times in training sessions. Due to the automated evaluation of hold time, this method was suitable as a feedback system in training. At this moment, the approach via a kinemetric method using a trained neuronal network for human pose estimation does not represent a satisfactory solution yet. However, special training of the neural network may possibly optimize this method and potentially make it an acceptable system too. The integration of measurement systems is an important approach for improving objective evaluations in gymnastics and can additionally improve the quality of information in this sport.

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KINEMATIC ANALYSIS OF DOUBLE BACK STRAIGHT SOMERSAULT AND DOUBLE BACK STRAIGHT SOMERSAULT WITH FULL TWIST ON RINGS

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Abstract

The rings are one of the six apparatuses in men's artistic gymnastics. The final element in a rings' routine is in many cases a crucial skill for scoring the routine. Most of the medallists on rings from the Olympic Games and World Championships for the last 20 years performed either the double back straight somersault or the double back straight somersault with a full twist. The purpose of this study was to conduct a kinematic analysis of double back straight somersault and double back straight somersault with a full twist on rings. The participants selected for this study were the world-class gymnasts Filip Yanev and Jordan Jovchev. The dismounts were recorded with a DV camera by following a standard method of kinematic analysis. During the execution phase, the ankle speed of Gymnast 1 reached 11.11 m/s and that of Gymnast 2 was 11.29 m/s, and the angular velocity increased substantially to 10.0 rad/s and 9.05 rad/s for Gymnast 1 and 2, respectively. The rotational impulse was sufficient for the successful execution of both dismounts. The actions of Gymnast 2 needed for the full twist, including a small arm asymmetry, began just before releasing the rings. The arching-to-piking action beneath the rings, as well as the powerful pull, combined with a sufficient swing of the legs, are crucial factors for the successful execution of the dismounts.

Keywords: *artistic gymnastics, still rings, dismount, somersault.*

INTRODUCTION

The high level of sports performance requires that gymnasts achieve optimal physical fitness and acquire an efficient technique of the gymnastics skills (elements). The sport of gymnastics is categorised as a group of conventional sports in which the sports achievement depends on the athlete's motor abilities, which are identified in the process of competition (Matveyev, 1981). Gymnasts perform gymnastic elements in accordance with particular motoric models, called ideal models of movement (Kolar et al., 2017), described in the Code of Points of the International Gymnastics Federation (FIG), and during competitions, gymnasts are scored by judges on the basis of this Code of Points.

One of the six apparatuses in men's artistic gymnastics is the still rings, which differ from the other apparatuses because of their design which requires static, eccentric, and concentric contractions during the execution of different skills

(Gorosito, 2013). In the beginning, the design of the rings was triangular with a straight part for the handgrip, and then it was changed to circular, which has been in use for more than 100 years. Although predominantly for recreational and school gymnastics, a new ergonomically-bent rings design was also proposed, which seems to preserve good kinaesthetic awareness of the handgrip (Pušnik, Čuk, & Hadžič, 2017). The rings can move freely in all directions, and this adds tremendous instability to the elements, which makes them more difficult and different from the technique for the other apparatuses (Sommer, 2008). The difficulty comes from the fact that gymnasts must pay attention to the movement of individual parts of their body, as well as to the deviation of the rings. In recent years, static elements have contributed to the development of the rings, and this requires significantly greater capabilities of upper body strength. The modern performance on the rings consists of swing elements, strength elements, and transitions between swing and strength elements or vice versa in approximately equal amounts (FIG, 2017).

Gymnastics provides almost limitless possibilities for biomechanical research, and consequently with its large number of elements, would require very many studies (Prassas, Kwon, & Sands, 2006). The elements performed on the gymnastics rings are difficult to analyse, and studies have been concentrated on strength elements (Bango, Sillero-Quintana, & Grande, 2013; Gorosito, 2013; Hübner & Schärer, 2015; Schärer & Hübner, 2016) or swing elements (Brewin, Yeadon, & Kerwin, 2000; Sprigings, Lanovaz, Watson, & Russell, 1998), but less research has been published on rings dismounts (Yeadon, 1994; Zou, Gong , Wang, & Wu, 2012). The final element in a rings' routine (the dismount) is in many cases a crucial skill for scoring the routine. Most of the 62 medallists on rings (75%) between 2000 and 2019 from the Olympic Games and World Championships performed either the double back straight somersault or the double back straight somersault with a full twist. Five Olympiads were held during this period: Sydney 2000, Athens 2004, Beijing 2008, London 2012, and Rio 2016 (FIG, 2019). The Olympic rings medallists performed either the double back straight somersault (26.7%, 4 gymnasts) or the double back straight somersault with a full twist (46.7%, 7 gymnasts) or with a double twist (13.3%, 2 gymnasts), Figure 1. Only 2 out of the 15 Olympic rings medallists for the last 5 Olympiads performed a different dismount.

Fifteen World Championships were also held during the last two decades: Ghent 2001, Debrecen 2002, Anaheim 2003, Melbourne 2005, Aarhus 2006, Stuttgart 2007, London 2009, Rotterdam 2010, Tokyo 2011, Antwerp 2013, Nanning 2014, Glasgow 2015, Montreal 2017, Doha 2018, and Stuttgart 2019 (FIG, 2019). Forty (85.1%) out of forty-seven World Championships rings medallists performed one of the following dismounts: double back straight somersault (21.3%, 10 gymnasts), double back straight somersault with a full twist (55.3%, 26 gymnasts), or with a double twist (8.5%, 4 gymnasts), Figure 1. The most common dismount performed by the Olympic and World Championships rings medallists for the last 20 years is the double back straight somersault with a full twist. Analysing such elements and providing methodological progressions for their attainment can greatly improve the training process, in addition to providing room for learning more difficult variations. Therefore, the purpose of this study was to conduct a kinematic analysis of double back straight somersault and double back straight somersault with a full twist on rings, concentrating on the descending and releasing part of the dismounts.

METHODS

The study was performed in accordance with the Declaration of Helsinki for Human Research (WMA, 2013), and informed consent was obtained from the participants.

The participants selected for this study were two world-class gymnasts: Filip Yanev (Gymnast 1, height 1.69 m; body mass 62 kg) and Jordan Jovchev (Gymnast 2, height 1.63 m; body mass 62 kg) from the Bulgarian National Team. The first gymnasts (National Champion on rings in 2010, silver medallists on vault at the 2002 European Championships, bronze medallist on vault in the 2004 World Cup Finals, and fifth place on vault at the 2004 Olympic Games), performed double back straight somersault, and the second gymnasts (World Champion on rings in 2001 and 2003, Olympic Vice-Champion in 2004, took part in six consecutive Olympic Games in 1992, 1996, 2000, 2004, 2008, and 2012), the most successful Bulgarian gymnast (FIG, 2020), performed double back straight somersault with a full twist on rings.

The dismounts on the rings were recorded in training conditions, in Sofia, Bulgaria, with a DV camera (50 Hz) by following a standard method of kinematic analysis and using Ariel Performance Analysis System (APAS). A rectangular frame with dimensions 5 x 3 m was used for space calibration, and 24 markers were added at each 1 m (x, y). The left foot, knee, hip, shoulder, and elbow joints; the hand, the top of the head, and a point on the frame of the rings were digitalised. Handstand was selected as the beginning and stable landing position as the end of the elements. The raw data were transformed into 2D with direct linear transformation and smoothed with a cut-off frequency of 7 Hz before being submitted for further analysis. The path (trajectory) of the main joints (shoulders, hips, and ankles) was determined. The linear velocity of the shoulder, hip, and ankle joints was calculated. The angular velocity (ω) of the body (ω of the line between CG of upper and CG of lower body parts) was calculated only on the transverse axis (axis of rotation of the somersaults). A graphics sequence for each dismount was produced, in which the selected poses (every 5th frame) were numbered sequentially. Additionally, the calculated parameters and variables of the two elements were compared to provide methodological recommendations for learning the double back straight somersault and progressing towards double back straight somersault with a full twist on the rings.

RESULTS

The dismounts for double back straight somersault (difficulty score of 0.3) and double back straight somersault with a full twist (difficulty score of 0.4) on rings are both from Group IV (Dismounts) as described in the Code of Points by FIG for the 2017-2020 Olympic cycle (FIG, 2017). Each fifth frame from the performances of both dismounts in training conditions is presented in Figure 2.

Both elements were divided into three phases (Preparatory Phase - I, Execution Phase - II, and Landing Phase – III). The linear velocity of the shoulder, hip, and ankle joints throughout both dismounts is shown in Figure 3.

In the first phase (descending phase), the actions of Gymnast 1 and Gymnast 2 are very similar. This phase represents a bail from a handstand similar to a backward longswing. In both cases, the preparatory phase starts from a handstand and continues to pose 5 / frame 25 (Figure 2). The gymnasts push the rings forward, which brings their bodies out of balance. Legs are leading the move with a slight pike position in the hips (pose 2 / frame 10, Figure 2) of Gymnast 1. Gymnast 2 performs the action in the same way, but without noticeable flexion in the hip joints. However, the second gymnast has a slight angle in the shoulder joints with his head out (pose 2 / frame 10, Figure 2). Arms are parallel and fully extended in the elbow joints, and the head remains slightly raised. Unlike Gymnast 1, the second gymnast opens the rings sideways, then narrows them back and pushes them forward. Thus, the bail continues to about 30 degrees above the horizontal line of the rings. After that, the gymnasts turn the rings slightly outward followed by bending their body backward when passing the level of the rings. The shoulders and chest become the leading parts of the movement, while the legs are significantly behind (pose 4 / frame 20, Fig. 2). The head remains slightly raised and both gymnasts continue in that position until their shoulders and chest reach hanging position, seeking to maximally extend the shoulder joints. This marks the end of the preparatory phase.

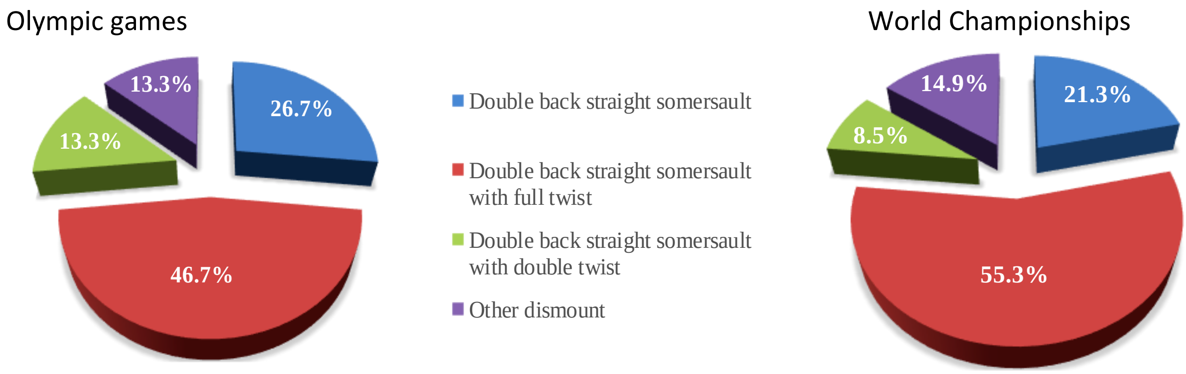


Figure 1. Percentage of the dismounts performed on rings by the medallists from Olympic Games and World Championships for the last 20 years (2000-2019).

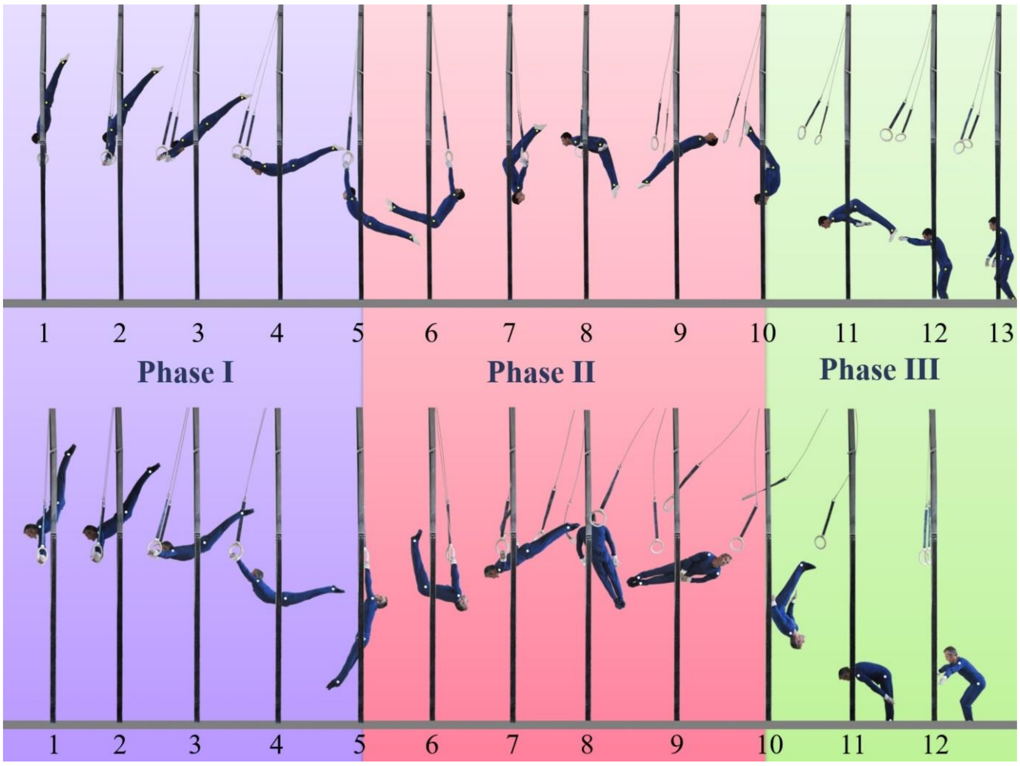
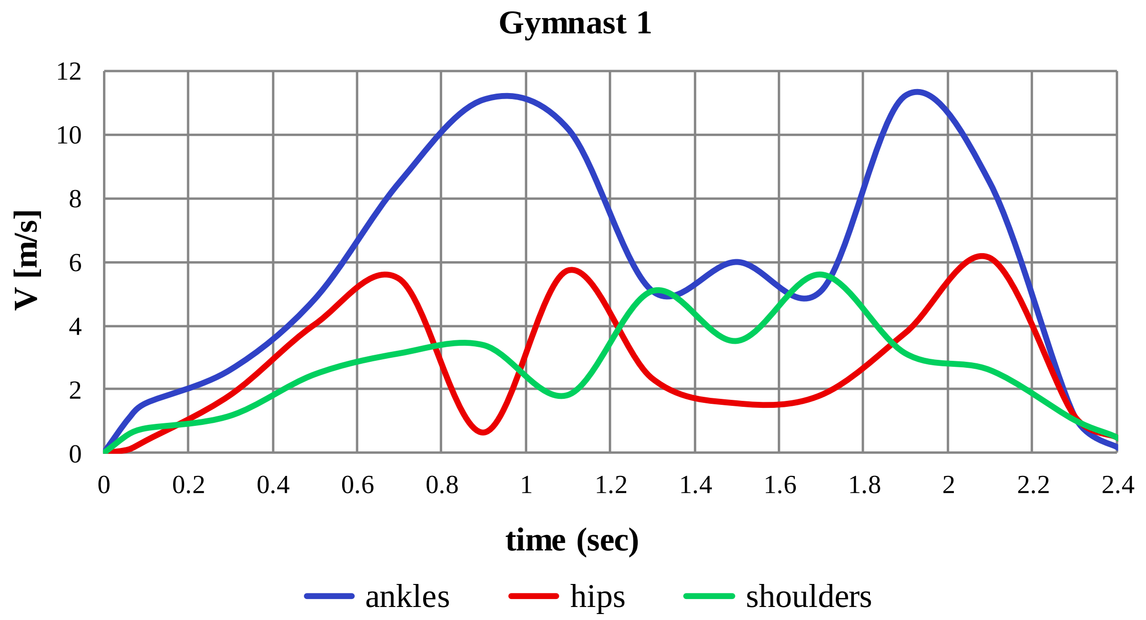


Figure 2. Graphics sequence of double back straight somersault (Gymnast 1) and double back straight somersault with a full twist (Gymnast 2) on rings.



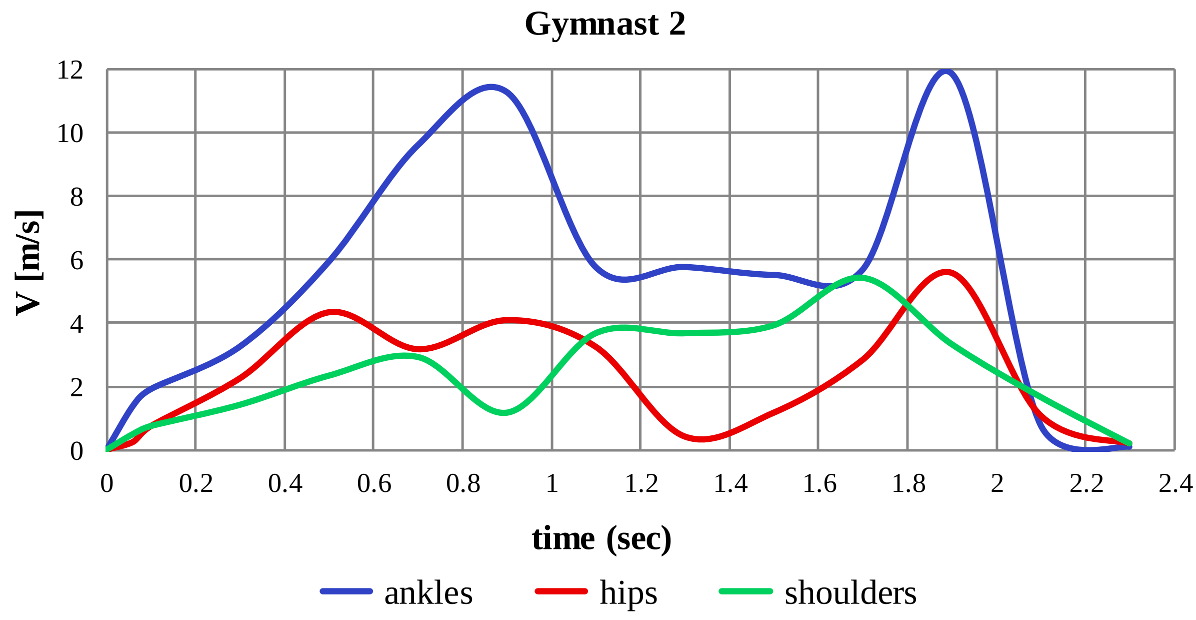


Figure 3. The linear velocity of the shoulder, hip, and ankle joints during double back straight somersault (Gymnast 1) and double back straight somersault with a full twist (Gymnast 2) on rings.

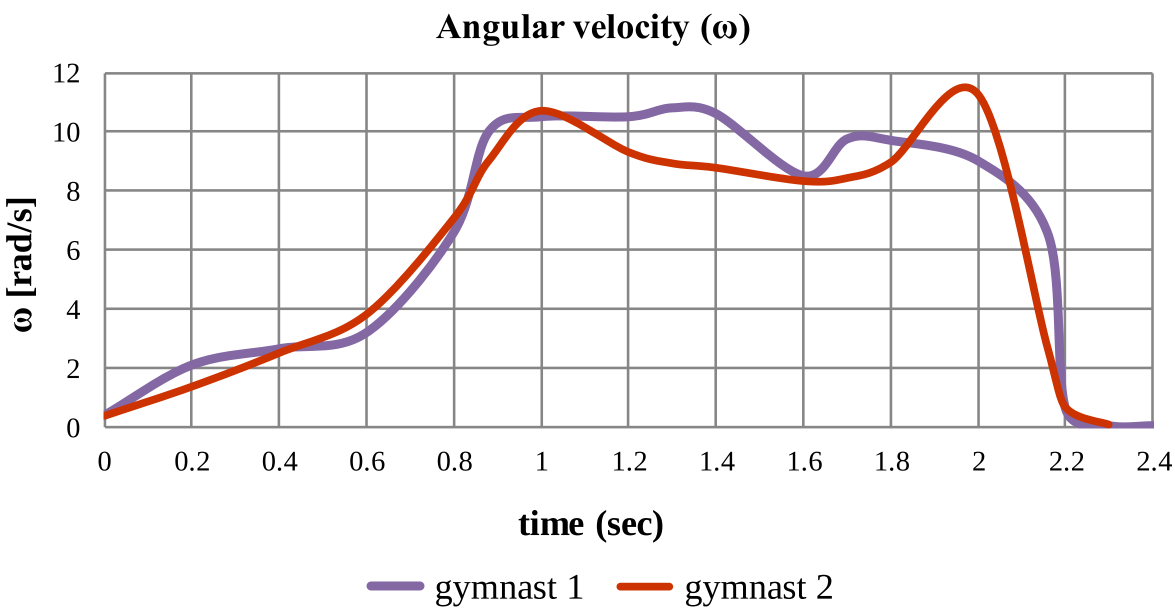


Figure 4. Angular velocity on the transverse axis (the axis of rotation of the somersaults) of double back straight somersault (Gymnast 1) and double back straight somersault with a full twist (Gymnast 2) on rings.

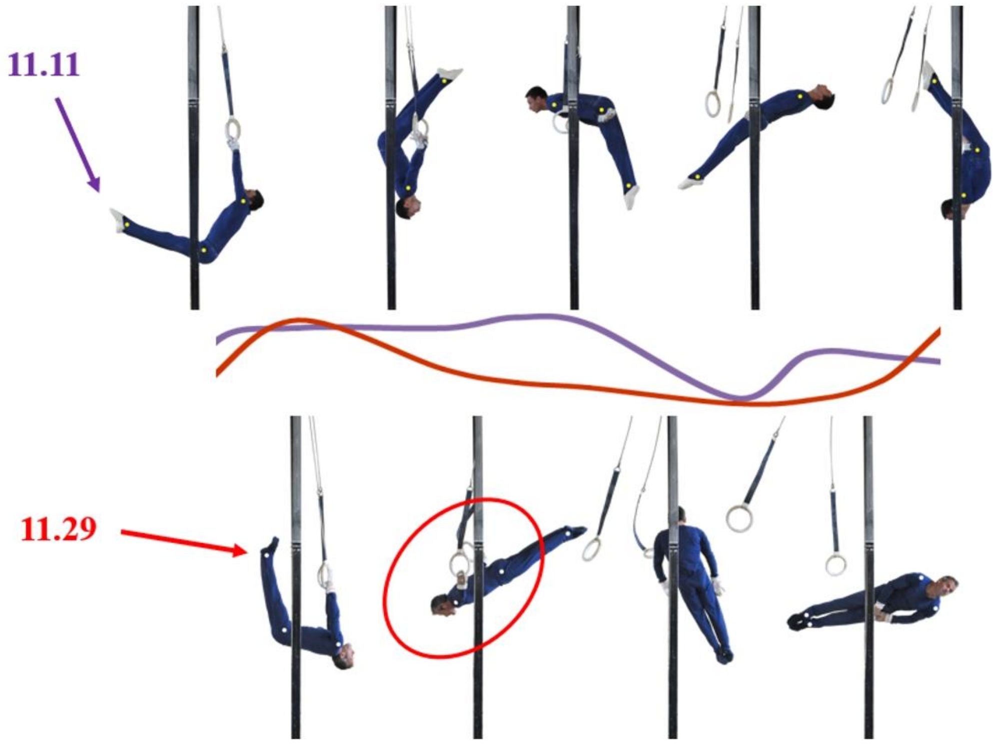


Figure 5. Actions during the execution phase of the dismounts, in addition to dynamics of angular velocity for Gymnast 1 (purple) and Gymnast 2 (red). The numbers show the peak linear ankle speed for Gymnast 1 (11.11 m/s) and Gymnast 2 (11.29 m/s).

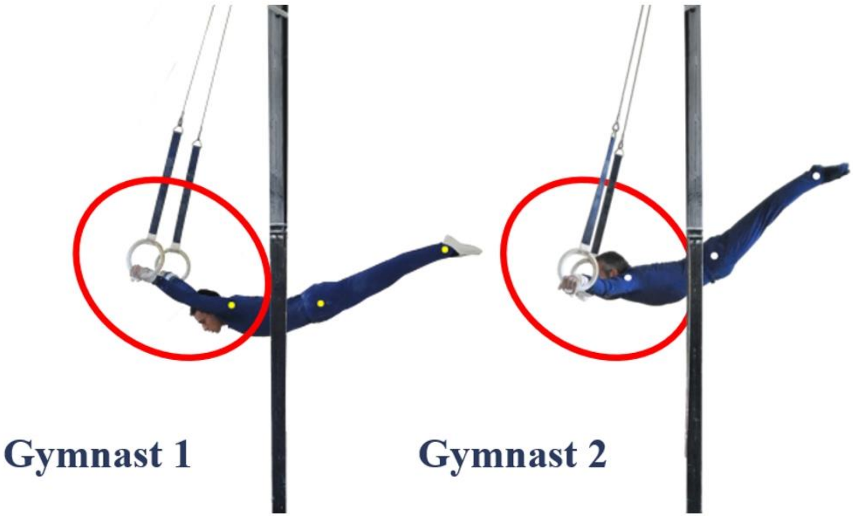


Figure 6. Differences in the technique of both gymnasts during the first phase of the dismount.

Figure 7. Yan Mingyong's technique during the first phase of the dismount (Zou et al., 2012).

The second phase (execution phase) begins with an active flexion move of the hips, in which the ankle speed of Gymnast 1 reaches 11.11 m/s and that of Gymnast 2 is 11.29 m/s (Figure 3 and Figure 5). At this point, the angular velocity increases its value substantially and reaches 10.0 rad/s and 9.05 rad/s for gymnasts 1 and 2, respectively (Figure 4). The legs perform a powerful swing forward and upward after passing the vertical beneath the rings. The body flexes in the hip joints nearly to 90 degrees and the shoulder angle is decreasing in both dismounts. This position is maintained until the knees are in line with the hand grasp of the gymnasts. After that, the arms are moving sideways (casting the rings) and Gymnast 1 releases the rings without changes in his body position (pose 7 / frame 35, Gymnast 1, Figure 2) while Gymnast 2 fully extends his body (pose 7 / frame 35, Gymnast 1, Figure 2). The different actions which are observed at the end of releasing the rings lead to some differences in the angular velocity of the gymnasts. The angular velocity of Gymnast 2 decreases slightly due to his fully extended position, while Gymnast 1 retains high values because of the configuration of his body, which remains slightly folded (Figure 4 and Figure 5).

The flexion action in the hip joints of Gymnast 1 after crossing the hanging position is more visible, which results in different speeds of the hip and shoulder joints of both gymnasts. A greater amplitude in the velocity curve at the hip joints is observed in Gymnast 1. The second gymnast releases the rings later, and as a result of a slight asymmetrical action of his arms at this moment (Figure 5), the body rotates around the longitudinal axis in the flight phase. Gymnast 1 remains flexed in his hips with his arms down and sideways until the end of the first somersault, whilst Gymnast 2 shows straight posture throughout the entire phase and begins twisting along the longitudinal axis immediately after releasing the rings. Both gymnasts have their centre of mass located at the height of the rings, which indicates the correct performance in pose 8 / frame 40 (for Gymnast 1) and pose 7 / frame 35 (for Gymnast 2) in Figure 2. Gymnast 1 unfolds his body with an active movement of his head and shoulders while his legs slow down, and these actions are visible especially after his shoulders pass between the ring cables in pose 9 / frame 45, Figure 2. The angular velocity decreases slightly due to the straightening of his body, which is followed by an overextension, and as a result, the speed of rotation increases slightly again (Figure 5). Thus, Gymnast 1 executes ¾ of the second somersault. Gymnast 2 executes the second somersault with a fully-stretched body, his head slightly turns towards the direction of the twist and his arms remain down. Thus, the gymnast performs a complete 360° twist and ¾ of the second somersault.

During the third phase (landing), the actions of both gymnasts are identical. In this phase of the two dismounts, the legs accelerate to reach the ground and ensure a stable landing. Due to the active flexion in the hips, the angular velocity of Gymnast 2 increases more than that of Gymnast 1 at the end of the flight phase. Both gymnasts show hips flexion in pose 11 / frame 55 for Gymnast 1 and pose 10 / frame 50 for Gymnast 2 (Figure 2), and land on the mat by amortization in the knee joints (pose 12 / frame 60 in both dismounts, Figure 2), so that the legs bend until the body is in a half-squat landing position.

DISCUSION

As it was shown in Figure 1, the most performed dismount by the Olympic and World rings medallists for the last 20 years is the double back straight somersault with a full twist, followed by the double back straight somersault. It is of particular interest for this study that in the period from 2000 to 2005, the Bulgarian gymnast Jordan Jovchev (Gymnast 2 in our study) was the only person among all medallists on rings at the World Championships and Olympic Games who performed the double back straight somersault with a full twist, while the other medallists performed its easier version without turning along the longitudinal axis of the body.

Artistic gymnasts have to overcome their weight, and in many cases their body mass is multiplied several times when tumbling and dismounting (Jemni, 2018). It has been shown that during performances of backward giant swing by elite artistic gymnasts, the peak combined tension measured in the ring cables reaches 9 bodyweights (Nissinen, 1983). This tension occurs as the gymnast passes through the bottom of the swing, which is also evident during dismounts. Research suggested that such tension increases the risk of ligament and muscular damage and causes increased pain in the shoulder joints (Caraffa et al., 1996). Subsequently, several studies concentrated on the minimising of the peak force at the shoulders during a backward longswing (Brewin et al., 2000; Yeadon & Brewin, 2003), providing simulation models for better control of the longswing and handstand (Yamada, Watanabe, Kiguchi, & Izumi, 2002), as well as an indirect video-based method for estimating combined cable tension throughout movements on rings (Brewin & Kerwin, 2003). In contrast with Gymnast 1, Gymnast 2 from our study opens his arms laterally in the first phase of the dismount, a technique, which in our opinion accumulates less energy (Figure 6). When arms are too open laterally at the descending phase, the distance between the centre of gravity and the point of the external force, which acts on the grip of the gymnast, is shorter. This is a prerequisite for the accumulation of less torque in relation to the center of gravity. However, based on our eye observations, as a result of more powerful leg swing, as well as his active hand action, a large rotational impulse is provided, which increases the speed and peak force, and it is sufficient for the flight phase. Brewin et al. demonstrated that the arching-to-piking aspect of the gymnasts' technique is the main way to limit the peak shoulder forces to a tolerable level, but the role of lateral arm movements during the descending may also minimise the shoulder force experienced by gymnasts (Brewin et al., 2000), and, therefore, reduce the risk of damage in ligaments and muscles. Additionally, when a gymnast descends from a handstand, the bending (arching) of the body must be within certain degrees, because excessive bending will reduce the effect of the bail (the descending). To a large extent, these body movements depend on the individual capabilities of the gymnast.

Zou et al. published a study on the kinematic characteristics of Yan Mingyong's dismount on rings in 2012 (Zou et al., 2012). The Chinese gymnast, who won the gold medal on rings at the 2009 World Gymnastics Championships in London (FIG, 2019), performed a double back straight somersault with a full twist for 2.48 sec, and that is similar to Gymnast 2 from our study, Jordan Jovchev (2.3 sec). Moreover, the technique photographed by Zou et al. (Figure 7), and applied by Yan Mingyong at the descending phase seems to be similar to the one used by Jordan Jovchev (Gymnast 2 from our study), in which the arms of the gymnasts move laterally in contrast with Gymnast 1, who keeps his arms parallel by pushing the rings forward.

Furthermore, similarly to the gymnasts from our study, the kinematic analysis of Yan Mingyong's dismount showed that his shoulder and hip angles decreased greatly when swinging beneath the rings. In addition to that, when releasing the rings, both Jordan Jovchev and Yan Mingyong keep a straight body with their hands close to the body in order to speed up the rotation needed for the twist around the longitudinal axes. In our study, it was observed that Jordan Jovchev uses asymmetrical arm action to initiate twists (Figure 5). When studying twisting techniques applied in dismount from rings, Yeadon concluded that even a small arm asymmetry was sufficient to establish the direction of twist, and observed that most gymnasts applied asymmetrical arm action to initiate twists (Yeadon, 1994).

Methodological progressions

We recommend that gymnasts learn certain elements of the double straight somersault, such as height and rotational movement, before performing rotations (twists) around the longitudinal axis. Both dismounts on the rings discussed in our study require a good technical foundation before one can start learning them. That includes the execution of a well-balanced handstand and backward longswing (giant swing) to, as well as through, a handstand. Gymnasts should also be able to execute double back somersaults in a tuck, pike and/or open tuck position with ease. Teaching progressions should follow basic pedagogic principles so that each progressive step includes a movement structure similar to the desired element (Kolar, Kolar, & Stuhec, 2002). Gymnasts have to perform a stable handstand with a minimum swing of the rings at the start of the execution of the dismounts. The methodological progressions can follow these steps:

- Double back pike somersault with emphasis on the moment of the release of the rings (the position of the body in relation to the rings);
- Double back straight somersault into a foam-filled dismount pit;
- Double back straight somersault onto soft mats (at ground level) in a dismount pit;
- Double back straight somersault onto soft mats (10 cm above the ground level) in a dismount pit;
- Double back straight somersault onto soft mats (20 cm above the ground level) in a dismount pit;
- Double back straight somersault with emphasis on the body shape in real conditions;
- Double back straight somersault with half twist into a dismount pit;
- Double back straight somersault with a full twist into a dismount pit;
- Double back straight somersault with a full twist onto soft mats (at ground level) in a dismount pit;
- Double back straight somersault with a full twist onto soft mats (10 cm above the ground level) in a dismount pit;
- Double back straight somersault with a full twist onto soft mats (20 cm above the ground level) in a dismount pit;
- Double back straight somersault with a full twist in real conditions.

The amplitude of the arching-to-piking action, as well as the powerful pull, combined with a strong swing of the legs, are crucial factors for the successful performance of the elements discussed in our study. In airborne rotational elements, including rings dismounts, the gymnast rotates around his centre of mass, so it is particularly important to control the somersaulting or twisting angular momentum. Prassas et al. stress that during the flight part, the total angular momentum should remain constant, so that altering the speed of rotation is possible by changing body configuration (Prassas et al., 2006). An insufficient swing beneath the rings in which the gymnast's centre of mass is below the level of the rings will lead to an incomplete rotation of double straight somersaults. The actions applied for the full twist around the longitudinal axis by Gymnast 2 in our study begin just before releasing the rings.

CONCLUSION

Both gymnasts in this study completed successfully their dismount on the rings. The rotational impulse was sufficient for the successful execution of both, the double back straight somersault and double back straight somersault with a full twist. The sufficient arching-to-piking action beneath the rings, as well as the powerful pull of the rings, are crucial factors for the successful execution of the dismounts. The twist around the longitudinal axes is initiated by a slight asymmetrical action of the gymnast's arms.

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TAKE-OFF HIP EXTENSION ANGLE INFLUENCE ON THE TUCKED BACK SOMERSAULT PERFORMANCE

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Abstract
Back somersault is a basic element of gymnastics; its performance is strongly influenced by the take-off phase. The present work aimed to study how hip extension in the take-off of the tucked back somersault influences the velocity of rotation and the height of the somersault. To this end, we recorded a total of 60 somersaults by 4 gymnasts (i.e., 15 somersaults each). There were three groups of somersaults based on the instructions that were given to the gymnasts: no specific instruction, somersault as high as possible and rotate as fast as possible. The records were then analyzed in order to quantify the following variables: maximal height of the mass center and maximal body angular velocity during somersault, the hip angle and the knee angle at the take-off. Gymnasts seemed to be inclined to bend their knees rather than extend their hips in order to carry out the instruction.

Keywords: *hip angle, angular velocity, mass trajectory center, back somersault.*

INTRODUCTION

One of the basic elements that gymnasts have to learn early in their career is the back somersault. The mastery of this exercise is fundamental for the gymnast to acquire the more complex skills that are needed for appropriate performance on all apparatuses, as claimed by Mkaouer, Jemni, Amara, Chaabène and Tabka (2013).

The quality of performance of back somersaults can be evaluated by two variables: the vertical displacement of the center of mass (COM) and the body angular velocity in the transverse axis (Mkaouer, Jemni, Amara, Chaabène & Tabka, 2012). Adequate equilibrium of height of the COM and rotational velocity signify that the gymnast is more likely to learn complex exercises. A good mastery of these two variables can also minimize the possibility of injuries and ensure gymnast's safety.

The take-off phase of somersaults is crucial for the adequate performance of the flight phase according to Mkaouer et al. (2013), see Figure 1. The ground reaction forces and positions of joints at the take-off have been analyzed in various studies. For example, Sadowski, Boloban, Wiśniowski, Mastalerz and Niźnikowski (2005) studied the round-off tucked back somersault in tumbling. According to them, favorable joint angles at the take- off are: shank-thigh 180°, thigh-trunk 180°, trunk-shoulder 152° and shoulder-forearm 165°. Furthermore, in a study on a double layout in tumbling, Sadowski, Boloban, Mastalerz and Niznikowski

(2009) reported that in the preparatory phase of somersaults, typical errors include: flexed knee joints, flexed hip joints, or extreme inclination of the gymnast in respect to the vertical line. Additionally, according to Hraski (2002), the average angular momentum in the flight phase was greater with higher horizontal and lower vertical velocity at the take-off. King and Yeadon (2004) indicate that, during the take-off phase, the gymnast is able to change the linear and the angular momenta of the somersault by applying muscular torques. Furthermore, they demonstrate that the main error gymnasts make is the bad timing of muscle contraction at the take-off. Mikl (2018) investigated the torques that should be applied to joints in order to maintain a determinate posture in somersaults, but her work is more focused on the flight phase.

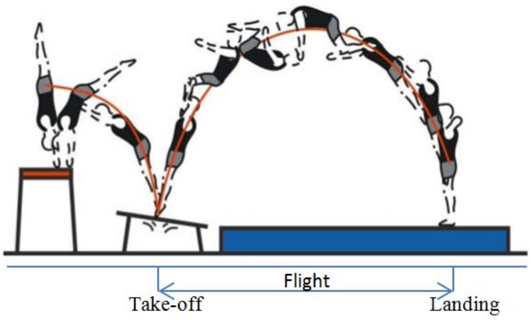

Figure 1. Phases of back somersault.

The hip angle is mentioned in various publications, and Mkaouer et al. (2012) note that this articulation seems to have a great importance during the back somersault, since they found a highly significant correlation between the vertical peak power and the angle of the hip joint. However, to our knowledge, no previous work has focused exclusively on the effect that the hip angle at the take-off has on specific characteristics of the back somersault. Consequently, the aim of the present work is to study how the hip angle at the take-off influences the maximal height of somersault (MHOS) and the maximal body angular velocity (MBAV) in the back-tuck somersault.

METHODS

Four female gymnasts were recruited for our study. Their characteristics were: IMC 19±1.63 kg/m^2, height 1.55 ± 0.04m, age 13.50 ± 0.18 years, weight 46 kg ± 1.97 kg, more than three years of experience in level 2 performance according to the FBG (Bolivian Federation of Gymnastics) standards. All gymnasts and their parents were informed in writing and orally and all parents signed a consent form. The experimental protocol was carried out in accordance with the Declaration of Helsinki (1964) and was approved by the Ethical Committee.

The following material was used for the exercises: a vault regulated at 1.35m; two mats of 0.30x2.00x1.50m; a 0.05x1.90x1.20m reception mat, a minitrampoline with an inclination of 7°. The exercises were carried out in front of a white background. Minitrampoline was chosen to help gymnasts change their usual technique without the risk of injury.

Each gymnast wore black clothes to contrast with the white background. The model utilized was “Havanan full body left side”. Therefore, each athlete had ten markers on her left side that were situated at the toes, at the lateral malleolus, at the lateral femoral condyle, at the great trochanter, at the acromion, at the medial epicondyle, at the ulna styloid process, at the chin and at the top of the head.

Each gymnast’s movements during the exercises were recorded with a Samsung android camera (S8) with 240 fps and 1280x1020 pixels resolution placed at 4.30 meters apart from the data acquisition region. We recorded and analyzed 15 somersaults (5x3 execution modes) for each gymnast.

The study started with ten minutes of a general warm-up. Next, the gymnasts had five minutes of a special warm-up to try the material that was used for our trial. Immediately after the last warm-up, the trial started.

The exercises that were analyzed began with a handstand on the vault table. Then, the gymnasts hit the minitrampoline and started to perform the back somersault as in Figure 1. In order to study the movement, the data starting at the take-off of the somersault and finishing at the reception mat was analyzed.

The somersaults carried out by the gymnasts were classified in three groups (5 somersaults per group), depending on the given instruction type. For the first group, no special instruction for the exercise was given (NI). For the second group, gymnasts were told to perform somersaults as high as possible (HS). Finally, for the third group, gymnasts were instructed to do back somersaults as fast as possible (FR). Each gymnast had five tries for each group of exercises. They had an average of 15 seconds to recover between tries and two minutes rest between the groups of different instructions. No feedback was given to the gymnasts about their somersaults.

Once the trial was finished, the field of view of the camera was calibrated. Two polystyrene sheets were located in the place where the gymnasts had performed the exercises. Each sheet was 50x100cm in size and was marked with 25x25cm squares, making a set of 45 calibration points.

All videos were analyzed with the software SkillSpector 1.3.2® (Mkaouer et al., 2013). From the data generated by this software, we used the hip angle, the knee angle, the MHOS and the MBAV. The angle of the knee and the hip at the take-off was measured in the first frame in which the toes lost contact with the minitrampoline.

Initially, the normal distribution of the data was tested by the Shapiro-Wilk test. However, since many data sets did not have normal distribution, mostly non-parametric methods were employed. As the four gymnasts carried out fifteen somersaults (five per modality), we first applied the Friedman K related samples test and then the Wilcoxon test for pairwise comparisons. Spearman Correlation Coefficient was applied to evaluate the correlation between variables. Finally, a polynomial fit was conducted with the hip angle as the regressor and MHOS and MBAV as the dependent variables: these three variables had normal distribution. The effect size was calculated in these three tests. The software used was: Tibco® statistica 13.0, ibm spss® statistics 26 and g*power 3.1®. The results were considered significant at 0.05.

RESULTS

As shown in Table 1, the instructions given to the gymnasts gave rise to statistically significant differences in the knee angle at the take-off, MHOS and MBAV, with p=0.000, and respectively p=0.008 and p=0.047. The effect size of Friedman test was w=0.574. Only the hip angle at the take-off did not vary significantly with the given instruction. Post-hoc Wilcoxon analysis with single-rank test was conducted for each variable with Bonferroni correction applied, resulting in a significance level set at p<0.017 and the effect size was w=0.440. The results of this post-hoc analysis are shown in Table 1 and the conclusion was that there was a statistically significant difference in knee flexion when the instruction “rotate as fast as possible” was given as compared to “no instruction” or “somersault as high as possible” (p=0.001 and p=0.000 respectively). For the hip angle at the take-off, none of the pairwise comparisons between the different instructions showed significant differences. For MHOS, a significant reduction in height was observed for the instruction “rotate as fast as possible” against “no instruction” (p=0.003). In MBAV, there was a significant increase of angular velocity for “rotate as fast as possible” as compared to “somersault as high as possible”.

The Spearman correlation coefficients obtained when all data from the three modalities were pooled (Table 2) had an effect size of q=0.616. This data showed a negative correlation between the hip angle and the knee angle at the take-off (r=-0.57). The knee angle at the take-off was positively correlated to MHOS (r=0.32); when the knees were more extended, the somersaults were higher. Finally, MHOS was negatively correlated to MBAV (r=-0.28) implying that higher somersaults can be detrimental to angular velocity. A significant polynomial regression was obtained for MHOS and MBAV with the hip angle (Table 2).

Polynomial regressions by the hip angle had significances for MHOS and MBAV (p=0.003; R^2=0.18 and p=0.02; R^2=0.13). Figures 2 and 3 highlight the relationships between the hip angle at the take-off and MHOS and between the hip angle at the take-off and MBAV in general data.

Table 1
Comparative Statistics of three modalities "NI" no instruction, "HS" somersault as high as possible and "FR" somersault as fast as possible.

Friedman K related test

Variables	χ^2	Sig.
Knee angle at the take-off	21.700	0.000**
Hip angle at the take-off	5.700	0.058
MHOS	9.700	0.008**
MBAV	6.100	0.047*

Wilcoxon single-rank test

	"NI" vs	"HS"	"NI" vs	"FR"	"HS" vs	"FR"
Variables	Z	Sig	Z	Sig	Z	Sig
Knee angle at the take-off	-1.381	0.167	-3.397	0.001**	-3.771	0.000**
Hip angle at the take-off	-1.083	0.279	-2.203	0.028*	-1.643	0.100
MHOS	-0.859	0.391	-2.949	0.003**	-2.128	0.330
MBAV	-0.542	0.588	-1.867	0.062	-2.389	0,017*

MHOS: Maximal height of somersault, MBAV: Maximal body angular velocity. (*) significant at p<0.05 and (**) significant at p<0.01

Table 2
Spearman correlation and Polynomial regressions.

	Variables	MHOS	MBAV
Spearman C.	Knee angle at the take-off	0.321*	0.212
	Hip angle at the take-off	0.109	-0.213
		R	p value
Polynomial Reg.	MHOS vs Hip angle at the take-off	0.425*	0.003*
	MBAV vs Hip angle at the take-off	0.355*	0.021*

MHOS: Maximal height of somersault, MBAV: Maximal body angular velocity. (*) significant at p< 0.05

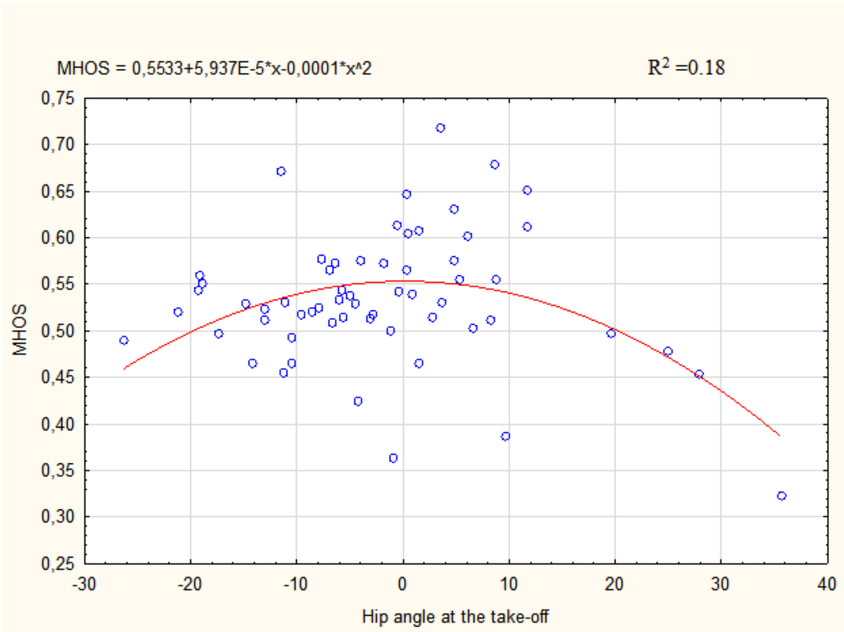

Figure 2. Polynomial regressions by the hip angle had significances for MHOS.

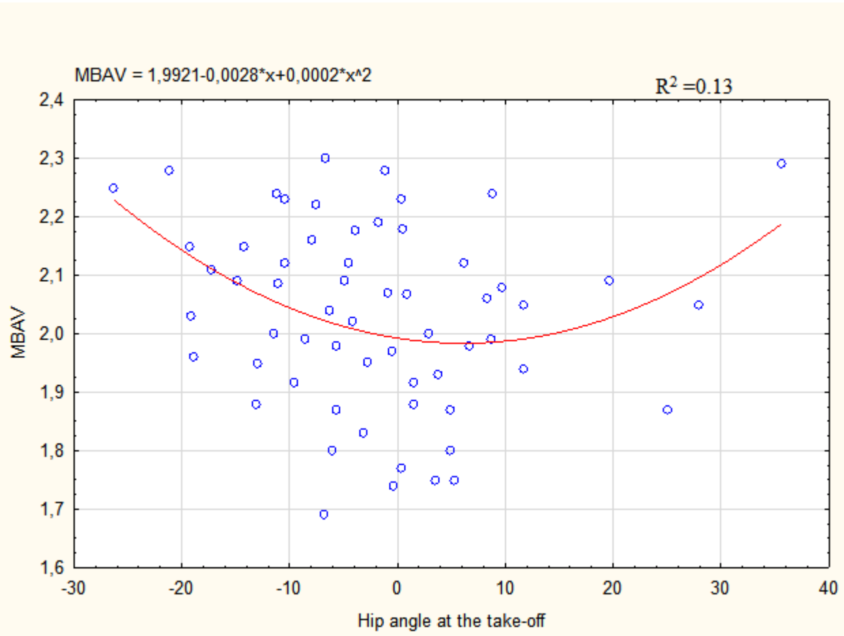

Figure 3. Polynomial regressions by the hip angle had significances for MBAV.

DISCUSSION

The purpose of this study was to find a correlation between the hip angle and MHOS and/or the hip angle and MBAV. We used three different instructions to increase the variability of the hip angle. However, the given instructions influenced the knee angle instead of affecting the hip angle. One reason for this result might be in that the gymnasts adopted less favorable biomechanics because the instruction gave rise to an "unplanned" motion, as described by Brown, Brughelli and Hume (2014). Gymnasts were instructed to perform somersaults in a way that was different from what they normally did and, since they could not correctly plan the somersault, the neuromuscular contraction was not the expected one. Additionally, Asseman, Caron and Crémieux (2008) indicate that previous training for different skills advantages gymnasts only if they perform the exercises in their usual training conditions.

Gymnasts bent more their knees when they were instructed to "rotate as fast as possible" in comparison to when "no instruction" or "somersault as high as possible". At the same time, when gymnasts were told to "rotate as fast as possible", the MHOS was significantly lower and the MBAV was significantly higher. Flexed knees seem to cause a decrease in the somersault height and an increase in angular velocity. Moreover, MHOS was significantly correlated to the knee angle for pooled data. Flexed knees are considered one of the main errors in the preparation for the somersault (Sadowski et al., 2005). It is therefore not surprising to lose height when these errors appear. Knee flexion means a relaxed extensor musculature of the lower limbs and absorption of forces exerted by the trampoline at this level according to Caine, Russel and Lim (2013). The absorption of forces could cause a decrease in MHOS. At the same time, knee flexion produces an important inclination of the body. In such cases, the take-off velocity vector does not pass through the COM and by then the somersault height decreases (Król, Małgorzata, Sobota & Nowak, 2016). On the other hand, this inclination carries the center of mass backward, which causes more lever arm (the distance in the horizontal axis between the center of mass and the point of contact between the feet and the trampoline) and consequently more torque as per Król et al. (2016). We recommend that trainers monitor the gymnast to avoid body inclination.

The hip angle did not have significant linear correlations with MHOS or MBAV. However, a relatively weak but significant polynomial regression between MHOS or MBAV and the hip angle was obtained (Figure 2 and 3). The hip angle influenced indirectly MHOS and MBAV. One trend that was observed in our pooled data was the correlation between the hip and the knee angles at the take-off (Table 2). Therefore, if the knee angle influenced MHOS and MBAV, the hip angle also had an indirect effect. This trend can be explained by the fact that a kinematic closed chain is formed in the lower limbs by the contact between the feet and the trampoline (Donskoi & Zatsiorski, 1988).

Finally, the negative correlation obtained between MHOS and MBAV (r=-0.28) is in agreement with Hraski (2002) who reported that the average angular momentum in the flight phase was greater with greater horizontal velocity and lower vertical velocity at the take-off.

CONCLUSIONS

Our gymnasts tended to bend their knees rather than extend their hips in order to carry out the given instructions. Knee flexion is considered a technical error and causes a decrease in the height of somersault. However, knee flexion favored a higher angular velocity. The hip angle and the knee angle were connected in the same closed kinematic chain. Therefore, the hip angle indirectly influenced the height and the angular velocity. We recommend further studies of the effect of the hip angle at the take-off in somersaults. In such studies, gymnasts should be given instructions that are more specific to this angle.

We recommend that coaches carefully monitor the position of the gymnast's knees and avoid backward body inclinations that are detrimental to the technique. Also, coaches should consider that non-specific instructions can lead to knee flexion due to "unplanned" movements.

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ECCENTRIC PEAK TORQUE OF THE KNEE FLEXORS AND EXTENSORS RELATES TO BACKWARD SOMERSAULT HEIGHT IN FEMALE JUNIOR ARTISTIC GYMNASTS

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Abstract

Artistic gymnastics consist of a high amount of jumping actions with rotations around one or more axes. To achieve an optimal flight height to perform the desired number of rotations, the movement pattern and the floor characteristics have to be concerted optimally. To account for the required leg stiffness to utilize the floor's elasticity, the leg musculature has to generate high forces during the ground contact in an eccentric manner. Thus, eccentric strength of the knee musculature might play an important role for somersault height and run-up velocity in the vault. We investigated the correlation of eccentric peak torque of the knee flexors and extensors and vertical jumping height with backward somersault height and sprinting velocity in female junior artistic gymnasts. The results showed medium to strong, significant correlations between eccentric peak torque and backward somersault height as well as sprinting velocity. Vertical jumping height revealed significant correlations with somersault height and sprinting velocity. Eccentric strength seems to play an important role in joint stiffness regulation to utilize the elastic recoil of gymnastic floors and springboards. In the sprint approaching the vault, the same mechanism seems apparent and is in accordance with findings regarding the sprint in different sports.

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Keywords: *artistic gymnastics, velocity, strength.*

INTRODUCTION

Artistic gymnastics is characterized by a high amount of jumping actions with rotations around one or more axes of the body. During the last decades a great increase in difficulty of the performed elements can be observed (Brüggemann, 2005). Potop (2014) points out that according to the Code of Points provisions, high difficulty and complexity of the acrobatic connections in the floor apparatus are necessary. Even if the amount of forward jumping is largely increasing today, these elements are often performed using backward take-offs preceded by a linear run-up and the combination of a round-off followed by a flic-flac (Geiblinger, Morrison & McLaughlin, 1995; King & Yeadon, 2003) and culminate in a variation of the backward somersault that enables greater flight height and angular momentum than can be achieved by performing forward or sideward somersaults (Hraski, 2002). King & Yeadon (2003) identify the vertical velocity and angular momentum as critical factors for successful performance since the product of these factors determines the amount of rotation that can be achieved. Accordingly, the results of Mkaouer, Jemni, Amara, Chaabène & Tabka (2013) indicate that a greater elevation of the centre of mass during the flight phase allows for better performance of the backward somersault.

To achieve an optimal flight height to account for enough time to perform the desired number of rotations, the movement pattern and the floor characteristics have to be concerted optimally (King & Yeardon, 2003; Sands et al., 2013). By technical evolution, the elastic behaviour of the gymnastics spring-floor has been increased and optimized through decades which requires a modification of the stiffness characteristics of the ankle and knee joint (Sands et al., 2013). Accordingly, Arampatzis, Brüggemann & Morey-Klapsing (2000) observed a positive influence of higher leg stiffness on the amount of energy that is stored in the floor surface and reutilized during the propulsive phase of the jump, while Hansen, Hvid, Aagaard & Jensen (2019) report correlations of sprint performance and rate of force development with tumbling performance in TeamGym athletes. Nevertheless, it has to be noted that TeamGym athletes perform on a tumbling track as well as on a regular gymnastics floor. To account for the desired leg stiffness to utilize the elasticity of the floor, the leg musculature has to produce correspondent high forces during the ground contact in an eccentric manner.

Comparable mechanisms can be observed when regarding the vault apparatus in artistic gymnastics. Kalinski, Atikovic, Jelaska & Milic (2016) analysed the performance in the vault apparatus of elite female gymnasts between 2008 and 2015 and concluded that a development towards more and more difficult vaults can be observed. In this apparatus as well, a high leg stiffness is aimed at to utilize the elastic properties of the spring board and to divert the horizontal movement velocity of the run-up into vertical take-off velocity (Hansen et al., 2019).

Since several studies have shown the importance of eccentric activation of the hamstrings in sprinting (Sugiura, Saito, Sakuraba, Sakuma & Suzuki, 2008; Yu et al., 2008) and eccentric training for this muscle group produced significant improvements in sprinting velocity (Ishøi et al., 2018), eccentric hamstring strength should be connected to run-up velocity for the vault.

Therefore, we hypothesize that eccentric strength of the knee flexors and extensors plays an important role for backward somersault height and run-up velocity in the vault in artistic gymnastics.

METHODS

The aim of this study was to investigate whether eccentric peak torque of the knee flexors and extensors relate to backward somersault height and run-up velocity for the vault in junior artistic gymnasts. 18 female national level junior artistic gymnasts participated in this investigation. Eccentric peak torque for knee flexors and extensors were measured at two movement velocities. Backward somersault height and sprint velocity between 18 and 20 meters were determined on a gymnastics running surface during vault training and on an indoor track, respectively. Additionally, jump-and-reach performance was assessed. All participants completed a familiarization session to each of the testing procedures one week before the actual tests were conducted.

18 female national level junior artistic gymnasts participated in this investigation. The mean age was 12.70 ± 2.00 years, their height was 1.483 ± 0.0958 m and weight 41.50 ± 9.68 kg. All subjects and their parents or legal guardians were informed of the experimental risks involved with the research and provided informed written consent. The research design was approved

by the institutional review board. The study was carried out with respect to the use of human subjects and according to the Declaration of Helsinki.

The participants performed the combination round off – flick-flac – backward somersault on a gymnastics competition spring floor (Spieth Gymnastics GmbH, Altbach, Germany). The landing was performed on an elevation of 1 m consisting of mats to provoke maximum height in the somersault. This was done because it is a common training method for somersaults executed with a focus on height. The execution of this test is displayed in figure 1.

The height was measured as maximum difference of the greater trochanter to the floor. For this purpose, a reflective marker with a diameter of 0.5cm was placed on the right greater trochanter and was tracked in the sagittal plane with 100Hz using a Sony FDR-AX700 camera (Sony Corporation, Tokio, Japan).

The videos were analysed using the software SIMI MOTION (Simi Reality Motion Systems GmbH, Unterschleißheim, Germany).

Eccentric leg strength was determined using the ISOMED2000 isokinetic device (D&R Ferstl GmbH, Hemau, Germany) with a measuring rate of 200Hz. Peak torque measurements were performed in a prone position for the knee flexors and a supine position for knee extensors with 30°/s and 150°/s according to the protocol of Alt, Knicker & Strüder (2020). After individual warm-up the participants performed 5 maximal eccentric contractions per velocity and muscle group. The return into starting position always occurred passively at 120◦/s. Both absolute peak torque and peak torque relative to bodyweight were analysed.

Alt, Knicker & Strüder (2014) report a test-retest-reliability of ICC = 0.829-0.886 for these eccentric test modes with the used device.

The sprint test was performed - after an individual warm up - over a distance of 30 meters on an indoor track. 5 attempts were measured with a rest period of 5 minutes between attempts. Velocity in the segment between 18 and 20 meters (zero referring to the starting point) was detected with 100Hz using a LAVEG laser diode system (model LEM-300W) by JENOPTIK Technologie GmbH (Jena, Germany). This segment was chosen because the official competition rules allow a maximum length of 25 meters for the run-up in the vault and a 2 meter-segment from 7 to 5 meters in front of the table is generally used to measure the running velocity of handspring vaults (Naundorf, Brehmer, Knoll, Bronst & Wagner, 2008).

The start was executed in an upright standing position. No command was given and every tested individual started the test at an individually chosen point of time. A test-retest reliability of $r = 0.99$ ($p < 0.05$) is indicated for this test (Türk-Noack & Schmalz, 1994).

The detection of the jump-and-reach height was carried out using a wooden wall and magnesia on the participants' right hand to mark the achieved height. The difference to the previous marked reaching height in a standing position was then measured using measuring tape.

Participants were shown how to perform a maximal vertical countermovement jump. They were instructed to jump straight up and touch the highest point on the wall they could reach with the tips of the fingers of their right hand. Participants were allowed to practice until they felt comfortable with the equipment and technique. Each participant carried out 5 trials with an inter-jump rest period of at least 30 seconds. The wall was wiped clean from the magnesia marks of the previous jump before each trial.

The data was analysed using SPSS 11.5 (SPSS, Inc., Chicago, IL, USA). Kolmogorov-Smirnov test was used to check for normal distribution. As this test revealed no significant results, Pearson's product-moment correlation was used to determine the strength of the relationships. The level of significance for all tests was set a priori to $p \leq 0.05$.

According to Keiner, Sander, Wirth, Hartmann & Yaghobi (2014), the correlation coefficient was classified as follows: 0 = no correlation, $0 < | r | < 0.2$ = very weak correlation, $0.2 < | r | < 0.4$ = weak correlation, $0.4 < | r | < 0.6$ = medium correlation, $0.6 < | r | < 0.8$ = strong correlation, $0.8 < | r | < 1.0$ = very strong correlation, $| r | = 1$ = perfect correlation.

RESULTS

The descriptive data are displayed in table 1. The backward somersault test showed a mean height of 1.35 ± 0.16 m. The mean run-up velocity for the vault was 7.66 ± 0.35 m/s. The eccentric strength tests show greater peak torque values for 150 °/s compared to 30 °/s.

Figure 1. Execution of the somersault test.

Table 1
Descriptive data of the performed Tests.

	Mean	Max	Min	SD
BSH [m]	1.35	1.70	1.09	0.16
v 18-20 [m/s]	7.04	7.66	6.56	0.35
J&R [cm]	47.11	59.00	35.00	5.50
Quad 30 [Nm]	107.33	211.19	62.11	38.82
Quad 150 [Nm]	108.83	194.50	74.41	31.19
Ham 30 [Nm]	42.14	86.11	22.23	18.09
Ham 150 [Nm]	44.33	79.11	28.90	13.72
Quad 30 R [Nm/kg]	2.58	3.94	1.69	0.63
Quad 150 R [Nm/kg]	2.66	4.28	1.81	0.64
Ham 30 R [Nm/kg]	0.98	1.46	0.59	0.21
Ham 150 R [Nm/kg]	1.06	1.41	0.91	0.14

BSH = Backward Somersault Height; v 18-20 = sprint velocity between 18 and 20 meters; J&R = Jump-and-reach height; Quad = Quadriceps; Ham = Hamstrings; R = relative to bodyweight

Table 2
Correlation coefficients of the absolute peak torque values and jump-and-reach height with backward somersault height and sprint velocity between 18 and 20 meters.

	J&R	*Quad 30*	*Quad 150*	*Ham 30*	*Ham 150*
BSH	0.696**	0.709**	0.696**	0.840**	0.814**
v 18-20	0.594**	0.345	0.448*	0.474*	0.511*
* = p < 0.05; ** = p < 0.01					

Table 3
Correlation coefficients of the relative peak torque values with backward somersault height and sprint velocity between 18 and 20 meters.

	Quad 30 R	*Quad 150 R*	*Ham 30 R*	*Ham 150 R*
BSH	0.241	0.021	0.748**	0.437*
v 18-20	0.027	0.000	0.342	0.258
* = p < 0.05; ** = p < 0.01				

The calculation of the correlation coefficients of the backward somersault height with the Jump-and-reach height and the absolute eccentric strength parameters revealed significant, medium to strong correlations ($p < 0.01$) (Table 2). Interestingly the greatest correlations were observed for the eccentric peak torque of the knee flexors.

The correlations regarding the sprint velocity with the eccentric strength tests and jump-and-reach height revealed medium significant correlations ($p < 0.05$) for the eccentric peak torque of the hamstrings and the eccentric peak torque of the quadriceps while eccentric peak torque at 30°/s did not relate significantly to the sprint velocity. The greatest significant coefficient ($p < 0.01$) could be observed for the achieved height in the jump-and-reach test.

Interestingly, when calculating the peak torque values relative to bodyweight, no significant correlations for the sprint velocity were found. When using relative peak torque, only the knee flexors' strength showed significant correlations with backward somersault height (Table 3).

DISCUSSION

The study revealed medium significant correlations of eccentric peak torque of the knee extensors at 150°/s and the knee flexors at 30°/s and 150°/s as well as jump-and-reach height with the run-up velocity in the gymnastics vault. This is in accordance with previous findings that eccentric hamstring strength is particularly important for sprint performance. This is due to the observation that the greatest hamstring length is apparent right before ground contact of the foot while the muscles are also activated (Schache, Dorn, Blanch, Brown & Pandy, 2012; Thelen, Chumanov, Best, Swanson & Heiderscheit, 2005). In this position the hamstrings have to provide for a high amount of energy absorption (Chumanov, Heiderscheit & Thelen, 2007; Schache et al., 2012; Thelen et al., 2005) that is linked to the achieved running velocity (Chumanov et al., 2007). Additionally, low eccentric hamstring strength was identified as a risk factor for hamstring injuries while sprinting (Hicks, 2017; Jonhagen, Nemeth & Eriksson, 1994). Since propulsion in the maximum velocity phase of sprinting is believed to be realized primarily via hip extension with great back-swing velocity (Bezodis, Kerwin & Salo, 2008; Hunter, Marshall & McNair, 2005; Seagrave, 1996; Wiemann & Tidow, 1995), the main contribution of knee and ankle joints is the amortization of the ground reaction forces' vertical component to counteract a lowering of the body's centre of mass (Hunter, Marshall & McNair, 2004; Hunter et al., 2005; Simonsen, Thomsen & Klausen, 1985; Wiemann & Tidow, 1995). Thus, the stiffness of the knee joint seems to be of high importance in this phase (Bret, Rahmani, Dufour, Messonnier & Lacour, 2002; Chelly & Denis, 2001). To provide for the necessary amount of knee joint stiffness, the influence of eccentric strength of the knee extensors seems apparent. Since antagonistic co-contraction increases joint stiffness as well as short-latency stretch reflexes (Nielsen, Sinkjær, Toft & Kagamihara, 1994), a contribution of hamstring maximum strength to knee joint stiffness in sprint running is conceivable as well. Of course, it needs to be considered that the executed strength tests did not include the hip flexors and extensors that are of crucial importance for sprint performance (Bezodis et al., 2008; Hunter et al., 2005; Seagrave, 1996; Wiemann & Tidow, 1995).

Regarding the backward somersault height, significant medium to high correlations with jump-and-reach height as well as eccentric peak torque of the knee extensors and flexors at both angular velocities could be observed. The former reflects the results of Mkaouer, Jemni, Amara, Chaabène & Tabka (2012) that a backward somersault and a countermovement jump with arm swing seem to be similar kinematically and kinetically in their vertical components. The latter appears to be in accordance with the findings of Kashuba, Khmelnitska & Krupenya (2012) who report knee angles between 163.9° and 175.3° for the ground contact after the combination round off – flick-flac in approach to the vault table. In this case again, eccentric strength of both knee extensors and knee flexors seems to impact joint stiffness via co-contraction to utilise the short-latency stretch reflexes via a stretch-shortening-cycle (Nielsen et al., 1994) and to benefit from the energy stored in the elastic floor surface during the propulsive phase of the jump (Arampatzis et al., 2000).

It is noteworthy, that although eccentric muscle actions of the studies muscles are a fundamental part of daily activities, maximal eccentric strength testing must be regarded as rather unusual and therefore shows greater familiarization effects than concentric testing (Dirnberger, Huber, Hoop, Kösters & Müller, 2013). This observation is explained by different neuronal patterns specific to the type of contraction (Wirth, Keiner, Szilvas, Hartmann & Sander, 2015) which might possibly lead to initial inhibition in unfamiliar subjects (Dirnberger et al., 2013). Therefore, it is important to mention that the participants of this study were familiar with maximal eccentric contractions of the studies muscle group since they have participated in eccentric strength training as part of their athletic preparation prior to the conducted study.

CONCLUSIONS

Eccentric strength of the knee flexors and extensors appears to be an important requirement for female artistic gymnasts in vault and floor apparatus.

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A COMPARISON OF TIME OF FLIGHT AND HORIZONTAL DISPLACEMENT SCORES IN TRAMPOLINE GYMNASTICS ROUTINES

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Abstract

In trampoline gymnastics, elements with low difficulty values are given more place in the first routines in accordance with the international competition rules. In the second routines, because the difficulty value of all the elements performed earn points for the gymnast, elements with high difficulty values are preferred. This difference may affect other score types in the routines. Accordingly, the aim of this study was to compare the time of flight and horizontal displacement scores in first and second routines. The results of the 2019-2020 Trampoline Gymnastics Turkish Championship constituted the data of the study. In both competitions, both the entire group and the female and male groups were evaluated. Except for the 2019 male horizontal displacement scores, the time of flight and horizontal displacement scores of all groups were found to be statistically significantly lower in the second routines compared with the first routines (p<0.05). According to these results, the trampoline gymnasts preferred more complex and difficult elements to obtain high difficulty scores in the second routines in accordance with the international rules, which may have caused them to achieve lower time of flight and horizontal displacement scores compared with the first routines. Trainers and gymnasts should aim to increase the difficulty score without decreasing the total score while choosing elements for second routines. To find this difficulty level, trainings and trial competitions can be performed with routines with different difficulty scores.

Keywords: *trampoline gymnastics, time of flight, horizontal displacement, difficulty.*

INTRODUCTION

Although the birth of trampoline gymnastics dates back to 1934, it has been an Olympic branch since the Sydney 2000 Summer Olympic Games (Federation Internationale De Gymnastique [FIG]) and its popularity has been increasing every year. Although it is a relatively new branch in Turkey and competitions have been regulated since 2006 (Turkish Gymnastics Federation), males aged 17-21 were able to develop quickly enough to win the championship in the Synchronized Competition in 2017 Trampoline Gymnastics World Age Group Competition.

Trampoline exercises are also used as a teaching method for other gymnastics branches and mostly require balance, movement control skills, and visual, kinesthetic, vestibular perception (Atilgan, 2013). Trampoline gymnastics competitions consist of three routines, with each routine comprising ten elements. A routine is characterized by high and rhythmic jumping movements and should include forward and backward somersaults and twisting movements, although the difficulty level varies according to the age group. All routines must be conducted without interruption and intermediate straight jumps (2017-2020 Code of Points Trampoline Gymnastics, [CoPTG] 2016). Since the difficulty value of each element in the second and the final routine is added to the total score, it is very important to apply elements with high difficulty in these routines. The inability to resume the routines after a fall or a pause distinguishes trampoline gymnastics from other gymnastics branches. A trampoline gymnast has to develop their jumping skills in order to be able to perform technical movements consecutively with the least amount of errors. Thus, the gymnast will have enough time to perform the movement, go to the opening and landing phase, and prepare for the next movement. According to studies, a trampoline gymnast is exposed to 5-7 times their body weight in jumping phases (Briggs, 2014; Vaughan, 1980).

The time of flight (TOF) score, which is calculated with a standard electronic device, is added to the difficulty score, execution score, and horizontal displacement (HD) score in all routines (2017-2020 CoPTG, 2016), although there may be exceptions about diffuculty score by age groups. The TOF score refers to the total time the gymnast stays in the air during the routine and rewards the gymnast who can perform the elements in their routine while maintaining the height (Heinen & Krepela, 2016). The result of the electronic device is added directly to the score of that routine without any action. HD scores are calculated from the gymnast's horizontal displacements on the trampoline bed. The aim is to stay in the center of the trampoline bed and perform the elements without falls or injuries (Ferger, Helm, & Zentgraf, 2020). In addition, the inclusion of different score types in the total score can be specified as another aim. The maximum score that can be obtained in this section is 10. If the gymnast's point of the setting foot is not within the center lines from the first element's landing, the required deduction is applied and the total deduction is subtracted from the number of elements. Although the aforementioned deduction can be made electronically with a FIG-approved device, it can also be made by two judges (nos: 5 & 6) in the absence of the device. The judges watch live images on a screen in front of them from a camera installed on the trampoline to make the necessary deduction. In a study conducted with 25 male gymnasts competing in the Aere Word Cup in Brescia, the results of the electronic system were compared with the results of the judges, and the compatibility rate was 96.4% (Ferger & Hackbarth, 2017). In national competitions, in cases where an image is not available, this evaluation can be made with the naked eye, by the decision of the chair of the judges panel. For the landing of each element, a deduction in the range of 0.0-0.3 points can be applied according to the area where the gymnast sets foot from starting the first element. The score deductions to be applied according to the landing area are shown in Figure 1.

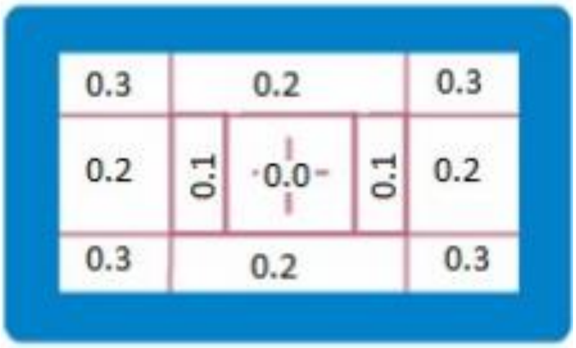

Figure 1. Evaluation of Horizontal Displacement (2017-2020 Code of Points Trampoline Gymnastics, 2016).

With changes according to the age group and the competition type, the difficulty value of at most four elements in the first routine earns points. Therefore, in the first routine, elements with lower difficulty values are mostly used and the aim is to perform them with the most accurate technique and with the least displacement on the trampoline bed. Given that the difficulty value of each element performed in the second routine and the final routine will earn points for the gymnast, these routines normally include complex elements with high difficulty values. Although it is necessary to improve the jump height and the speed to complete routines consisting of these complex elements, disruptions in the somersault or twist technique during the routine, and a failure to obtain sufficient time for the landing phase may cause the jumping height to decrease. While trying to absorb these mistakes, gymnasts can consciously narrow their jumping. Again, because the second routine consists of elements with high difficulty values, disruptions in the motion technique may cause involuntary displacements in the trampoline bed. In addition, when one of these two parameters is disrupted, it may affect the other negatively during the routine. Accordingly, the TOF and the HD scores of trampoline gymnasts may differ in the first and second routines. When the literature is examined, no studies have investigated this issue. The aim of this study was to compare the TOF and the HD scores of first and second routines (with high diffuculty points) in trampoline gymnastics.

METHODS

The results of the Trampoline Gymnastics Turkish Championships held in Mersin 1-3 March 2019, and 28 February–1 March 2020 constituted the data of this study. To use these results, permission was obtained from the Turkish Gymnastics Federation. In the competition held in 2019, there were male and female trampoline gymnasts in age categories of 10-12, 13-14, 15-16 and 17+ years, and male trampoline gymnasts in the 17-21 years age category; in the competition held in 2020, there were male and female trampoline gymnasts in the age categories of 10-12, 13-14, 15-16, 17-21 and 17+ years. Gymnasts who did not complete 10 elements in either one or both routines were excluded. The TOF and HD scores of the gymnasts who completed 10 elements in both routines were used as our data. In this regard, although the total number of gymnasts participating in the competition in 2019 was 92, the number of gymnasts included in the study was 60, and the number of gymnasts from 2020 included in the study was 63, although the total number of gymnasts participating in the competition was 92. The numbers of gymnasts included in the analysis according to sex and age groups are shown in Table 1. To determine the TOF score in these competitions, an acrosport TMD AS1T device, approved by FIG, was used as the time measuring device. HD scores were calculated by averaging the scores given by the two judges. In addition, according to the rules, there were special requirements that gymnasts had to apply while there were no difficulty points in the 10-12, 13-14 and 15-16 years age groups in the first routines. The difficulty score of two marked elements in the 17-21 years age category and four marked elements in the 17+ years age category was added to the first routine total score. It should be emphasized that in the second routines, as the age of gymnasts grows, the degree of diffuculty of elements increases due to an increased number of somersaults and twisting elements. The difficulty of all elements performed in each age group in the second routines was summed if there was no rule violation and included in the total score of the routine. Basic descriptive analyses were performed; the results are expressed using mean and standard deviation for quantitative variables. A boxplot test was performed to test whether there were any outlier data. The normality of the variables was studied using the Shapiro-Wilk test. Then, a paired-samples t-test was performed. The value of p was adjusted to $p<0.05$. All analyses were performed using the SPSS Statistics software (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY).

Table 1
Number of participants by sex.

Age Categories	2019		2020	
	Female	Male	Female	Male
10-12 years	16	16	18	16
13-14 years	10	4	9	1
15-16 years	7	1	6	4
17-21 years	-	-	-	3
17+ years	3	3	3	3

Table 2
TOF and HD Values in First and Second Routines from 2019.

	n	Mean	St. Dev.	P
First Routine TOF	60	13.50	1.87	
Second Routine TOF	60	13.25	1.58	0.003
First Routine HD	60	9.37	0.27	0.014
Second Routine HD	60	9.27	0.26	

Table 3
TOF and HD Values of Female and Male Gymnasts in the First and the Second Routines from 2019.

	Female (n=36) Mean±SD	p	Male (n=24) Mean±SD	p
First Routine TOF	13.61±1.38		13.33±2.46	
Second Routine TOF	13.45±1.27*	0.025	12.96±1.96*	0.040
First Routine HD	9.38±0.27		9.36±0.27	
Second Routine HD	9.23±0.25*	0.009	9.33±0.27	0.619

Table 4
TOF and HD Values in First and Second Routines from 2020.

	n	Mean	Sta. Dev.	p
First Routine TOF	63	13.74	1.71	
Second Routine TOF	63	13.53	1.47	0.001
First Routine HD	63	9.24	0.28	0.001
Second Routine HD	63	9.07	0.30	

Table 5
TOF and HD Values of Females and Males in the First and the Second Routines of 2020.

	Female (n=36) Mean±SD	p	Male (n=27) Mean±SD	p
First Routine TOF	13.46±1.62		14.11±1.77	
Second Routine TOF	13.25±1.43*	0.009	13.91±1.47*	0.041
First Routine HD	9.26±0.26		9.22±0.29	
Second Routine HD	9.11±0.31*	0.040	9.01±0.28*	0.001

RESULTS

A paired-samples t-test was used to determine whether there was a statistically significant mean difference between the first and the second routine. Data are shown as mean ± standard deviation, unless otherwise stated. There were no outliers, as assessed in the boxplot test. The assumption of normality was not violated, as assessed using the Shapiro-Wilk test (p>0.05). When the results of the 2019 Trampoline Gymnastics Competition were examined, unlike the first routines (13.50±1.87), all participants achieved lower TOF scores in their second routines (13.25±1.58). Second routine TOF scores decreased statistically significantly by 0.243 (95% CI: 0.085-0.401), t (59)=3.085, p<0.005. Dissimilar to the first routines (9.37±0.27), all participants achieved lower HD scores in the second routines (9.27±0.26). The second routine HD scores decreased statistically significantly by 0.103 (95% CI: 0.021-0.185), t (59)=2.527, p<0.05. Table 2 shows the 2019 trampoline routine data for TOF and HD.

Female participants jumped lower in the second routine (13.45±1.27) compared with the first routine jump (13.61±1.3), a statistically significant decrease of 0.164 (95% CI: 0.021-0.307), t (35)=2.335, p<0.05. Dissimilar to the first routines (9.38±0.27), female participants achieved lower HD scores in the second routines (9.23±0.25). The second routine HD scores decreased statistically significantly by 0.153 (95% CI: 0.040-0.265), t (35)=2.764, p<0.05. Male participants jumped lower in the second routine (12.96±1.96) compared with the first routine jump (13.33±2.46), a statistically significant decrease of 0.363 (95% CI: 0.019-0.707) in TOF scores, t (23)=2.181, p<0.05. Unlike the first routines (9.36±0.27), male participants achieved lower HD scores in the second routines (9.33±0.27). In the second routine HD scores, the difference (0.029) was not statistically significant (95% CI: 0.090-0.149), t (23)=0.504, p>0.05. Table 3 shows the 2019 TOF and HD values in the first and the second routines for the female and male gymnasts.

When the results of the 2020 Trampoline Gymnastics Competition were examined, unlike the first routines (13.74±1.71), all participants achieved lower TOF scores in their second routines (13.53±1.47). Second routine TOF scores decreased statistically significantly by 0.207 (95% CI: 0.090-0.324), t (62) = 3.535, p<0.005. Unlike the first routines (9.24±0.28), all participants achieved lower HD scores in the second routines (9.07±0.30). The second routine HD scores decreased statistically significantly by 0.172 (95% CI: 0.080-0.264), t (62) = 3.750, p<0.005. Table 4 shows the trampoline routine data for TOF and HD from 2020.

Female participants jumped lower in the second routine (13.25±1.43) as compared with the first routine (13.46±1.62), a statistically significant decrease of 0.215 (95% CI: 0.058-0.372) in TOF scores, t (35)=2.778, p<0.05. Dissimilar to the first routines (9.26±0.26), female participants achieved lower HD scores in the second routines (9.11±0.31). The second routine HD scores decreased statistically significantly by 0.149 (95% CI: 0.007-0.290), t (35) = 2.134, p<0.05. Male participants jumped lower in the second routine (13.91±1.47) as compared with the first routine jump (14.11±1.77), a statistically significant decrease of 0.215 (95% CI: 0.058-0.372) in TOF scores, t (35)=2.778, p<0.05. Unlike the first routines (9.22±0.29), male participants achieved lower HD scores in the second routines (9.01±0.28). The second routine HD scores decreased statistically significantly by 0.149 (95% CI: 0.007-0.290), t (35) = 2.134, p<0.005. Table 5 shows the TOF and the HD values in the First and the Second Routines from 2020 for the female and male gymnasts.

DISCUSSION

To our knowledge, this is the first study to compare the TOF and the HD scores of first and second routines of trampoline gymnasts. For 2019, when all participants were evaluated together, and when both female and male participants were evaluated separately, TOF scores in each group decreased statistically significantly in the second routines. Only for male gymnasts did HD scores not differ significantly between the first and the second routines. When all group and female participants were evaluated separately, it was clear that the HD scores were significantly lower in the second routine as compared with the first routine. The results of 2020 showed that the TOF and the HD scores were statistically lower in the second routine as compared with the first routine when all participants were evaluated together and when the evaluation was based on sex. Considering these results, the fact that trampoline gymnasts preferred more complex and advanced technique elements to increase the difficulty score in the second routines may have caused them to achieve lower TOF and HD scores than the first routines. It would be useful for trainers and gymnasts to consider these results when designing the second and the final routines.

In trampoline gymnastics, it is important to control the body position throughout the routines, to be able to complete 10 elements in the routines and to perform the elements with minimum errors. There are two basic phases in a trampoline gymnastics element. The first of these can be specified as the flight phase, the second as the contact phase. The contact phase is also divided into the landing phase and the take-off phase. The landing phase is the phase in which the gymnast ends the previous element and slows down, and the take-off phase is the phase in which the gymnast prepares for the next element (Helten, Brock, Müller, & Seidel, 2011). During the landing phase, the gymnast adjusts the lower limb angles and tightness to convert kinetic energy into elastic energy. To use elastic rebound after contact with the trampoline bed, the lower extremity joints are lengthened. This long body position is necessary to keep the energy required for the take-off phase at the maximum level (Qian et al., 2020). In the population in our study, it was shown that the flight phase was shorter in routines created with elements with high difficulty values. This might be because the gymnasts were not able to enter the landing phase in time after performing complex movements and thus not being able to perform the acceleration processes required for the take-off phase well enough. In direct connection to this, jumping height losses, directional distortions, and even increases in errors in the performance of the element can be seen in the next element. In a simulated trampoline gymnastics competition, elite male gymnasts took part in a study and presented two routines and a final routine, just as if they were in a real competition. Considering the counter movement jump results they applied after the first and the second routines, it was seen that there was a significant decrease after the second routine. In addition, when looking at the first 10 jumps of 20 maximal trampoline jump tests, it was found that the results of the post-second routines test were significantly lower than the initial values (Jensen, Scott, Krustrup, & Mohr, 2013). The 20 maximum trampoline jump test is a highly reliable test to measure the performance of trampoline gymnasts (Dyas, Green, Thomas, & Howatson, 2020). The results of this study showed that the gymnast could develop fatigue after each routine in trampoline gymnastics. In the same study, after the warm-up period applied, quadriceps muscle temperature was found to be lower before the second routines than before the first routines (Jensen et al., 2013). Due to the nature and rules of trampoline gymnastics, the whole group is expected to complete the first routines before starting the second routines. This period can be about half an hour depending on the number of gymnasts in the group. If the gymnasts can not stay active during this time, their body temperature may decrease as shown in the previous study. There are studies in the literature presenting evidence that low muscle temperature can negatively affect performance (Mohr, Krustrup, Nybo, Nielsen, & Bangsbo, 2004). In this study, in addition to the increase in the difficulty value, fatigue and inability to maintain body temperature may be added to the decrease in the TOF and the HD scores of the second routines. In another study conducted with 11 female trampoline gymnasts with an average age of 10.36 years, the gymnasts performed 20 jumps on the trampoline. Statistically significant differences were found between circulatory and respiratory system variables measured before and after their performance (Mohammed & Joshi, 2015). Similar changes are expected to occur after the first routine is performed during a competition. These physiologic responses may also affect the decrease in the TOF and the HD scores in the second routine.

In a study in which a European Championship was evaluated during the years when HD scores were not included in the scoring, the most important score among the determinants of the total score was the execution score in the qualifying round, followed by TOF and difficulty scores. In the same study, it was stated that the execution score was the most complex part in terms of performance evaluation and that the execution judges were not always consistent in terms of score deductions (Leskošek, Čuk, & Peixoto, 2018). Of course, this discrepancy can be somewhat resolved by including only median marks in scoring and by excluding other marks from scoring. Apart from that, gymnasts should also work on increasing their TOF and HD scores, which show more objective results, to increase their total scores. HD scores were included in the evaluation of trampoline gymnastics total scores in the last cycle (2017-2020 CoPTG, 2016). A high HD score for all routines is important for the total score. In addition, working on the evaluation criteria that give objective results for gymnasts and trainers, supports them motivationally and facilitates the evaluation of success. In terms of increasing the spectatorship of the branch, it can be stated as an important factor that there must be types of scores that can be understood by everyone in the creation of the total/final score (Ferger & Hackbarth, 2017).

It is undeniable that increasing the difficulty score is critical to improving the total score. However, while gymnasts and trainers focus on the difficulty score, they should try to predict whether execution scores, TOF and HD scores, will be adversely affected by this situation and if so, to what extent. In addition, it should not be forgotten that when the results of a competition are examined, even in FIG competitions, gymnasts with lower difficulty points can participate in the finals and even end the competition with a medal. The possible change in TOF and HD scores, which give objective evaluation results, can be examined by trying routines with different difficulty values in trial competitions held during the training period. Of course, due to the natural variability in human movements, the same skill cannot be exactly the same each time it is tried (Bartlett, Wheat, & Robins, 2007). Nevertheless, as these trials are repeated, trainers and gymnasts will be able to get an idea about creating a routine design that will not reduce the total score. For example, if adding 1/1 twisting to the movement to increase the value of an element performed in the middle of a routine by 0.2 points results in lowering TOF and HD scores in most trials, this would negatively affect the continuation of the routine and would be better not to pursue this path.

CONCLUSIONS

The results of this study show that TOF and HD scores may be lower in the second routine as compared with the first routine. The reason for this may be that, unlike in the first routine, all elements in the second routine are included in the calculation of the difficulty value, therefore elements with high difficulty values are preferred in the second routine and this situation negatively affects the landing and the take-off phase. Also, physiologic processes can support this result. In the second routine, especially young gymnasts should know that they can potentially score higher points from other areas of scoring with an optimal difficulty score and thus can obtain a higher total score and set the difficulty score target accordingly. Trainers should work on determining the optimal difficulty score that they can work on without negatively affecting the TOF, the HD and hence maybe the total score, and should train gymnasts accordingly.

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CREATION OF A TEST BATTERY FOR THE EVALUATION OF RHYTHMIC FEELINGS IN UNIVERSITY STUDENTS IN THE FIELD OF PHYSICAL EDUCATION AND SPORT

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Abstract
Optimal movement rhythmisation is considered one of the basic prerequisites for improvements in the quality of movement performance using a particular technique. Well-developed rhythm-movement patterns play a role in successful learning of various physical activities as well as in athletic performance. University students – future PE and sports teachers – should improve their rhythmic feel skills during their studies so that they can use them later in their work and develop them in their future students. This requires the creation of a test battery for the evaluation of rhythmic feel skills through a series of music tests. This paper presents the results of tests taken by 121 university students at UK FTVS in Prague, the Czech Republic, and AWFIS in Gdańsk, Poland. The test battery focused on three types of music-motor skills: perception skills and activities (items 1-18), reproduction skills and activities (items 19-27) and production skills and activities (item 28). The data were statistically processed using the classical test theory (factor analysis) and the item response theory (two-parameter model). Statistical methods also included reliability calculation and test validity. The expected rejection of the proposed hypothesis was confirmed both for the classical test theory and for the item response theory. The only exception was model 4 where, however, fit indices (especially TLI = 0.537) pointed more at a lack of evidence for hypothesis rejection than a perfect conformity of the model and data. The intention was to create and test models with the best data compliance. The best data compliance was found in models no. 1 and 5. Model 1 [CFI = 0.927, TLI=0.916, SRMR = 0.09, RMSEA (5 %) = 0.03, RMSEA (95 %) = 0.059] had a structure that corresponded to the proposed test battery and showed a relatively good compliance with data although IRT identified several problematic items. Model 5 [CFI = 0.956, TLI=0,942, SRMR = 0.073, RMSEA (5 %) = 0.03, RMSEA (95 %) = 0.111] was unidimensional (reproduction factor feeding items 19 through 27) and its fit indices showed better compliance of model and data. An optimised test battery should be developed based on these models followed by another validation of the test battery using statistical analyses.

Keywords: *musical-motor skills, test battery, rhythm, factor analysis, item response theory.*

INTRODUCTION

The concept of rhythmic feelings refers to both rhythm and feelings, things that we encounter in many areas of our lives. They play a key role in correcting both the physical and psychological development including, for example, breathing, verbal and memory skills. They are also the cornerstone of any physical activity technique, movement or athletic performance. This is especially true for gymnastics where movements and skills are learned in rhythmic structures with or without an apparatus and require the mastery of movement with optimal rhythm or, in other words, the execution of movement with the best time and space.

Gymnastic skills are also used in many other sports. A wide range of gymnastic coordination and fitness exercises are used in the training of young athletes in many sports as well as in the technical training for other sports that require a high degree of coordination (Strešková, 2005). Gymnastic exercises are often performed to music. Rhythmic gymnastics has the most sophisticated form of music-motor education. It is the basis of training for gymnastics as well as rhythmic gymnastics (Mihule & Šťastná, 1993).

As part of their study, future teachers and coaches learn how to develop and assess rhythmic aptitudes. In their future work, they should be able to apply their skills when training their students and athletes in order to improve their motor skills and athletic performance (Novotná et al., 2012).

Měkota and Novosad (2005) define rhythm as the dynamic and temporal division of movement. They describe the acoustic and visual aspects of rhythmic skills and divide these skills into rhythmic perception and rhythmic realisation. High-level rhythmic skills are believed to help with learning processes.

Váňová together with Skopal and Sedlák (2007, 2013) and Holas (1985) studied musicality in children. Their study inspired us to explore and develop tests for the evaluation of rhythmic feeling abilities with future physical education teachers and sports coaches, taking the definition of "rhythmic feeling" as our starting point.

Rhythmic feeling is considered a psychological category. In other words, it is one of the musical abilities, or internal structures, that is not directly manifested and as such cannot be directly measured. It is manifested externally through activities and perception, reproduction and production skills that, in turn can be measured. These activities and skills must be tested separately, and tests must eliminate their mutual interferences (Sedlák & Váňová, 2013).

Perception skills and activities are based on the tested subject's perception and internal processing and the evaluation of a situation. Reproduction skills and activities are based on the repetition of a reproduced (demonstrated) task. Production skills and activities are based on the production of rhythm or movement based on a specific task with a strong emphasis on creativity.

Music is an integral part of rhythm issues. Music creates ergogenic effects that improve work performance beyond expected levels of endurance, energy, strength, and productivity (Edworthy J. and H. Waring, 2006).

The presented research partially follows up on the results of a dissertation thesis of Brtníková (2008). Brtníková (2008) created a test battery for the diagnosis of musicality and motor skills in secondary school female students as part of their physical education classes. Her work is based on the previous research on music and movement practice by music experts Kos (1975), Mihule and Appelt (1963), and also on musicality tests developed by music experts Bentley (1966), Seashore (1915, 1936) and others. Similar to Brtníková (2008), Shmulevich and Povel (2000), Moseley (2004), Grühn, Galley and Kluth (2006) and others also used the tests of music experts in their original or modified version in music and movement practice.

More recent research in this area tends to focus primarily on the evaluation of already acquired specific motor skills, rather than on the actual level of rhythmic feeling itself.

The aim of this study is to present a design of a new test battery for assessing rhythmic feelings and relevant statistical analysis to assess whether the proposed test items can be part of a test battery and whether this test battery can be used in practice and can form the basis for possible future standardization. Tests that assess the rhythmic feelings of university students are still lacking in sports and physical education.

METHODS

The newly created test battery is based on findings reported in Czech and international literature and in collaboration with experts on sports and music. From Holas (1985), we took and applied the test structuring into several subtests. In the first section "Perception skills and activities", a new test content was created while keeping the example and the number of tests. The test structure and design builds on the work in music psychology and diagnostics by Váňová, Skopal and Sedlák (2007, 2013), which allowed for the interpretation of rhythmic feelings and its components.

Test description:

1) Perception skills and activities:

Each test section contains 1 sample and 6 test tasks.

A) Melodic memory – 3x listening to a familiar melody. The subject is asked whether or not there are any differences in the third recording.

B) Tonal feel – 2x listening to a tone sequence. The subject is asked whether another tone, played separately occurred in the recording.

C) Rhythm memory – each task contains three rhythmic sections played on percussion instruments. The subject is asked whether or not there are any differences in the third recording.

These three test partitions (A, B, C) are processed on a test CD. The subjects are provided with recordings including the sound marks and instructions. The testing takes place in a group setting. In addition to the rhythmic tasks, the tests also include tasks focused on other musical abilities. We were already aware of this inaccuracy when the test battery was created, so it is clear that the statistical analysis will reveal this fact and allow the appropriate changes to be proposed.

2) Reproduction skills and activities:

Each test section contains 3 test tasks.

A) Static rhythmisation (no movement) – three rhythmic variations reproduced by clapping.

B) Dynamic rhythmisation (movement in space) – subjects are asked to repeat a rhythmic movement sequence demonstrated by the examiner to a metronome beat of 114MM.

C) Rhythmisation with added elements (music and apparatus) – Subjects are asked to repeat a short rhythmic movement etude using wooden sticks.

The testing is done individually. Before each test, subjects can try out the etude and demonstrate the etude with verbal rhythmisation.

3) Production skills and activities:

A) Production with music and verbal rhythmisation

Subjects are asked to create a movement etude of eight 4/4 bars including a jump of his/her choice. The test section "Production skills and activities" contains only one item for time reasons. Therefore, this item is worked from the point of view of the regression analysis in relation to the previous two test sections.

The point scores in the individual tests of the test battery are recorded on paper sheets and then transcribed into a computer. 1 point = the subject performed the rhythmic test flawlessly, 0 points = the subject failed to perform the rhythmic task or performed it with mistakes. The skill diagnostic does not focus on the quality of the movement but purely on the rhythmic component of movement. The aim of the proposed diagnosis and evaluation of the rhythmic feelings is to find out which activities pose the biggest problems to students and where the biggest gaps are in their theoretical and practical education. The findings may indicate a lack of stimuli in the teaching of gymnastics and music-movement education. The results of the research should help steer teaching towards the learning of skills and activities that promote and develop rhythmic feelings.

Hypotheses

H1) The proposed test battery includes three dominant factors – perception, reproduction and production.

If H1) is disproved, we expect:

H2) Items 1 through 18 explained through the perception factor.

H3) Items 19 through 27 explained through the reproduction factor.

The testing sample consisted of university students, both female and male, over the age of 19, studying Physical Education and Sports. The test included 121 students – 48 women and 73 men. The students were recruited at the Faculty of Physical Education and Sport, Charles University (UK FTVS; n = 76) and the Akademia Wychowania Fizycnego i Sportu, Gdańsk (AWFIS; n = 45). The tests were translated into Polish for the Polish subjects.

Testing took place during 4 to 5 lessons (1 lesson took 75-90 minutes) in the gymnastics gym and the surrounding area. During the testing, in addition to the examiner, another teacher was present and delivered the teaching.

The research tested the level of rhythmic feelings in 121 subjects using 28 items in a newly created test battery. Rhythmic feelings were not demonstrated directly but through the perception (items 1-18), reproduction (items 19-27) and production (item 28) skills and activities. The statistical analysis of the results was performed using the R software.

At first an exploratory factor analysis (EFA) was performed, one of the methods of classical test theory (CTT). The goal of EFA was to find the true number of existing factors and assesses the factor load on test items, thus getting an insight into the structure of the proposed test in order to assign different factors to the relevant groups of test items. Further, a confirmatory factor analysis (CFA) was performed, which is, again a part of the CTT. Based on the EFA results, a model was created that assigned factors to different item groups according to the test structure. The conformity of the models with the measured data was determined on the basis of the so-called fit indexes. Specifically, in this case, a model was created with 3 factors - perception (items 1 to 18), reproduction (items 19 to 27) and production (item 28). The production factor consisted of a single item which was included for the purposes of a regressive analysis. Classical test theory considers the test battery as a whole, which means that if only some items or groups of items from the test battery were analysed, the results would not be valid. This is because the CTT considers the items to be interdependent and any item that would be excluded from the test would remove essential test information. This consideration is particularly satisfactory for those tests that have already undergone initial optimization and are used in a stable form. A completely new test was created for this research, which is why the item response theory (IRT) was applied to a portion of the statistical processing in order to allow individual evaluation of each item and to treat every item as a separate test tool (Urbánek & Šimeček, 2001).

RESULTS

Exploratory factor analysis

In the R statistical software, an exploratory factor analysis was performed using the *psych library* and the measured data, the number of extracted factors and the rotation type as input for the specific commands. The rotation types used in this analysis are the “varimax” argument, which is part of the orthogonal rotation1 type, and the “oblimin” argument, which is part of the oblique rotation2 type. Extracted factors were counted for values 3 and 4 using the minimal residue extraction method.

Three factor extraction. The application of the three extracted factors did not yield a good compliance between the model and data, as documented by the TLI (Tucker-Lewis Index) with a value of 0.863, although the (Root Mean Square Error of Approximation) index was rather favourable with a value of 0.032. More information about the factors was provided by a percentage value of spread, explained by the relevant factor. The biggest spread value was detected for factor 1 (14%), followed by factor 2 (6%) and factor 3 (4%). The total value of the spread explained by the three extracted factors was 24%, which is a very small value.

Four factor extraction. The results yielded by four factor extraction were more favourable in terms of the fit indexes (RMSEA = 0.025, TLI = 0.928), which was to be expected because the additional factor contributed to the explanation of a larger part of the total spread (a total of 28%). A factor load analysis also showed a trend similar to the three-factor extraction in that it was observed that factor 1 fed primarily items 19-28 (with some exceptions). Other load factors did not feed items in a way that would indicate a clear trend in line with the test design.

Another output included in the EFA was a test of the internal consistency of the test battery using the Cronbach alpha numeric parameter. This value was calculated to be 0.8, which is generally considered as acceptable (the threshold typically being 0.7) although some authors (Lance, 2006) accept this test as reliable only at values higher than 0.9. It should be mentioned that the reliability is calculated for the entire test battery and is considered constant for the entire interval of subjects' skills.

EFA conclusion. In the light of the above results, it can be stated that in the proposed test battery concept (three factors corresponding to specific items), there was only one factor feeding items 19 – 28. The question, however, is whether it was the reproduction factor or the production factor or a factor combining these two manifestations of rhythmic feelings. More testing with more than one production item would be needed to answer this question. Another finding stemming from the EFA was that at least four factors would need to be extracted in order to ensure sufficient model-data compliance.

Confirmatory factor analysis

The confirmatory factor analysis worked with a specific model structure design. Two models (Model 1 and Model 2) were analysed – both assigned the relevant three factors to all items as per the proposed test battery. In one case (Model 2), we calculated a regression analysis of the production-perception and production-reproduction relationships.

Figures 1 and 2 show the structure of the two models.

The final fit indexes show model compliance with the measured data. It is apparent that the model-data compliance was not acceptable. The only favourable index was the RMSEA index. However, literature (Hu & Bentler, 1999) indicates that a proof of model-data compliance requires more indexes with results under or above the calculated value. In this particular case, CFI and TLI indexes yielded very low values. The chi-square test rejected the hypothesis of the proposed models.

CFA conclusion. Three dominant factors were assumed in this analysis. Based on the fit index values, both models failed to show good compliance with the measured data. A detailed analysis of the co-variation values (standard deviations, spreads) would be possible, but these values were not interpreted due to the fit index results.

Item response theory

As part of the item response theory (IRT), the relationship between the latent variable (θ – theta) and the item response was studied. In this case, the latent variable was the factor and the item response characterised by the probability distribution above the latent variable. This distribution was defined by three parameters – the difficulty parameter, the discrimination parameter and the guessing parameter.

Factor analysis using IRT

In this section, a factor analysis was performed in the R software using the *mirt library*. Several models were designed and tested. Model 1 had the same structure as model 1 in the confirmatory factor analysis section and the factor correlation was permitted. Model 2 was based on model 1 but the perception factor included only items 13 to 18 because the first twelve items focused on tonal feelings and melodic memory. Model 3 assumed that the first 18 items were defined by the same factor and similarly Model 4 considered items 13 through 18. Model 5 included items 19 through 27 in a single factor using a two-parameter model.

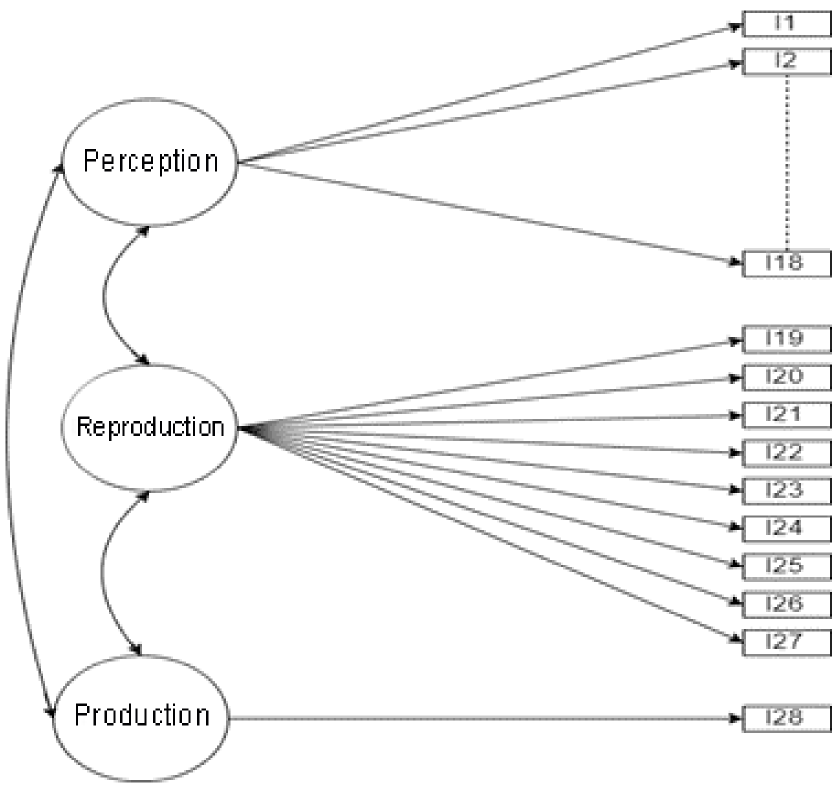

Figure 1. Structure of Model 1.

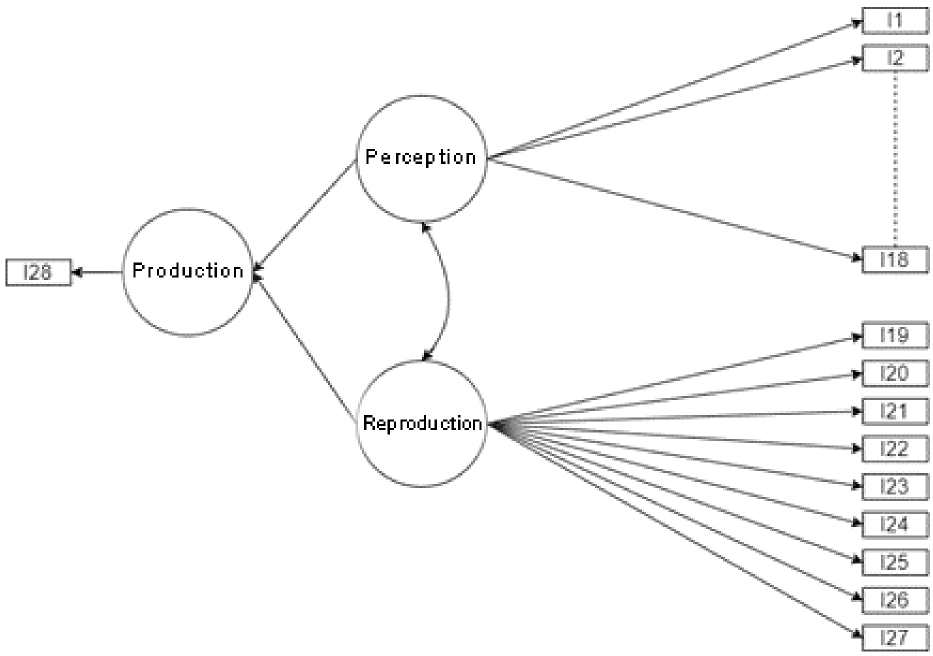

Figure 2. Structure of Model 2.

Table 1
Final fit indexes of the proposed models 1 to 5.

	CFI	TLI	RMSEA	RMSEA (5 %)	RMSEA (95 %)	SRMR	p (χ)
Cutoff	> 0.9	> 0.95	< 0.06	< 0.05	< 0.08	< 0.08	> 0.05
Model 1	0.927	0.916	0.046	0.03	0.059	0.09	0.001
Model 2	0.926	0.907	0.067	0.044	0.087	0.088	0
Model 3	0.866	0.825	0.045	0.012	0.067	0.089	0.036
Model 4	0.907	0.537	0.075	0	0.18	0.11	0.168
Model 5	0.956	0.942	0.074	0.03	0.111	0.073	0.016

Table 2
Correlation matrices of model 1.

	F1	F2	F3
F1	1		
F2	0.795	1	
F3	0.696	0.974	1

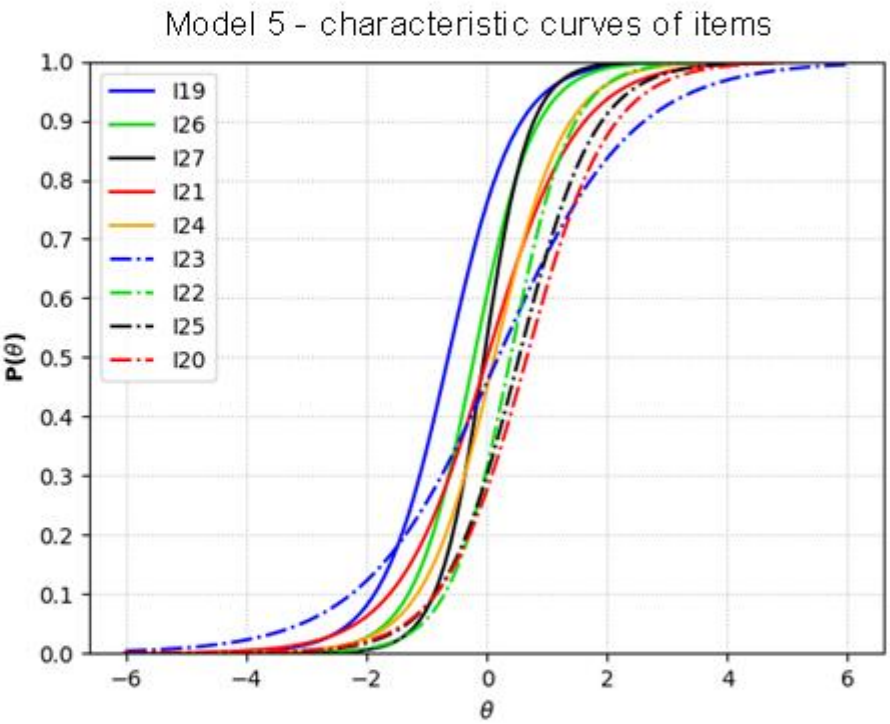

Figure 3. Characteristic curves of items 19 to 27 of model 5.

The above table shows that the worst fit indexes were found for Model 4 and Model 3 where TLI values reach especially low values. Rather surprisingly, the chi-square test forced a rejection of all models with the exception of Model 4, which showed favourable results despite the fact that TLI, which was based directly on the chi-square test, gave very unfavourable results. For this reason, Model 4 is no longer considered. Model 2, once again, showed unfavourable results with only two of the six indexes being acceptable. The most favourable results were yielded by Model 1 and Model 5 with relatively satisfactory values for the initial test battery analysis.

Model 1

It turned out that for items 1, 8, 15 and 18 focused on perceptual skills and activities, the difficulty parameter is up to a hundred times higher than for all other items (I1 = 34.3; I8 = 78.17; I15 = 53.39; I18 = 32.53). This means that for a proband, in order to have a 50% chance of answering an item correctly, it must have a latency value several times higher than for other items. On the latency scale from -6 to 6, which includes all other items, the characteristic curves of items 1, 8, 15, and 18 then appear as horizontal lines — that is, they do not discriminate at all on this scale. The empirical reliability of the perception factor was 0.77, the reproduction factor 0.85 and the production factor 0.85. From this it can be concluded that the largest measurement error occurs in the perception factor.

The correlation coefficients between factors are also important variables (Table 2). Significant values of correlation with positive signs can be observed, which the design concept implicitly assumed. The most interesting is the correlation coefficient between factor 2 (reproductive ability) and factor 3 (production ability), which is based on 0.974 and suggests that these two factors correlate very significantly. The question is how this correlation coefficient would change if factor 3 contained more than one item.

Model 5

Regarding the values of the parameters of individual items, all values of the discrimination parameter came out greater than 1, i.e. the characteristic curves of the items (Figure 3) have the trend direction. It can be seen from the figure that item 23 has the lowest sensitivity, the slope of which is the least steep, while item 27 distinguishes the most. Another monitored parameter is the difficulty parameter, which distinguishes between difficult items (small difficulty parameter) and easy items (large difficulty parameter). In the legend, it is then possible to follow from top to bottom the most difficult items (items 19 and 26) to the simplest (items 25 and 20). The value of empirical reliability for model 5 was 0.785.

Conclusion of statistical results

All proposed hypotheses had to be rejected because the chi-square determined perfect model-data compliance. It was clearly impossible to not reject these hypotheses for the newly created test although the aim was to detect a good compliance rather than a perfect one.

Based on the results of the factor analysis using the classic test theory, the model-data compliance was not acceptable. In a factor analysis, part of the item response theory, two models were found with an acceptable data compliance considering that this was only a pilot test. One of these models included three factors and the other model included only one factor, specifically reproduction skills.

DISCUSSION AND CONCLUSIONS

This paper introduced research using a test battery for the evaluation of three aspects of rhythmic feelings in tested subjects. The purpose of the statistical analysis was to verify that the test structure was really a three-factor structure and, if possible, to differentiate each factor. Both the classical test theory and the item response theory led to a rejection of the proposed hypothesis (models) on a 95% level of significance, the only exception being Model 4 in the item response theory. Considering other fit indexes (especially TLI, which is based on the chi-square test), the results may be interpreted as failing to identify sufficient evidence for model rejection. In the current form, therefore, the test cannot be used to assess rhythmic feelings but requires optimisation, followed by more testing and statistical analysis.

Hypothesis rejection had been expected because very few newly designed test batteries have passed the chi-square test. However, this research was focused more on finding good model-data compliance according to different fit indexes, rather than a perfect compliance in a chi-square test.

Based on the results of the statistical analysis, the following recommendations can be proposed for the next testing:

- if possible, increase the number of test subjects by at least twofold (the more, the better),
- reduce the number of items falling into perceptual skills and activities, or, in consultation with a music expert, review the difficulty of existing items (1 to 18),
- in the new test include only those items from the section of perceptual skills and activities that focus on rhythmic memory,
- include more items in the section of production skills and activities and observe a correlation coefficient between the factor of reproductive abilities and production abilities. Only then will it be revealed whether these two factors are really so significantly correlated,
- reduce the number of items in the reproductive skills and activities section, for time reasons. The statistical analysis performed will help you decide which items to exclude.

Based on previous recommendations, the new structure of the test could look like this. The perception skills and activities section could include only 6 items focusing on rhythmic memory. The reproduction skills and activities section could include 4-6 items considering that this part of the test is the most time consuming. The production skills and activities section could include 2-3 items. The new test battery would thus include a total of 12-15 items. This would significantly reduce the time needed for conducting the test and would also probably increase the informative value of the test. However, newly gathered results must be assessed by statistical analysis before any decision regarding further optimisation or standardisation of the test battery.

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ANTHROPOMETRIC AND MOTOR CHANGES AFTER ONE-YEAR AEROBIC GYMNASTICS TRAINING IN YOUNG GYMNASTS

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Abstract

The purpose of this study was to investigate the effect of one-year specific aerobic gymnastics training on selected anthropometric and motor parameters in 6-11-year-old girls. 23 girls (average age in the beginning of the study was 8.04 ± 1.22 years) were involved in the study representing 2 different aerobic gymnastics sports clubs in Slovakia. The selected group completed their regular trainings and competitions for a period of one year. Measurements were taken in January 2019 and January 2020, in the middle of the preparatory period. Normality of distribution of the traits was examined using the Shapiro-Wilk test. Data were analyzed using Wilcoxon signed-rank test. Considering anthropometric parameters, there were significant changes ($p\leq0.01$) in body height, body weight and BMI. Considering motor parameters, the mean values of straddle support hold and back extension endurance test increased significantly to the level of $p\leq0.05$. The mean values of 4x10m shuttle run, standing long jump, modified push-ups, sit-ups in 60s increased significantly to the level of $p\leq0.01$. No significant changes were observed in bent arm hang test or hanging knee tucks. On the other hand, the values of 1 leg stand with eyes closed and 2-min endurance shuttle run decreased insignificantly.

Keywords: *aerobic gymnastics, anthropometric changes, motor changes, motor abilities, sports training, young gymnasts.*

INTRODUCTION

Aerobic gymnastics is one of the gymnastics types that is recognized by the International Gymnastics Federation (FIG). According to its performance structure, it is characterized as an aesthetic-technical discipline with energy coverage from the anaerobic glycolytic system. Previous investigation of aerobic gymnastics routine performance (Kyselovičová & Danielová, 2012) revealed that the values document clear anaerobic dominance and anaerobic energy metabolism. However, Kyselovičová et al. (2016) also noted, that it is rather complicated to assess the physiological and energetic demands during exercises of relatively short duration, changing intensity, and types of muscle activation.

Aerobic gymnastics' performance is characterized by its content and demonstration originating from traditional aerobics making its structure somewhat different from other types of gymnastics. The highest demands are placed on the execution and physical fitness of competitors (Hájková et al., 2006).

Athletes are required to demonstrate complex high-intensity movements to music, involving many gymnastics and dance-based skills, difficult elements and acrobatic moves, displaying the discipline's variety and creativity. Routines are evaluated by judges who consider three different aspects: difficulty, artistic value and execution (Raiola et al., 2012; FIG, 2017). The highest scores are earned by the gymnasts who perform difficult routines with high accuracy and a proper technique (Prassas et al., 2006).

In aerobic gymnastics, as well as in other sport disciplines, there is a constant demand for an ever-increasing performance level. The level of physical fitness is dependent on the innate predispositions and environmental factors, such as, for example, primarily training. It is also believed that in order to achieve a high degree of complex motor performance, the training needs to begin in early childhood as it plays an important role in the development of motor skills (Sawczyn et al., 2000; Kochanowitz et al., 2010). The success of each gymnast is highly dependent on the level of their motor abilities (Jemni et al., 2006). Therefore, a systematic examination of training effects is needed. The evaluation of the motor skill levels requires the use of objective, quantitative and qualitative criteria. There are many techniques available for measuring motor abilities and the general level of motor fitness. They serve not only to assess the current level of motor abilities, but also to monitor improvement during the process of training (motor development). However, it is necessary to continually monitor the training effects of each athlete to allow the individualization of training loads (Kochanowitz et al., 2006; Ortega et al., 2008; Zaporozhanov et al., 2012)

Many authors (Gallahue et al., 2012; Piek et al., 2012) agree that early childhood is considered to be the ideal age for the development of fundamental movement skills that become the basis for both skills needed for the daily life as well as specific movements needed for the participation in different sports and physical activities. Sports preparation, in general, positively influences children's health in terms of physical fitness, and it also improves anthropometric measurements like body weight and body composition (Fisher et al., 2005). Differences in the levels of physical fitness and motor coordination in children who are actively involved in sports can partly be explained by the number of hours spent doing their chosen sport (Opstoel et al., 2015). Physical activity during the period of growth results in significant changes in anaerobic strength and aerobic capacity. It has also a beneficial impact on aerobic and muscular strength, coordination and muscular endurance (Ortega et al., 2008). On the other hand, gymnastics is one of the key sports that play an important role in the development of children as it offers a wide range of locomotive, stability and body control movements such as transitions from dynamic to static elements and frequent changes of the body position in space (Culjak et al., 2003; Bressel et al., 2007; Pajek et al., 2010). Regular gymnastics training contributes to the development of coordination, strength, muscular endurance, flexibility and balance (Bencke et al., 2002; Werner et al., 2012). According to Douda et al. (2008), important factors for the execution of gymnastics seem to be anthropometric characteristics, flexibility, aerobic capacity, and anaerobic power.

There have been a few studies researching the effects of a long-term gymnastics training on both anthropometric and motor parameters (Tibenská et al., 2010; Živčić et al., 2012; Mertashl et al., 2015; Mlsnová, 2016). However, the amount of research, especially in aerobic gymnastics, is insufficient and we felt the need to expand the knowledge in this field. The aim of our study was to discover the changes in the selected anthropometric and motor parameters after one-year specific aerobic gymnastics training of 6-11-year-old girls.

METHODS

The examined sample consisted of 23 girls involved in aerobic gymnastics. Their average age in the beginning of the study was 8.04 ± 1.22 years, the average sport age was 3.07 ± 1.35 years, height 130.21 ± 9.21 cm and mass 26.88 ± 6.10 kg. Girls were attending aerobic gymnastics classes in two different sports clubs and completed regular trainings and competitions for a period of one year. They trained on average 5.02 ± 0.68 hours a week (except during summer and winter holidays) and participated in on average 4.26 ± 2.36 competitions in Slovakia and the Czech Republic. In general, our training program included general physical preparation, learning and performing routines and difficult elements, and specific gymnastics preparation. Each training session also included warm-up and cool-down exercises. The trainings' content followed the one-year training cycle (Table 1.)

Measurements were taken in January 2019 and January 2020 in the middle of the preparatory period (lasting from the beginning of December till the end of February). They consisted of anthropometry tests (body height, body mass, BMI) and 10 standardized tests picked from the test battery used by the Slovak Gymnastics Federation for the selection of the national team (SGF 2018). The test battery included the following tests: 1. one leg stand with eyes closed, 2. 4x10m shuttle run, 3. standing long jump, 4. bent arm hang, 5. straddle support hold, 6. back extension endurance test, 7. hanging knee tucks, 8. modified push-ups, 9. sit-ups in 60s, 10. 2min endurance shuttle run (7m).

Normality of distribution of the traits was examined using the Shapiro-Wilk test. Results pointed out that the variables were not normally distributed, therefore, the Wilcoxon signed-rank test was used for all the variables. Significance levels for all statistical analyzes were considered as $p \leq 0.05$ and $p \leq 0.01$.

RESULTS

After the one-year aerobic gymnastics training, we noted significant changes in selected anthropometric parameters. The mean value of body height increased by 4.3 % ($p \leq 0.01$), body weight increased by 12.7 % ($p \leq 0.01$) and BMI increased by 4.5 % ($p \leq 0.01$). Detailed data of all anthropometric parameter are presented in Table 2.

Table 1
Approximate trainings' content during the one-year training cycle of the examined group.

Phase	Preparatory 1	Competitive 1	Transition 1	Preparatory 2	Competitive 2	Transition 2
Month	Jan Feb	Mar Apr May	Jun Jul	Aug Sep	Oct Nov	Dec
Content	routine construction	routine perfection	acrobatics	routine construction	routine perfection	acrobatics
	new elements	technical prep.	transitions	new elements	technical prep.	transitions
	conditioning	psychological preparation	new elements	conditioning	psychological preparation	new elements
	physical preparation	physical preparation	break	physical preparation	physical preparation	2-week holiday

Table 2.
*Changes in selected somatic and motor parameters (x̄ - average value; sd - standard deviation; EC - eyes closed; PU – push-ups; ET - endurance test; SR - shuttle run; * p≤0.05; ** p≤0.01).*

	PARAMETERS	Input		Output	
		x̄	sd	x̄	sd
anthropometric parameters	body height [cm]	130.21	9.21	135.86**	9.41
	body weight [cm]	26.88	6.10	30.30**	5.96
	BMI	15.59	1.57	16.29**	1.51
motor parameters	1 leg stand with EC [s]	32.00	18.81	27.2	20.97
	4x10 m shuttle run [s]	12.78	0.67	12.02**	0.77
	standing long jump [cm]	142.78	16.38	153.96**	19.51
	bent arm hang [s]	36.10	19.77	38.87	23.32
	straddle support hold [s]	13.58	8.81	19.54*	10.23
	back extension [number]	36.87	10.55	45.83*	25.58
	hanging knee tucks [number]	14.22	5.70	15.48	7.43
	modified PU [number]	17.70	3.67	21.35**	4.50
	sit-ups in 60 s [number]	39.43	4.94	43.87**	7.32
	2-min endurance SR [number]	18.48	2.19	18.22	1.93

Motor changes. The mean values of the following motor tests increased significantly at the level of p≤0.05: straddle support hold and back extension endurance test. The following tests increased significantly at the level of p≤0.01: 4x10m shuttle run, standing long jump, modified push-ups, and sit-ups in 60s. No significant changes were observed in the following tests: bent arm hang test and hanging knee tucks. On the other hand, the values of 1 leg stand with eyes closed and 2-min endurance shuttle run decreased insignificantly. Detailed data of all tests are presented in Table 2.

DISCUSSION

The results of the study revealed that the examined group of girls improved significantly in most of the examined parameters, which leads to the conclusion that aerobic gymnastics training has beneficial effects on the development of motor abilities in 6-11-year old children. It is commonly known that physical and motor development of children is further enhanced when they grow in a supportive environment that offers multiple developmentally appropriate activities (Božanić et al., 2011; Šalaj et al., 2019). On the other hand, positive effects of gymnastics training itself is undoubtable and can be seen in many other research findings (Fallah et al., 2015; Mertashl et al., 2015; Karachle et al., 2017).

Aerobic gymnastics, as one of the types of gymnastic that offer a wide range of complex movements, plays an important role in the development of motor abilities. According to Jemni et al. (2006), aerobic gymnasts are characterized by incredible neuromuscular connections and high level of strength, power, flexibility, and muscular endurance, as well as speed and coordination. Typical for aerobic gymnastics performance are frequent changes of the body position in space, transitions from static to dynamic elements and vice versa (Culjak et al., 2003; Bressel et al., 2007). However, some authors (Beunen et al., 1999; Caine et al., 2001) have stated that it is impossible to establish the effects of training on performance in gymnastics due to such factors as limitations in the available data, incomplete information about the training process and inability to consider other factors affecting growth and maturation.

Surprisingly, our study revealed that the examined group's performance in the test examining postural stability decreased, which is contrary to other researchers' findings. Poliszczuk et al. (2012) examined the dynamic balance abilities over the period of 2-year training in young rhythmic gymnasts. They noted that their ability to maintain dynamic balance increased as they progressed in their training. In the study by Boraczyński et al. (2013), the authors noted significant changes in the static balance test in 7-year-old girls after completing a 12-month specific artistic gymnastics training. Akın (2013) analyzed the effects of 12-week gymnastics training on preschool children and noted a positive effect on the development of balance abilities as well. We don't have an explanation for the decrease of balance abilities in our research group; however, it might have been the result of dramatic changes in postural control that may occur around the eigth year of life (Forssberg, 1985; Shumway-Cook & Woollacott, 1985). Another performance decrease was seen in the 2-min endurance shuttle run. This particular test is used to assess the level of aerobic fitness; however, the score can be highly influenced by the practice and motivation levels. For this reason, the scoring can be subjective, and it does not have to reflect a decrease in the group's performance level.

There have also been significant changes in the anthropometric parameters like body weight, body height and BMI. These findings were expected and can be attributed to the process of biological maturation during the one-year period of the research. According to Laczo (2014), the dynamics of the growth of school-age children (6-11 years) is characterized by a 5cm annual increment. However, it should be noted that an increase in body mass can have a negative influence on performance in aesthetic sports as there is a high power to body mass ratio (Boraczyński et al., 2013). Similar results could be seen in many other research findings (Tibenská et al., 2010; Poliszczuk et al., 2012; Genc, 2020).

CONCLUSION

The positive effects of one-year aerobic gymnastics training on the group of 6-11-year-old girls could be seen in most of the examined parameters. Considering anthropometric parameters, the mean values of body height, body weight, and BMI increased significantly at the level of $p \leq 0.01$. Considering motor parameters, significant changes at the level of $p \leq 0.05$ were observed in the following tests: straddle support hold and back extension endurance test. Significant changes at the level of $p \leq 0.01$ were observed in the following tests: 4x10m shuttle run, standing long jump, modified push-ups, and sit-ups in 60s. Positive but insignificant changes were observed in the following tests: bent arm hang test and hanging knee tucks. The values of 1 leg stand with eyes closed and 2-min endurance shuttle run decreased insignificantly. It is important to note that coaches did not specifically paid attention to a performance improvement in the selected tests during the period of one-year training. The gymnasts completed their regular trainings and competitions that included general physical preparation, performance of the routines and difficulty elements of aerobic gymnastics. An analysis of the results of our study makes it possible to conclude that:

1. The body height, body weight and BMI of examined group increased considerably.
2. One-year aerobic gymnastics training had positive effects on the development of explosive power of lower limbs, explosive power of back muscles, explosive power of upper limbs, speed and dynamic and static power of abdominal muscles.
3. Coaches should pay more attention to the development of static power of upper limbs, balance abilities and aerobic fitness.
4. More research concerning the effects of aerobic gymnastics training on motor abilities is needed to expand the knowledge in this particular field.

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MUSCLE FLEXIBILITY AND EXPLOSIVE POWER IN YOUNG ARTISTIC GYMNAST BOYS AT DIFFERENT PERFORMANCE LEVEL

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Abstract
A gymnast can not succeed without enough muscle strength and endurance. The aim of this study was to determine the differences between explosive power and flexibility in young boy gymnasts at different performance levels. Ninety-five young boys who participated in this study were divided into three groups: two artistic gymnast groups (N=53) and a sedentary (N=42) group. Artistic gymnasts were classified by their performance level and sports history to an elite (E, N=15) and/or a non-elite (Ne, N=38) group. The explosive power of subjects was determined via vertical and standing long jumps. The sit and reach flexibility test was used to determine lower body muscle flexibility. Our results showed that explosive power and flexibility test records were significantly different among the three groups (P≤0.001). They led to a conclusion that sport specific exercise training resulted in a concurrent improvement in explosive power and flexibility of young gymnasts.

Keywords: *explosive power, flexibility, young gymnast.*

INTRODUCTION

There are plenty of studies focused on anthropometrical & physiological characteristics of high level performance (Alp & Gorur et al., 2020; Marinšek & Pavletič, 2020; Mahoodet al., 2001) and talent identification in sports (Elferink-Gemser et al., 2004). Blanksby et al (Blanksby et al., 1986) stated that success of any talent detection and development program completely relies on clear comprehension of specific performance requirements in different kinds of sports. Data on these requirements, based on the diversity of anthropometrical, physiological and physical fitness measurements, is helpful in all sports including gymnastics, a highly specialized discipline, which involves excellent use of flexibility and explosive power (Kinser et al., 2008).

Muscle flexibility refers to the absolute range of movement in a joint or a series of joints, and length in muscles that cross the joints to induce bending movement. Flexibility varies among individuals, particularly in regards to differences in length of multi-joint muscles (Blakey & Educational, 1994). Similarly, the term explosive power refers to the ability to exert maximum muscular contraction instantly in an explosive burst of movements (Bompa & Buzzichelli, 2015). Researchers have shown that flexibility as a pain-free range of motion

(ROM) and explosive power are the two crucial factors in gymnast's performance. For example, Douda et al. found some morphological and physiological characteristics in elite gymnastics, including flexibility and explosive power. In other words, they were significantly higher in elite gymnasts compared to non-elite gymnasts (Douda et al., 2008).

Most studies so far have focused on the information about the relationship between the body composition and physical fitness in children from developed countries (Douda et al., 2008; Linthorne et al., 2005) with conflicting results, as well as on the biomechanical and kinematical characteristics of elite athletes, narrowed down to biomechanical long jump characteristics such as velocity, angle, and the distance of jumping (Muraki et al., 2005). As we mentioned, there are similar research studies in some other sports. For instance, Hansen et al (Hansen et al., 1999) investigated performance differences between 11-year-old elite and non-elite soccer players over a two-year period. Their results showed an initial preponderance in broad jump and isometric strength in elites as opposed to non-elites that remained in place throughout the two-year period. Kubo et al (Kubo et al, 2006) compared fat-free mass and thicknesses of various muscles among judo players in three different levels including Olympians, universal competitors and a group who did not participate in intercollegiate competitions. They reported the best scores for the first group, followed by universal competitors and the third group.

Overall, our review of literature indicates that limited and inconclusive data are available regarding young artistic gymnasts at different performance levels. In spite of a fairly universal recognition of the need for flexibility and explosive power in gymnastics, surprisingly little research has been conducted to compare flexibility and explosive power in young gymnast at different performance levels. Thus, the present study attempted to elucidate the potential effects of training specificity on muscle flexibility and anaerobic power in young artistic gymnasts at different performance levels. In other words, since our subjects were in the same age group and were teenagers, we wanted to know to what extent their differences were due to sport-specific training for young gymnasts as this may have different effects on flexibility and anaerobic power. Therefore, the aim of the present investigation was to study the possible effects of training specificity on muscle flexibility and anaerobic power in young artistic gymnasts at different performance levels.

METHODS

Ninety five healthy children volunteers performed the fitness and performance tests. Before the beginning of the study, invitation letters were sent to the parents for passive consent to their children's participation. The young athletes' participation was totally voluntary even with their parents' consent and all procedures were approved by University Hospital authorities. The inclusion criteria were: sedentary lifestyle (for a minimum of at least 9 months prior to participating in the testing), normal resting heart rate, absence of cardiovascular and pulmonary signs and symptoms. Exclusion criteria included obesity (BMI greater than or equal to 30 kg/m^2), presence of musculoskeletal disorders, history of cardiovascular disease, orthopedic problems, or other medical conditions that would contraindicate exercise. The anthropometric parameters and health related physical fitness were assessed in 95 boys who participated in this analysis. The children were divided into two groups: gymnasts (N=53) and sedentary (N=42). Within the gymnast group, athletes were classified on the basis of their sports history and performance level in an E (N=15) or a NE (N=38) group with those who won first to third place in official competitions as elite gymnasts and those who trained for 6 to 9 months and did not earn any position in official competitions as beginners.

The subjects completed a 15 minute warm-up (consisting of walking around the mat, streching the muscles, jogging, joints rolls & calestenics, running, floor stretching) at 60–75% of their personal capacity before the physical test protocols were performed. Each testing session was conducted and monitored by the investigators. The subjects were encouraged to exert maximal effort in all tests. Following the initial evaluations, the subjects were instructed to maintain the same level of physical activity throughout the study (three training sessions per week, each session lasted between 75 to 90 min). The subjects performed two different types of jumps: standing long jumps (LJ) and vertical jumps (VJ) as well as the sit and reach test to measure flexibility.

For LJ, the child stands behind a line marked on the ground with feet slightly apart. The subject takes off and lands using both feet, swinging the arms and bending the knees to provide forward drive. The subject attempts to jump as far as possible.

The vertical jump height was determined using a force platform with specifically designed software (Bioware, Kistler, Switzerland). Ground reaction as well as moments of force were collected by a Bertec force plate (Model 4060A). A video-based (60 Hz), three-dimensional motion analysis system (Motion Analysis Corp.) was used to collect and process the cinematic data. Cinematic data were refreshed by a low-pass, fourth-order Butterworth filter with an effective cutoff frequency of 8Hz. Jumping height was determined as the centre of mass displacement calculated from force development and measured body mass. Each subject had three trials interspersed with a one minute rest interval between the jumps. During the test, subjects used hands in the jumping motion. The best jump from each subject was used in data analysis (Lucertini et al., 2013).

The subjects were seated on the ground with their legs fully extended in front of them, feet 20 centimeters apart, toes pointed upwards, and soles of the feet flush with the base of the flexibility box. If it was difficult for the subject to fully straighten their legs, an assistant could help press the legs down by applying pressure above or below the knees. The push could be smooth and static, no bouncing or lunging was allowed. The subject then reached slowly forward, the fingertips of both hands remaining in contact with the slide at all times. Once the subjects had reached their farthest extension point, the position had to be held for a “two count”.

The participant was allowed two more attempts, if desired, and the best of the three was recorded. The scores were measured in half-centimeter increments, rounding up to the nearest half-centimeter. Subjects were asked to do each repetition at maximum power. Also, in order to increase the subjects' motivation, the record of each repetition was announced loudly and there were special rewards for five people per group who achieved the best results. The test was performed without shoes. These tests are easy to administer, can be done both indoors or outdoors, and a young population can be assessed in a short time (Opstoel et al., 2015).

Anthropometric measurements were taken by one operator (CM) using conventional criteria and measuring procedures. Weight was assessed to the nearest 0.1 kg using a certified electronic scale (Tanita electronic scale BWB-800 MA (Wunder SA.BI. Srl)) (2). Height to the nearest 0.01 m was measured using a Harpenden portable stadiometer (Holtain Ltd., Crymych, Pembs. UK). The body mass index (BMI) was calculated as kg/m^2 (Siahkouhian & Esmaeilzadeh, 2011).

One-way ANOVA was used to detect differences among the groups. If differences were found, the Tukey's post hoc test was used to analyze differences among the specific groups. The Pearson product-moment correlation was also used to determine the relation between the selected variables. The significant level for statistical analysis was set at 0.05.

RESULTS

Standing long jump records showed that there were significant differences among the three groups (mean±SD of E, NE, and sedentary groups: 156.20±16.38 vs. 140.68±25.16 vs. 120.62±34.68 cm respectively; P≤0.01, Figure 2).

Comparison of vertical jump records also showed that there were significant differences among the three groups (mean±SD of E, NE, and sedentary groups: 29.47±4.89 vs. 26.58±5.45 vs. 21.74±9.65 cm respectively; P≤0.05, Figure 3).

Findings showed that there was a strong significant correlation between VJ

Physical characteristics of the subjects are presented in Table 1. Muscle flexibility comparison of the three groups using One-way ANOVA is shown in Figure 1. Our results revealed that sit and reach records were significantly different among the three groups (mean±SD of in E, NE, and sedentary groups: 21.53±2.9 vs. 14.13±5.61 vs. 5.62±4.16 cm, respectively; P≤0.001, Figure 1).

(r=0.72, P≤0.001) and LJ (r=0.63, P≤0.01) in flexibility in the E group. A significant positive correlation was found between VJ and LJ (r=0.84, P≤0.001) in the E group. Results also showed a significant positive correlation between VJ (r=0.54, P≤0.01) and LJ (r=0.49, P≤0.01) in flexibility in the NE group. A significant positive correlation was found between VJ and LJ in the NE group (r=0.64, P≤0.001). No significant correlation was found between variables in the sedentary group (Table 2).

Table 1
Demographic data of the subjects in the three groups.

Variables	Sedentary	Intermediate	Elite	p value
Number	42	38	15	-
Age (yrs)	8.79±1.74	9.53±1.33	9.93±1.48	0.855
Height (cm)	130.12±11.52	126.61±10.78	128.87±10.55	0.636
Weight (kg)	31.43±11.01	27.89±4.27	24.67±4.62	0.421
BMI (kg/m^2)	21.45±3.58	19.72±5.07	18.65±4.12	0.764

Table 2
Correlation coefficient between flexibility and lower body explosive power among three groups.

Groups	E Group	NE Group	Sedentary Group
		Flexibility	
Vertical Jump	R= 0.72 P≤ 0.001	R= 0.54 P≤ 0.01	R= -0.03 P≤0.8
Long Jump	R= 0.63 P≤ 0.01	R= 0.49 P≤0.05	R= 0.20 P≤0.19

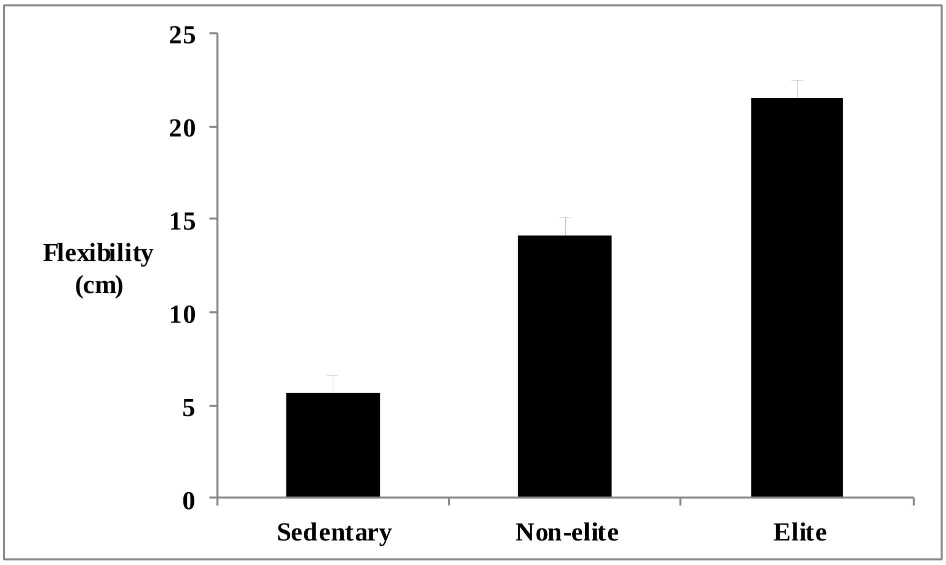

Figure 1. Comparison muscle flexibility in the three groups.

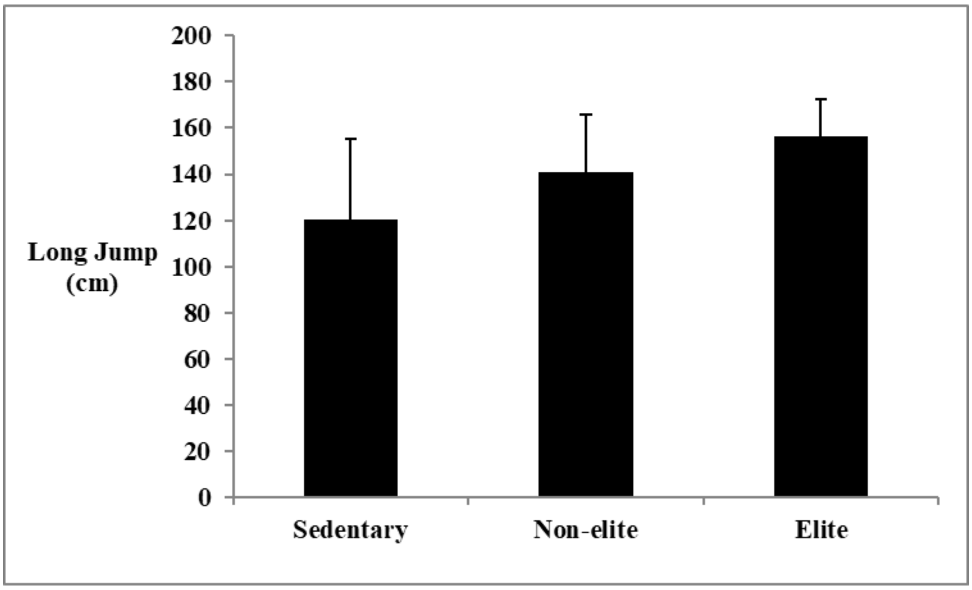

Figure 2. Comparison standing long jump records in the three groups.

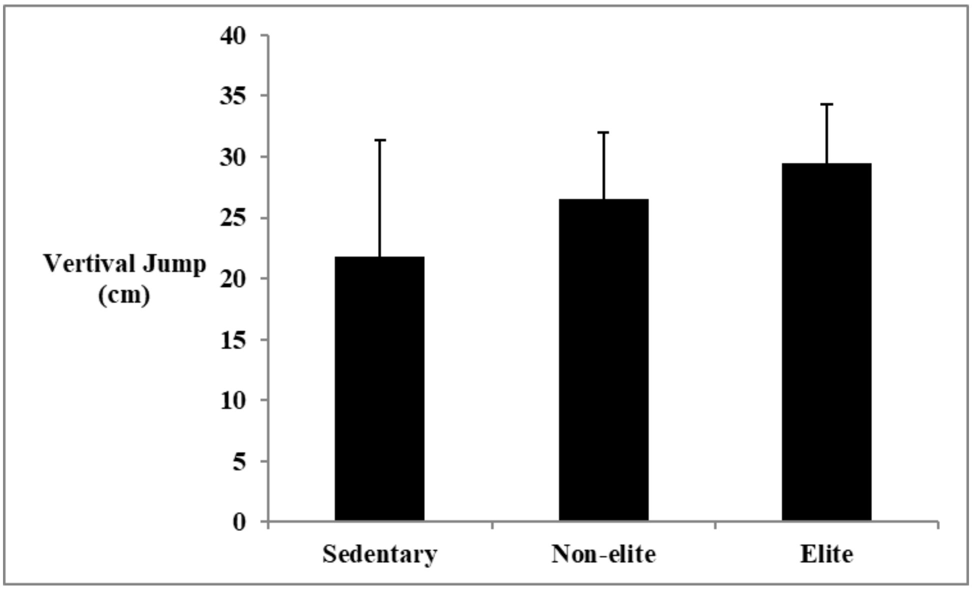

Figure 3. Comparison vertical jump records in the three groups.

DISCUSSION

In contrast with other studies, we focused mainly on young boy artistic gymnasts at different performance levels rather than on high class athletes. We matched the artistic gymnasts ages at different performance levels in the three groups to minimize the effects of maturation on the performance (Chimera et al., 2004). This leads to more accurate conclusions, refers to the differences between the performance characteristics of the subjects, and helps to distinguish the role of training on superiority. Another reason we studied young boys was because younger children have immature joints. In addition, we included young boys only to avoid delaing with the differences in physical abilities between boys and girls due to the muscular growth of young boys (Kamtsios, 2008).

Our results revealed that muscle flexibility and explosive power were significantly different among the three groups. In fact, the E artistic gymnasts had higher muscle flexibility and explosive power than the NE artistic gymnasts and the sedentary subjects indicating that these abilities are crucial for gymnastic performance (Karve, 2015). Both the E and the NE artistic gymnasts recorded well above the reported values for the sedentary subjects. Among sports disciplines, gymnastics has always been known for its intensive training (Malina et al., 2013). Monem et al (Jemni et al., 2006) surveyed and compared the performance level of the upper body and the lower body in national (N) and international (I) level gymnasts in relation to their training schedule. They argued that differences in quality and quantity of their strengh training, implemented by coaches, led to their preponderance in performance compared to another group. Similarly, it has been shown that whole body vibration (WBV) improves flexibility and explosive strength of lower limbs in young trained artistic gymnasts and at least maintains the initial level of performance (Dallas & Kirialnais, 2013; Dallas et al., 2014; Dallas et al., 2014). In fact, it has been shown that the status and improvement of physical conditioning in pre-adolescence is significantly related to the kind and extent of physical activity performed (Mellos et al, 2014). It can therefore be argued that specific kinds of gymnastic trainings have significant effects even on younger children. Also, this might indicate that the E artistic gymnasts are better trained for sprints and able to utilize more ATP-CrP in short sprints (Kuznetsova et al., 2015).

While there are studies that demonstrate superiority of muscle strength (Hansen et al., 1999), maximal anaerobic power (Kubo et al., 2006), fat-free mass (Lopes et al., 2005) and peak power (Lucertini, Spazzafumo,), in E athletes compared to NE ones, there are also others, such as Malina et al (Malina et al., 2013) and Kuno et al (Kuno et al., 1995), who disagree. Our results are consistent with the results of those researches who reported preponderance of elite athletes.

A higher degree of explosive power in the E artistic gymnasts compared to the NE and the sedentary subjects may be due to their training status. This may provide an explanation for the discrepancy in values (Massidda et al., 2014). It seems that anaerobic metabolism, specifically the ATP-CrP system, is more developed in E artistic gymnasts than in others, indicating that sport-specific training may influence the ATP-CrP energy production (Kuznetsova et al., 2015; Fernandez-Villarino et al., 2015). This indicates that the explosive power is mainly related to the specificity of training.

Hence, jumping performance may be more dependent on the specificity of training, since it is reasonable to assume that the higher explosive power in the E artistic gymnasts is due to their better neuromuscular coordination (Mehrtash et al., 2015). In addition, it seems that practicing gymnastics at the professional level causes neuromuscular adaptations, including an increase in tension and muscle elasticity, and a reduction in the sensitivity of the Golgi tendon organs. Stretch reflection occurs during the eccentric contraction phase, and leads to a further facilitation of the motor unit recruitment during concentric contraction. Additionally, tissue transplantation stores elastic energy, and if muscles contract quicker, components of connective tissue can produce more power. Finally, the sensitivity of the Golgi tendon organs that play a protective role against too much pressure on muscles decreases in the course of professional practice of gymnastics (Chimera et al., 2004, Impellizzeri et al., 2008).

We showed a strong relation between muscle flexibility and explosive power in the E gymnasts, while the NE artistic gymnasts showed moderate relationships between muscle flexibility and explosive power. Previously Živković et al (Živković & Lazarević, 2011) reported a strong linear connection between the set of tests of dimensions of flexibility and explosive power as a predicting system and a criterion variable for sprint speed at 100 and 200 metres.. The strong relationship between muscle flexibility and explosive power in the E artistic gymnasts indicates that elasticity of the muscles may play an important role (Wilson & Flanagan, 2008). As muscle flexibility and explosive power are mainly recruited in the gymnastic routines, it seems that the specificity of the training with regards to the motor patterns used in gymnastic emphasizes the more complex neuromuscular tasks and facilitates a concurrent improvement in these abilities.

CONCLUSIONS

Overall, our results revealed that sport-specific exercise training has a substantial effect on improvement of explosive power and flexibility even in young gymnasts. It seems that increased experience of gymnastic exercise training did not limit the lower body muscle flexibility; rather, it improved muscle flexibility concurrent with the lower body explosive power.

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ACUTE EFFECTS OF DYNAMIC AND PNF STRETCHING ON LEG AND VERTICAL STIFFNESS ON FEMALE GYMNASTS

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Abstract

*The purpose of the study was to investigate the acute effect of Dynamic (DS) and PNF stretching on leg (K_{leg}) and vertical stiffness (K_{vert}) on female gymnasts. Thirty-one female athletes from various types of gymnastics (artistic, rhythmic, team gymnastics) participated in this study ([Mean ± SD] age: 22.32 ± 3.35 years, height: 164.87 ± 4.96 cm, body mass: 57.20 ± 6.54 kg) performed 30 sec running bouts at 4.44 m *s-1, under 3 different stretching protocols (PNF, DS, and no stretching [NS]). The total duration in each stretching condition was 6 minutes, and each of the 4 muscle groups was stretched for 40 seconds. Leg and vertical stiffness values were calculated using the "sine wave" method. No significant influence of stretching type on Kleg and Kvert were found after DS and PNF stretching. However, significant changes were found in Fmax, Dy, flight time (tf), step rate (SR), and step length (SL) after DS and PNF stretching protocol, indicating that DS produced greater changes compared to PNF protocol.*

Keywords: *warm-up activities, kinematic, kinetic, gait.*

INTRODUCTION

In order to improve their physical and psychological preconditioning but also to reduce the risk of injury (Woods, Bishop, and Jones, 2007), athletes in various sports perform warm-up before their training or competition. The static (SS) and dynamic stretching (DS) as the most common forms of stretching in the warm-up with the resulting benefits on flexibility have been extensively documented (Dallas, Tsiganos, Tsolakis, Tsopani, Di Cagno, Smirniotou, 2014). Although there is no agreement on which of them is the most effective method in flexibility, it is widely accepted that DS utilizes movements that mimic the specific sport or exercise in an exaggerated yet controlled manner altering the musculotendinous system (MTS) (Herda, Costa, Walter-Herda, Valdez, and Crammer, 2013), therefore, altering stretch-shortening cycle (SSC) performance. DS involves controlled movements of the limbs within the ROM (Fletcher, 2010). However, there is no clear consensus on how stretching influences performance, with DS reported to both improve (Hough, Ross, Howatson, 2009) or reduce performance (Costa, Herda, Herda, and Cramer, 2014).

Many authors agree that during SSC activities, active muscles of the MTS are pre-stretched and absorb energy, part of which is temporarily stored in a series of elastic elements and later reutilized in the phase where the muscles act concentrically to enhance the maximum mechanical power produced during the concentric phase (Svantesson, Ernstoff, Bergh, and

Grimby, 1991). It has been shown that lower limb stiffness affects power production during an SSC skill in adults, indicating that those with a stiffer MTS might benefit from faster elastic recoil during the upward, concentric, phase of the skill (Arampatzis, Schade, Walsh, and Brϋggemann, 2001). Furthermore, the use of elastic energy that has been stored during SSC exercises is affected by an optimum level of musculotendinous stiffness (Belli and Bosco, 1992).

Previous findings examining male subjects report that DS has no positive effects on running performance at a moderate pace (Zourdos, Wilson, Sommer, Lee, Park, and Henning, 2012) and it does not change leg and vertical stiffness during submaximal running (Pappas, Paradisis, Exell, Smirniotou, Tsolakis, and Arampatzis, 2017).

Another form of stretching to improve flexibility is the proprioceptive neuromuscular facilitation stretching (PNF). There are two neuromuscular mechanisms involved in PNF movement patterns: (a) reciprocal inhibition refers to the contracting of the target muscle (TM) (agonist) and relaxing of the opposed muscle (OM) (antagonist) that facilitates muscle contraction, and (b) the inverse stretch reflex or the Golgi tendon reflex is the protective mechanism that causes a relaxation in the muscle if too much tension is produced. Active motion is used to arouse the reciprocal inhibition response, increasing the lengthening of the muscle (Holcomb, 2000). PNF stretching prior to exercise has been found to increase MTU stiffness (Rees, Murphy, Watsford, McLachlan, and Coutts, 2007). The acute effect of PNF stretching on performance showed contradictory results (Bradley et al., 2007; Dallas et al., 2014; Kay et al., 2015; Konrad et al., 2017; Manoel et al., 2008).

It is considered that PNF stretching can produce an increase in MTU stiffness which is believed to be linked to an increased ability to store and release elastic energy. PNF stretching involves SS and isometric contractions in a cyclical pattern to enhance joint ROM (Funk et al., 2003), with two common techniques being contract-relax (CR) and contract-relax agonist contract (CRAC) (Sharman, Cresswell, and Riek, 2006). Both methods (PNF, DS) have been shown to increase the range of movement (ROM) (Lucas and Koslow, 1984); however, it is debatable which method is the most effective (Hardy and Jones, 1986). The distinctive characteristic of PNF is a brief isometric contraction that, performed while the muscle is held on stretch, lasts between 5 and 10 seconds (Hindle et al., 2012; Leblebici, Yarar, Aydın, Zorlu, Ertaş, and Kıngır, 2017; Marek et al., 2005; Sa, Matta, Carneiro, Araujo, Novaes, and Oliveira, 2016) with some of them showing a reduction in stiffness (Sa et al., 2016) and others showing no significant changes. Maybe this isometric contraction may act as pre-activation resulting in a consequent increase in muscle strength.

A lot of studies used the spring mass model (SMM) to describe lower limbs stiffness (Blickhan, 1998; Pappas et al., 2017). Although stiffness is considered an important factor in running performance (Arampatzis et al., 2001), the acute effects of different stretching methods during training and competition on vertical and leg stiffness are not well known. No other studies have examined the acute effect of PNF stretching on vertical and leg stiffness. In gymnastics, performing vaults on the table horse and/or during an acrobatic series, e.g., rondat backward salto, or in rhythmic gymnastics during the preparatory phase of a gymnastics series, athletes need to acquire a great amount of horizontal velocity in a short time with a few strides allowing them to perform the exercises that follow. To the authors' knowledge, only one study (Pappas et al., 2017) has examined the influence of SS and DS on male physical education students' leg stiffness during running, concluding that DS has no influence on leg or vertical stiffness, even though it has been proposed that DS reduces MTU stiffness. Nevertheless, no studies have determined the effects of DS and PNF stretching on vertical and leg stiffness in the same setup. Thus, this study is the first that has examined and compared the effects of DS and PNF stretching on leg and vertical stiffness, i.e., the kinematic and kinetic variables during submaximal treadmill running on female gymnasts. A secondary purpose was to inform future warm-up protocols and physical preparation if there were benefits to PNF or DS. It was hypothesized that both PNF and DS would acutely change the leg and vertical stiffness during treadmill running.

METHODS

Thirty-one female participants from various types of gymnastics (artistic, rhythmic, team gymnastics) participated in this study ([Mean ± SD] age: 22.32 ± 3.35 years, height: 164.87 ± 4.96 cm, body mass: 57.20 ± 6.54 kg, training experience: 10.63 ± 4.96 years). All subjects were healthy and recreationally training 8 to 12 hours per week according to their gymnastics training course. No participants with any lower extremity injuries in the prior 4 months were included and none of them had any lower limb length asymmetry. Ethical approval was gained from the Research Ethics Committee of the National and Kapodistrian University of Athens, School of Physical Education and Sports Science, and each participant signed informed consent forms before testing.

We used a randomized, counterbalanced, within-subjects experimental design to compare the acute effects of dynamic stretching (DS) and PNF stretching on leg and vertical stiffness during treadmill running. The study carried out over the course of 4 visits on non-consecutive days and at the same time of the day. On the first visit, the familiarization with the stretching methods and exercises was performed. On the second, third and fourth visit, the subjects were randomly selected to perform one of 3 possible conditions: (a) PNF stretching (PNF), (b) dynamic stretching (DS); and (c) control (without stretching) (CON).

Stretching Protocols. During 3 laboratory visits, the subjects performed the PNF, DS or control protocols in random order.

Proprioceptive Neuromuscular Facilitation (PNF) stretching. PNF stretching incorporates SS and isometric contractions in a cyclical pattern to enhance joint ROM (Sharman et al., 2006). The PNF stretches used the "hold relax" method (HR) in which the target muscle (TM) was lengthened and held in that position while the participant contracted the TM to its maximum isometrically for 6 seconds (Sa et al., 2016) against manual resistance (applied by the researcher), followed by a 10-second passive stretch (Etnyre and Abraham, 1986). The participant flexed the dominant leg to a knee-joint angle of 90º. For the contract phase of the PNF stretch, a padded chair was placed beneath the foot so the participant could apply maximal isometric tension at a 90º knee-joint angle. Two repetitions of each stretching exercise for each muscle group were held for 10 seconds at a point of discomfort but not pain, as acknowledged by the participant. There was no rest between the two trials. Verbal encouragement was provided during each muscle activation. The average time of each stretching period was 4 minutes approximately.

Dynamic Stretching (DS). For DS, a technique similar to the procedures of a previous study (Pappas et al., 2017) was used.

PNF flexibility conditioning protocol

Quadriceps. For the contract phase of the PNF stretch, participants were sat on a padded desk and maximal isometric tension, against manual resistance applied by the researcher at a point of mild discomfort as acknowledged by the participant, with knee extensors muscle at a 135° knee-joint angle applied approximately for 6 seconds. After a period of 3 seconds relaxation, the participant, standing upright with one hand against a wall for balance, flexed the TM to a knee-joint angle to stretch knee extensors muscles for 10 seconds.

Hamstrings. For the contract phase of the PNF stretch, from supine position, the knee flexors of the TM were moved in a stretch position via hip flexion, as indicated verbally by the participant, while maintaining full knee extension and the foot dorsi-flexed to 90º. The participant's contralateral control limb was held in contact with the support surface. The participant then attempted to maximally activate the knee flexors and hip extensors of the preferred limb for 6 seconds. After a period of 3 seconds relaxation the participant activated the agonist muscle groups (knee extensors and hip flexors) of the TM for 10 seconds.

Hip extensors. For the contract phase of the PNF stretch, from prone position with hip joint at the end of an elevated surface, flexed hip of the TM approximately at 135º applying maximal isometric tension of hip extensors for 6 seconds. After a period of 3 seconds relaxation the participant flexed the preferred leg from supine position on hip and knee joint trying to approach the chest, stretching the hip extensors muscles for 10 seconds.

Plantar flexors: For the contract phase of the PNF stretch, from upright position, supporting the foot tip (tread) on the end of an elevated surface in dorsal flexion, the participant maintained maximal isometric tension of the plantar flexors against a manual resistance applied on the participant's shoulders by the researcher at a point of mild discomfort, as acknowledged by the participants, for 6 seconds. After a period of 3 seconds relaxation from the same position, the participant tried to bring the heels to the lowest position to stretch the plantar flexors muscles for 6 seconds.

No stretching. The participants sat for 6 minutes and did not perform any stretching.

Before each pre-test, participants completed a 5-minute warm-up on the treadmill at 2.22 m $\cdot s^{-1}$. They randomly performed 1 of the 3 stretching exercises (PNF, DS, and CON), followed by post-tests. All participants completed three warm-up conditions, performed on different days with 48 hours apart, in a counterbalanced order. During the pre-tests and post-tests, they performed 30-second running bouts at 4.44 m $\cdot s^{-1}$on a motorized treadmill at their preferred step rate and length. This submaximal speed was chosen as an average of the range of running speeds (3.33–6.67 m $\cdot s^{-1}$) used in previous studies (Morin, Dalleau, Kyrolainen, Jeannin, and Belli, 2005; Pappas et al., 2017). To calculate vertical and leg stiffness the method described by Morin et al. (2005) was used.

$$K_{vert} = F_{max} \cdot \Delta y_c^{-1}$$

$$F_{max} = mg\frac{\pi}{2}\left(\frac{t_f}{t_c}+1\right)$$

$$\Delta y_c = -\frac{F_{max}{t_c}^2}{m\pi^2} + g\frac{{t_c}^2}{8}$$

$$K_{leg} = F_{max} \cdot \Delta L^{-1}$$

$$\Delta L = L - \sqrt{L^2 - \left(\frac{vt_c}{2}\right)^2} + \Delta y_c$$

K_{vert} is the vertical stiffness; K_{leg}, the leg stiffness; F_{max}, the maximal ground reaction force during contact; Δ_y, the vertical displacement of the center of mass; **m**, the body mass; t_f, the flight time; t_c, the contact time; **ΔL**, the lower limb length variation; and **L**, the resting lower limb length.

Data Analysis. The Quintic Biomechanics v21 (Sutton, United Kingdom) software was used for the analysis of all video-recorded steps. The leg and vertical stiffness calculation were based on the method of "sine wave" as suggested by Morin et al. (2005). To calculate leg and vertical stiffness, the mean values of flight time and contact time of 10 consecutive steps were used, whereas for the estimation of step rate and step length the method by Paradisis and Cooke (2001) was applied.

The IBM SPSS (version 24) was used for the statistical analyses. The arithmetic mean, SD, and range were calculated for each variable and trial. Raw data were checked for normality using a Shapiro-Wilk test as the sample size was .50. To explore the impact of time (pre-stretching and post-stretching) and condition (PNF, DS, and CON) on the dependent variables, a 2-way (time 3 condition) repeated measures analysis of variance was used for the statistical analyses. Sphericity was checked using Mauchly's test, and the Greenhouse-Geisser's correction on degrees of freedom was applied when necessary. In cases where interaction between time and condition was detected, the simple effects were investigated, and Bonferroni's correction was used. In the absence of interaction, the main effects of the 2 factors (time and condition) on the dependent variables were investigated. All statistical significances were tested at a = 0.05.

RESULTS

No significant interaction effect was found between condition and time for contact time ($F_{(2, 60)} = 0.483$, $p > 0.05$). A significant main effect was found for condition ($F_{(2, 60)} = 10.295$, $p < 0.001$, $\eta^2 = 0.255$, power = 0.983); post hoc comparisons indicated statistically significant greater contact time of the NS compare to the other two conditions ($F_{(1, 30)} = 1.100$, $p > 0.05$; table 1).

A statistically significant time by condition interaction ($F_{(2, 60)} = 6.781$, $p < 0.005$, $\eta^2 = 0.184$, power = 0.906) was found in flight time. The post hoc analysis showed a significant increase in flight time after PNF (mean difference = 5.386 s, p < 0.005, 95% CI = -0.009-0.002 s) and DS (mean difference = 8.015 s, p < 0.001, 95% CI = -0.012-0.005 s) (table 1).

A significant interaction effect was found between condition and time for step rate ($F_{(2, 60)} = 6.063$, $p < 0.005$, $\eta^2 = 0.168$, power = 0.870), with the post hoc analysis indicating a significant decrease in step rate after PNF stretching (Mean difference = -1.921 Hz, p < 0.005, 95% CI = 0.020 – 0.106 Hz) and after DS Mean difference = -3.273 Hz, p < 0.001, 95% CI = 0.050 – 0.161 Hz) (table 2).

The interaction effect between condition and time was significant for step length ($F_{(2,60)} = 6.631$, $p <.005$, $\eta^2 = 0.181$, power = 0.899), with the post hoc analysis indicating a significant increase in step length after PNF stretching (Mean difference = 1.950 m, p <0.005, 95% CI = -0.045 - -0.008 m) and after DS (Mean difference = 3.159 m, p < 0.001, 95% CI = -0.065 - -0.023 m) (table 2).

Furthermore, a significant interaction effect between condition and time was found for **Δy** ($F_{(2, 60)} = 6.748$, $p < 0.005$, $\eta^2 = 0.184$, power = 0.904), with post hoc analysis indicating a significant increase in **Δy** after PNF (mean difference = .0019 m, p < 0.01, 95% CI = -0.003-0.001 meters) and DS (mean difference = .0031 m, p < 0.001, 95% CI = -0.005-0.002 meters) (table 3).

The interaction effect between condition and time was statistically insignificant for **ΔL** ($F_{(2, 60)} = 2.267$, $p > 0.05$, $\eta^2 = 0.070$, power = 0.414). A significant main effect was found for condition ($F_{(2, 60)} = 13.680$, $p < 0.001$, $\eta^2 = 0.313$, power = 0.997); post hoc comparisons indicated statistically significant increase in **ΔL** after PNF and DS conditions. Further, a significant main effect was found for time ($F_{(1, 30)} = 5.151$, $p < 0.05$, $\eta^2 = 0.147$, power = 0.593) (table 3).

No significant interaction effect was found between condition and time for leg stiffness ($F_{(2, 60)} = 0.015$, $p > 0.05$). A significant main effect was found for condition ($F_{(2, 60)} = 8.520$, $p < 0.001$, $\eta^2 =$

0.221, power = 0.942); post hoc comparisons indicated statistically significant differences between PNF and Control condition (table 4) due to the greater values of the NS condition.

Further, no significant main effect was found for time ($F_{(1, 30)} = 1.100$, $p > 0.05$). The interaction effect between condition and time was statistically significant for vertical stiffness ($F_{(2, 60)} = 3.919$, $p < 0.025$, $\eta^2 = 0.116$, power = 0.685), with post hoc analysis indicating a significant decrease in vertical stiffness after PNF (mean difference = 0.667 ($kN \cdot m^{-1}$), $p < 0.05$, 95% CI = 0.071-1.263 ($kN \cdot m^{-1}$) and DS (mean difference = 1.209 ($kN \cdot m^{-1}$), $p < 0.05$, 95% CI = 0.378-2.041 ($kN \cdot m^{-1}$) (table 4).

A significant interaction effect between condition and time for $\mathbf{F_{max}}$ was revealed ($F_{(2, 60)} = 5.233$, $p <.005$, $\eta^2 = 0.149$, power = 0.813), with post hoc analysis indicating a significant increase in $\mathbf{F_{max}}$ after PNF (mean difference = 1.543 kN, $p < 0.05$, 95% CI = -0.038-0.003 kN) and DS (mean difference = 2.533 kN, $p < 0.001$, 95% CI = -0.051-0.017 kN) (table 4).

Table 1
*Mean values, SD, and percentage difference for temporal and spatiotemporal variables between pre- and post-measurement for the three conditions. **

	Tc (ms)	tf (s)
PNF		
Pre	0.202 ± 0.01	0.103 ± 0.02
Post	0.202 ± 0.01	0.109 ± 0.02 †
Δ%	0.19	5.38
DS		
Pre	0.206 ± 0.01	0.105 ± 0.02
Post	0.207 ± 0.01	0.113 ± 0.02 †
Δ%	0.67	8.01
NS		
Pre	0.207 ± 0.01	0.111 ± 0.02
Post	0.207 ± 0.01	0.111 ± 0.02
Δ%	0.23	0.34

*tc = contact time; tf = flight time; PNF = Proprioceptive Neuromuscular Facilitation; DS = dynamic stretching; NS = no stretching. †Significant difference between pre-measurement and post-measurement (p < 0.05).

Table 2
*Mean values, SD, and percentage difference for temporal and spatiotemporal variables between pre- and post-measurement for the three conditions. **

	SR (Hz)	SL (m)
PNF		
Pre	3.283 ± 0.23	1.358 ± 0.09
Post	3.220 ± 0.22 †	1.385 ± 0.09 †
Δ%	-1.92	1.95
DS		
Pre	3.227 ± 0.23	1.383 ± 0.09
Post	3.121 ± 0.17 †	1.420 ± 0.07 †
Δ%	-3.27	3.16
NS		
Pre	3.150 ± 0.19	1.414 ± 0.08
Post	3.141 ± 0.18	1.418 ± 0.08
Δ%	-0.29	0.27

SR = step rate; SL = step length; PNF = Proprioceptive Neuromuscular Facilitation; DS = dynamic stretching; NS = no stretching. †Significant difference between pre measurement and post measurement (p < 0.05).

Table 3
*Mean values, SD, and percentage difference for stiffness, kinetic, and kinematic variables between pre measurement and post measurement for the conditions. **

	ΔL (m)		Δy (m)	
PNF				
Pre	0.171	± 0.02	0.0465	± 0.01
Post	0.173	± 0.02†	0.0484	± 0.01 †
Δ%		1.36		4.01
DS				
Pre	0.177	± 0.01	0.0481	± 0.01
Post	0.183	± 0.01†	0.0512	± 0.01 †
Δ%		2.88		6.43
NS				
Pre	0.181	± 0.01	0.0504	± 0.01
Post	0.182	± 0.01	0.0506	± 0.01
Δ%		0.53		0.46

*ΔL = change in leg length; Δy = vertical displacement of the center of mass; PNF = Proprioceptive Neuromuscular Facilitation; DS = dynamic stretching; NS = no stretching

Table 4
*Mean values, SD, and percentage difference for stiffness, and kinetic, variables between pre measurement and post measurement for the conditions. **

	Kleg (km.m -1)		Kvert (km.m-1)	Fmax	
PNF					
Pre	7.91	± 1.63	29.094 ± 4.47	1.336	± 0.19
Post	7.90	± 1.47	28.427 ± 4.13†	1.356	± 0.17†
Δ%		-0.07	-2.29		0.11
DS					
Pre	7.56	± 1.13	28.084 ± 4.25	1.333	± 0.18
Post	7.51	± 1.34	27.016 ± 3.34	1.357	± 0.17
Δ%		-0.27	-0.53		2.53
NS					
Pre	7.53	± 1.25	27.162 ± 3.60	1.356	± 0.17
Post	7.51	± 1.34	27.016 ± 3.34	1.357	± 0.17
Δ%		-0.27	-0.53		2.53

* PNF = Proprioceptive Neuromuscular Facilitation; DS = dynamic stretching; NS = no stretching. Kleg = leg stiffness; Kvert = vertical stiffness; Fmax = maximal ground reaction force; †Significant difference between pre measurement and post measurement ($p < 0.05$

DISCUSSION

The purpose of this study was to examine the acute effect of DS and PNF stretching on leg (K_{leg}) and vertical stiffness (K_{vert}) and in kinematic and kinetic variables during submaximal treadmill running on female gymnasts. The comparison of DS and PNF stretching protocols revealed no significant influence of stretching type on K_{leg} and K_{vert}. However, significant percentage differences (Δ%) were found in F_{max}, Dy, flight time (t_f), step rate (SR), and step length (SL) after DS (1.54; 6.43; 8.01; -3.27; and 3.16, respectively) and PNF stretching protocol (0.11; 4.01; 5.38; -1.92; and 1.95, respectively), indicating that DS produced greater changes compared to PNF protocol.

The results of the study are consistent with findings from a previous study (Pappas et al., 2017) which revealed that DS did not influence leg or vertical stiffness during treadmill running on male physical education student. DS seems to result in a small increase in lower limb force production which may have an impact on running mechanics, even though it has been proposed that DS reduces MTU stiffness after four 30-second bouts of DS (Herda et al., 2013). It is possible that the persistence of the stiffness is due to an internal mechanism of the lower limbs that tends to keep the level of stiffness unchanged (Pappas et al., 2017).

The reduction in MTS stiffness, referred to in a previous study (Herda et al, 2013), may be due to the greater number of repetitions (4-5) that they applied. It should be noted that despite the beneficial effect of stretching on the kinetic and kinematics variables, there was no improvement in regards to the stiffness of the lower limbs. Possible explanations for DS effectiveness may be attributed to the mechanisms resulting from an increase in temperature within the muscles such as a reduction in joint and muscle stiffness, greater nerve impulse conduction rate, force velocity relationship alterations, and increased glycogenolysis, glycolysis, and high energy phosphate breakdown (McMillian et al., 2006).

It is mentioned that both protocols (DS, PNF stretching) used in the present study produce an improvement in the spring mass characteristics (F_{max}, ΔL, Δy). The increase in F_{max} after DS may be attributed to physiological factors associated with a more active warm-up (Fletcher, 2010). The longer flight time and the greater Δy that are present in both protocols are the result of the larger F_{max} and the unchanged contact time. It is noteworthy that the lower limb compression during the stance phase did not change significantly after DS and PNF stretching. Therefore, the increased F_{max} may be the result of more efficient energy storage and return or a more efficient motor unit force production. The elevated F_{max} resulted in a longer step length and consequently a lower step rate during running.

Our results reinforce findings of Pappas et al. (2017) who examined the effects of DS stretching on stiffness during running on male participants and found percentage differences (Δ%) in F_{max}, Dy, t_f, SR, and SL were 1.74, 4.50, 5.84, -2.12, and 2.25 values that are comparable with our results. The observed production of greater force from the lower extremities at the same contact time after the DS led to a longer flight time and an increased vertical displacement of the CoG on contact that may allow for more efficient storage and reuse of the elastic energy and may also have done more mechanical work at the same degree of compression (Pappas et al., 2017). Producing greater force from the lower extremities at the same contact time, following DS, led to a longer flight time and increased vertical displacement of the CoG upon contact. Therefore, it is possible that the lower limbs showed more efficient storage and reuse of the elastic energy after the DS, and also generated more mechanical work at the same degree of compression. This more efficient post DS performance improved the length and stride frequency (Pappas et al., 2017).

No other studies examined the acute effect of PNF stretching on stiffness during running; therefore, direct comparison is not possible. Data of Marek et al. (2005) suggest that both PNF stretchings reduce the force- and power-producing capabilities of the leg extensors during voluntary maximal concentric isokinetic muscle actions at 60 and $300^{o} \cdot s^{-1}$. This reduction may be due to the duration of isometric contraction and the resulting fatigue of the TM during the stretching regime, but also the duration of the stretching protocols ranging from 15 (Konrad et al., 2017; Young and Elliot, 2001) or 20 to 30 s (Barroso et al., 2012; Bradley et al., 2007; Marek et al., 2005; Sa et al., 2016). The differing effect for PNF stretching on kinetic and kinematic variables during treadmill running suggests that a neurological facilitation might be present from the preceding contraction of the TM used in the hold-relax method (Young and Elliott, 2001). In contrast to the traditional view that muscles are subject to relaxation after a twitch, other researchers claim that a lingering discharge (facilitation) results from the contraction phase of the PNF stretch (Moore and Hutton, 1980). The findings of the present study have practical applications. Although neither DS nor PNF stretching influence leg or vertical stiffness during submaximal running, both forms of stretching cause changes in kinematic parameters associated with step rate (SR), step length (SL) and lower limb's force production which in turn positively affect the running speed.

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THE INVESTIGATION OF APPROACH RUN IN TERMS OF AGE, GENDER, BIO-MOTOR AND TECHNICAL COMPONENTS ON VAULTING TABLE

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Abstract

Vault is one of the main apparatuses for both female and male gymnasts in artistic gymnastics (AG). The optimal vaulting technique depends on many variables, such as the approaching run. Gymnastics is one of the early specialization sports as it is necessary to start training at an early age. For this reason, the aim of the current study was to investigate the relationship among age, biomotor and technical components in relation to the approach run velocity and other variables in AG. Furthermore, similarities and differences between genders were researched. Twenty female and twelve male gymnasts took part in the study. Speed, agility, explosive power, run-up velocity were measured. Additionally, Reactive Strength Index (RSI) and Peak High Velocity distances (PHV_Distance) were calculated. Kinematic parameters during the handspring vault were calculated by a two-dimensional video analysis. A statistical comparison between genders was performed by the Mann Whitney U test. The relationships between parameters were given by Spearman correlation coefficients (r). Anaerobic power, 0-20 m speed, 20 m speed velocity, and the hand contact time were significantly different between genders (p<0.05). The approach run significantly correlated with the chronological age (r=0.66; p=0.002 for female and r=0.96; p<0.001 for male gymnasts), PHV_Distance (r=0.69; p=0.001 for female and r=0.97; p<0.001 for male gymnasts) and the biological age (r=0.69; p=0.001 for female and r=0.97; p<0.001 for male gymnasts). As the approach run velocity increases, vaulting performance is affected positively. While speed tests significantly correlated with the approach run in male gymnasts, there was no correleation for females. In addition, trainers should keep in mind that the relationship between bio-motor development and biological age of gymnasts is important in training programs.

Keywords: *vaulting table, peak high velocity distance, maturity level, kinematic analysis.*

INTRODUCTION

Unlike most other sports, which usually consist of a few activities or apparatuses, artistic gymnastics (AG) includes multiple competition performances on different apparatuses. The vaulting table is one of the main apparatuses for both female and male gymnasts. Gymnasts may perform several vaults chosen from the Code of Points (CoP) which determines the difficulty level. Handspring is considered as a fundamental vault element for gymnasts due to its developmental role in the acquisition of more complex vaults (Irwin & Kerwin, 2009). Each element performed on the vault table comprises seven distinctive phases: running, jumping on the take-off board, take-off board support, the first flight phase, table support, the second flight phase, and landing (Čuk and Karacsony, 2004; Atiković & Smajlović, 2009; Atiković, 2012; Prassas et al., 2006; Takei, 2007). The optimal vaulting technique depends on many variables (Eb et al., 2012). Three biomechanical variables are suggested to be predictors of a successful vault run: (1) degrees of turns around the transversal axis, (2) degrees of turns around the longitudinal axis, and (3) body's moment of inertia around the transversal axis in the second flight phase (Atiković & Smajlović, 2011). Furthermore, successful performance requires optimisation of all seven phases (Elizabeth et al., 2010). Among these phases, the vault run is considered to be the basis of the kinetic energy production (Atiković, 2012; Naundorf et al., 2008) and the approach-run is crucial to achieve task dependent velocity before the vaulting motion (Haigis & Schlegel, 2020). Small velocity decreases at the approach run stage may be necessary for visual adjustments in the final steps to land onto the take-off board (Bradshaw, 2004). Gymnasts usually reach the maximum run-up speed a couple of meters before the final foot contact, before they hit the take-off board (Čuk and Karacsony, 2004; Eb et al., 2012). The ability to take off is critical to perform vault elements (Bradshaw & Rossignol, 2004).

Gymnastics is categorized as one of the early specialisation sports branches. It requires many skills, such as coordination and a developed central nervous system. In order to succeed in sports like gymnastics, it is necessary to start training at an early age (Temürçi et al., 2020). As training starts at an early age, the explosive power of gymnasts may be influenced by specific training (Bencke et al., 2002). It is critical for gymnasts (Salam & Jaafar, 2020) to have adequate explosive power to implement movements while maintaining body control. Long-term athlete development (LTAD) is an approach to sport that describes a model that starts in childhood and follows a planned, systematic, and person-centred path (Balyi et al., 2013). On the other hand, biological maturity is determined using the skeletal age, gender development status and somatic maturity (Malina and Bouchard, 1992). In LTAD, athletes' personal characteristics such as age, physical and mental maturity are considered (Temürçi et al., 2020).

Biomechanical characteristics of a movement, affected by bio-motor development, is a factor that decides the difficulty of an element in gymnastics. In addition, jumping performance and running speed are reported to be predictors of the vaulting ability in gymnastics (Fernandes et al., 2016). The running approach in vaulting is carefully measured and rehearsed by gymnasts to ensure reliable performance. However, some problems such as balking, finding the run-up uncomfortable, or landing on the back of the take-off board contribute to sub-optimal vaulting performance. Due to our limited knowledge on this topic, these incidences of poor vault running may be frustrating for both the gymnasts and their coaches (Bradshaw, 2004). For this reason, the aim of the current study was to investigate the relationship between age, bio-motor development and the approach run. Gender differences were also investigated.

METHODS

Twenty female and twelve male national team gymnasts participated in this study; the descriptive data of gymnasts is given in Table 1.

All gymnasts performed the handspring element in a gymnastics hall. Before the tests, gymnasts completed a standardised warm-up for approximately 15 minutes (Mkaouer et al., 2018) including jogging, different jumps, stretching and preparations for the handspring vault. The vaulting table was adjusted to a height of 1.25m for female gymnasts (FIG, 2016a) and 1.35m for male gymnasts (FIG, 2016b). Participants did not receive any verbal encouragements during the experimental sessions. Before the experimental session started, gymnasts were given standardised instructions explaining the tests and they were familiarised with the experimental sessions.

Calculation of Peak High Velocity Distances. Gymnasts' chronological ages were recorded and Peak High Velocity (PHV) distances for each gymnast were calculated according to the following equations (Mirwald et al., 2002):

For men: Maturity Offset = –9.236 + [0.0002708 × (leg length x sitting height)] + [–0.001663 × (age x leg length)] + [0.007216 × (age x sitting height)] + [0.02292 × (body weight/height)]

For women: Maturity Offset = –9.376 + [0.0001882 x (leg length x sitting height)] + [0.0022 x (age x leg length)] + [0.005841x (age x sitting height)] + [—0.002658 x (age x body weight)] + [0.07693 x (body weight/height)]

Speed measurements. To determine gymnasts' speed, photoelectrical timing gates (FusionSport, Australia) were used. Gymnasts were asked to stay behind the first timing gate and be ready to sprint. When they broke the beam of the first gate, the timing started. The test was completed when the gymnast ran through the second gate which was 20m away from the first gate (Örs et al., 2017).

Pro Agility Test (ProAg-T). A timing gate at the starting line (Fusionsport, Australia) was placed for the ProAg-T test. On the left and right side, pins were positioned 5 yards apart (4,57m). When set, each gymnast initially touched the right pin followed by the left pin and finished the test by passing the starting line. The completion time for each gymnast was recorded (Daves and Roozen, 2012).

Run-up velocity measurements. The approach velocity leads to the performance of more difficult vaults and approach runs typically maximise it (Bradshaw, 2004). Furthermore, the running velocity is expected to increase with a certain rhythm. Especially the velocity of the athlete in the last 10meters is considered to be the most important indicator of performance (Bayraktar & Çilli, 2018). For this reason, the last 10 meters were divided into two parts to examine whether there was a change in speed in the last phases of the run, compared to the whole 10 meters:

(1) 13-8 meters (V_1),
(2) 8-3 meters (V_2),
(3) 13-3 meters (V_{10}).

The photocells (SmartSpeed, FusionSport, Australia) were placed to the last 10 meters of the vault run-up to the mat to measure the run-up velocity (Figure 1). The photocells used to determine the running times of gymnasts were placed at 3m, 8m, and 13m in front of the vaulting table (perpendicular). The photocell at 13m away from the vaulting table triggered the chronometer, the one at 3m away stopped it. The photocell at 8m recorded the split time. The following equations were used to calculate the velocity of the last 10m approach run separately for 5m and 10m.

$$Velocity\ (V) = Distance\ /\ Time$$
$$Velocity\ (V) = 5m\ /\ Time$$
$$Velocity\ (V) = 10m\ /\ Time$$

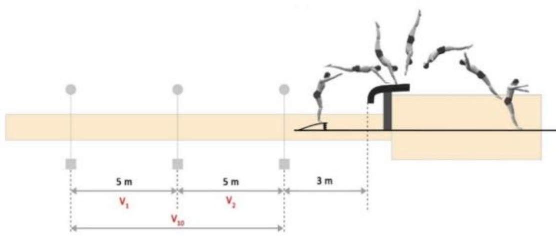

Figure 1. Photocell Placement.

Countermovement Jump (CMJ). To calculate the countermovement jump (CMJ) height, an electronic timing gate and a Smartjump mat were used (SmartSpeed, FusionSport, Australia). Gymnasts performed three maximal CMJ (Marques et al., 2009). From a standing position, gymnasts performed the crouching action (knees in full extension) and an immediate jump to reach the maximum height. Any influence of arm swings was eliminated by keeping hands on the hips (Vescovi & McGuigan, 2008). All gymnasts performed three repetitions and the best one was recorded.

Drop Jump (DJ). Gymnasts performed three maximal jumps on the electronic Smartjump mat (SmartSpeed, FusionSport, Australia) at 40cm DJ height. Gymnasts were instructed to step out of the box one foot at a time and not jump, and then jump as high and fast as possible on landing. After landing, gymnasts were asked to stay on the jumping mat. Flight Time (FT), Contact Time (CT) in milliseconds and Reactive Strength Index (RSI) which is FT to CT ratio were recorded (Markwick et al., 2015).

To determine the anaerobic power of gymnasts the following equation (Lewis formula) was used:

Power (P) = $\sqrt{4.9 \ x \ Body \ weight \ (kg)} \ x \ \sqrt{Vertical \ jump \ height \ (cm)}$ *(In this formula 4.9 is constant).*

A camera capable of recording at 120Hz was used for motion capture; it was set perpendicular to the vault table. Reflective markers were placed for a two-dimensional analysis on the nine anatomic landmarks: 1) heel, (2) lateral malleolus, (3) fifth metatarsal, (4) lateral femoral epicondyle, (5) anterior superior iliac, (6) hip, (7) elbow, (8) shoulder, (9) wrist (Örs & Turşak, 2020).

All markers were set on the facing side of the camera. A two-dimension video analysis was conducted by using a tracker software to calculate: (1) take-off angle, (2) penultimate-CT, (3) Take-off-Foot-CT, (4) Hand-CT variables.

IBM-SPSS 20.0 (Armonk, NY) was used for the statistical analysis. Descriptive characteristics of the gymnasts were presented as mean and standard deviation (±SD). The Mann Whitney U test was used for a statistical comparison of the genders. To express the correlations among variables, Spearman correlation coefficients (r) were used. The r value of correlation coefficient was classified as; $r \leq 0.49$ weak relationship; $0.50 \leq r \leq 0.74$ moderate relationship; and $r \geq 0.75$ strong relationship as used by Portney and Watkins (2015). A statistical significance level was at $p<0.05$.

RESULTS

The descriptive data of gymnasts are given in Table 1.

Drop jump contact time, RSI, ProAg-T, 5m-Reaction-Mat, V_Loss_1, V_Loss_2, V_Loss_3, last stride, horizontal and vertical jump, take-off angle, penultimate-CT, take-off-Foot-CT, approach run V10m and velocity usage percentage variables showed no statistically significant differences between genders ($p>0.05$). A comparison of the variables according to gender is given in Table 2.

Approach run showed statistically significant correlation with chronological age ($r=0.66$; $p=0.002$ for female and $r=0.96$; $p<0.001$ for male gymnasts), PHV_Distance ($r=0.69$; $p=0.001$ for female and $r=0.97$; $p<0.001$ for male gymnasts) and biological age ($r=0.693$;

p=0.001 for female and r=0.965; p<0.001 for male gymnasts) (Table 3).

Correlations among the approach run velocities and the last stride velocity, the horizontal and the vertical velocities on the take-off board are given in Table 4. The approach run velocity showed a statistical significance and positive correlations with V13-8m (respectively for female and male gymnasts; r: 0.86; p<0.001; r: 0.99; p<0.001), V8-3m (respectively for female and male; r: 0.91; p<0.001; r: 0.90; p<0.001) for both female and male gymnasts. Only V_Jump (vertical) showed no statistically significant relationship with the approach run velocity for female gymnasts (p>0.05).

Correlation results among the approach run, explosive power and agility variables are given in Table 5. There was no statistically significant relationship between the approach run velocity and CMJ, DJ-40, RSI, 0-20 m, ProAg-T, 5m-Reaction-Mat for females (p>0.05). Moreover, DJ-CT and RSI showed no statistically significant correlations with the approach run velocity for male gymnasts (p>0.05).

The approach run and kinematic variables showed no statistically significant relationship (p>0.05) except TO-Angle for female gymnasts (r=0.59; p=0.007) (Table 6).

Table 1
Descriptive demographic variables by gender.

Variables	Gender	
	Female (n=20)	Male (n=12)
Training age (years)	7.10±2.40	9.75±2.45
Chronological age (years)	13.26±1.63	16.53±2.95
PHV_Distance (years)	0.65±1.37	0.48±2.31
PHV_age (years)	12.60±0.38	16.05±0.86
Biological age (years)	12.65±1.37	14.48±2.31
Body weight (kg)	2.59±0.30	3.28±0.69
Body height (cm)	147.56±7.06	159.92±12.93
Sitting height (cm)	78.26±3.92	83.59±7.57
Leg length (cm)	69.30±4.27	76.33±5.70
BMI (kg/m^2)	18.02±1.97	20.18±3.50
Body fat percentage (%)	16.82±4.82	10.82±10.23
HG_Total_Relative	1.04±0.14	1.30±0.15

PHV: Peak High Velocity; BMI: Body Mass Index; HG: Hand Grip

Table 2
Comparison of the variables.

Variables	Gender			
	Female (n=12)	Male (n=20)	U	p
CMJ	30.53±3.53	39.06±5.74	21.500	*0.000**
DJ - 40 cm	32.14±4.67	41.87±7.76	29.500	*0.000**
DJ - CT	0.23±0.28	0.24±0.11	77.500	*0.098*
RSI	3.16±1.05	2.89±1.14	91.000	*0.259*
Anaerobic power (watt)	471.87±81.01	727.81±250.21	47.000	*0.004**
0-20 m (s)	3.52±0.15	3.17±0.25	27.500	*0.000**
ProAg-T (s)	5.81±0.49	5.36±0.45	61.000	*0.032*
5m-Reaction-Mat (s)	0.59±0.13	0.59±0.09	106.000	*0.933*
V_Loss_1 (s)	0.37±0.46	0.49±0.44	97.500	*0.381*
V_Loss_2 (s)	-0.30±0.35	-0.19±0.52	109.000	*0.668*
V_Loss_3 (s)	-1.06±0.69	-0.85±0.77	100.000	*0.436*
Last stride (m)	2.62±0.24	2.85±0.36	63.500	*0.055*
Jump (horizontal) (m)	1.81±0.23	1.70±0.29	95.000	*0.330*
Jump (vertical) (m)	0.86±0.15	0.86±0.16	119.500	*0.984*
Take-off-angle (°)	47.52±6.22	45.56±4.45	100.500	*0.448*
Penultimate-CT (s)	0.11±0.01	0.11±0.01	119.000	*0.966*
Take-off-Foot-CT (s)	0.12±0.01	0.11±0.01	70.500	*0.043*
Hand-CT (s)	0.25±0.06	0.18±0.05	32.000	*0.001**
Approach run -V10m- (m/s)	6.67±0.41	7.29±0.90	62.000	*0.024*
20m speed velocity-V10-20m-(m/s)	6.63±0.36	7.53±0.95	34.000	*0.001**
Velocity Usage percentage (%)	100.79±5.74	96.86±4.52	71.500	*0.059*

CMJ: Counter Movement Jump; DJ: Drop Jump; CT: Contact Time; RSI: Reactive Strength Index
*p<0.05

Table 3
Approach run and age variables correlations.

Variables		Chronological age	PHV_Distance	Gender
Approach run velocity -V10m- (m/s)	r	0.66**	0.69**	Female
	p	0.002	0.001	
	r	0.96**	0.97**	Male
	p	p<0.001	p<0.001	

PHV: Peak High Velocity
**p<0.001

Table 4
Approach run and velocity correlations.

Variables		V13-8m	V8-3m	V_Last stride	V_Jump (Horizontal)	V_Jump (vertical)	Gender
Approach run velocity -V10m- (m/s)	r	0.86**	0.91**	0.64**	0.52*	0.15	Female
	p	p<0.001	p<0.001	0.002	0.020	0.519	
	r	0.99**	0.90**	0.90**	0.90**	0.59*	Male
	p	p<0.001	p<0.001	p<0.001	p<0.001	0.045	

*p<0.05
**p<0.001

Table 5
Correlations among the approach run, explosive power and agility variables.

Variables		CMJ	DJ- 40	DJ - CT	RSI	Anaerobic power (watt)	0-20 m	ProAg - T	5m-Reaction -Mat	Gender
Approach run velocity -V10m- (m/s)	r	-0.14	0.34	0.45*	-0.30	0.82**	-0.16	-0.24	0.28	Female
	p	0.550	0.137	0.049	0.195	p<0.001	0.511	.0323	0.268	
	r	0.91**	0.62*	-0.12	0.12	0.95**	-0.90**	-0.78**	-0.62*	Male
	p	p<0.001	0.031	0.713	0.713	p<0.001	p<0.001	0.003	0.031	

CMJ: Counter Movement Jump; DJ: Drop Jump; CT: Contact Time; ProAg - T: Pro Agility Test
*p<0.05
**p<0.001

Table 6
Approach run velocity and kinematic variables correlations

Variables		TO-Angle	Penultimate-CT	TO-Foot-CT	Hand-CT	Gender
Approach run velocity -V10m- (m/s)	r	-0.59**	0.27	0.22	-0.51*	Female
	p	0.007	0.257	0.353	0.023	
	r	-0.55	-0.25	0.44	-0.26	Male
	p	0.067	0.428	0.155	0.418	

TO: Take-off; CT; Contact Time
*p<0.05
**p<0.001

DISCUSSION

The aim of the current study was to investigate the relationship between age, bio-motor and technical components specifically in relation to the approach run velocity and other variables in artistic gymnastics, and differences in genders were looked into as well. While anaerobic power, 0-20 m speed, 20m speed velocity, and hand contact time were found to be different between genders, other variables showed no significant differences. The approach run showed statistically significant correlations with chronological age, PHV_Distance, biological age, V13-8m and V8-3m.

The progress of velocity for the vault run in AG for the last ten years prior to the 2007 World Championships was analysed by Naundorf et al. (2008). According to the results of their study, the maximum approach run velocity of female gymnasts (n=51) during the handspring was reported to be 8.37 m/sec while the moderate approach run velocity for male gymnasts (n=62) was 9.00 m/sec. In the same study, authors compared the approach run velocities from the 2007 and 1997 World Championships and reported that gymnastics became faster for the past 10 years relative to their study year. In the current study, the mean approach run velocity was 6.67 m/sec for female gymnasts and 7.29 m/sec for male gymnasts. As seen from the comparison of our results and Naundorf et al. (2008), there are substantial differences in the approach run velocities. These differences may be attributed to the gymnasts' mean ages. In the current study, their mean age was 13.26±1.63, 16.53±2.95 for women and men respectively. Naundorf et al. (2008) analysed the World Championships and even those gymnasts who participated in the World Championships for the first time were at least 16, therefore female gymnasts were older than in our study. Furthermore, the numbers of gymnasts were also different. While 51 women and 62 men gymnasts were analysed by Naundorf et al. (2008), we analysed 12 women and 20 men gymnasts.

Vaulting in gymnastics has similar characteristics as the long jump and the pole vault in that it involves running toward a target. However, there are less complex post-flight actions in the long jump. Still, it is comparable to the gymnastic vaulting in the approach phase (Bradshaw, 2004). Bayraktar and Cilli (2017) conducted a biomechanical analysis of the long jump and reported that the speed reached at the end of the velocity test was considered the maximum speed. If the approach run speeds are more than 100%, it means that the sprint test was not performed at the maximum speed. The approach run that reaches 90% of the speed ability is considered a good level in many sports (such as long jump) where horizontal speed is important (Bayraktar & Çilli, 2017). Moreover, most of the necessary energy is produced by the run-up velocity; an effective conversion of the optimal run-up speed to the vertical speed at the board and the table is of paramount importance. A high horizontal velocity can create risks for a proper landing. As the gymnast cannot alter his/her horizontal velocity in the air, he/she stops or absorbs it during landing and thus increases his/her chances of a perfect landing (without a forward step). If the horizontal velocity is low, absorbing the horizontal energy at the landing without a step is easier. On the other hand, due to a higher flight phase, an increased impact on landing may increase the risk of injuries. (Eb et al., 2012).

In our results, the approach run velocities and velocity loss were similar for both genders. In vaulting, gymnasts need an adequate linear and angular momentum during the approach run and the table contact to complete the rotational needs in the post-flight phase (Hiley et al., 2015). In other words, as the approach run velocity increases, other components of the element and performance are positively affected. Moreover, the stride frequency and the stride length are considered to be components of the speed run. On the other hand, contact time is a sub-component of stride frequency and the longer the contact time, the greater the loss of speed. In a similar way, flight duration is also stated as a loss of time. In gymnastics, the approach run to the vault is not expected to be performed with a maximum speed run. An optimal approach run will become the basis for the next element. The velocity loss during the mentioned phases may help gymnasts to perform the element to a required quality.

The table contact time has been analysed in previous studies (Takei et al., 2000; Takei 1990; Takei and Kim, 1990, Kwon et al., 1990) and reported to be between 0.16-0.25 seconds. In our study this variable ranged between 0.18-0.25 seconds for both female and male gymnasts. These results seem to support the literature. Moreover, Farana and

Vaverka (2012) reported foot CT as 0.120 seconds and hand CT as 0.156 seconds for high level female gymnasts. In our study the average foot CT and hand CT were found to be 0.120 and 0.250 seconds respectively. While our results regarding the foot CT seem to support the literature, the hand CT of female gymnasts differs substantially from the literature. These differences may be due to the different level of gymnasts participating in each study. Farana and Vaverka (2012) worked with eight top level gymnasts with an average of 19.9 years who competed in a Grand Prix (2010, Ostrava) while our participants were 20 national team members with an average age of 13.3 years. As a result, the takeoff-Foot-CT of gymnasts was similar, but the hand-CT was longer for female gymnasts. The difference may be attributed to the fact that gymnasts in Farana and Vaverka (2012) were in an official competition and their performance may have required difficult movement in the second flight.

When the correlation between anaerobic power and approach run were examined, high correlations were found both for female and male gymnasts. Strength is one of the anaerobic power components. Girls reach PHV at the age of 12 while boys reach PHV at the age of 14 (Malina, Bouchard & Bar-Or, 2004). In the current study, PHV distances were 0.65 and 0.48 in females and males respectively, showing that they have just reached their peak body height. PHV is critical for strength training. However, the relationship between anaerobic power and approach running speed due to strength development determined in this study can be explained by the fact that gymnastics is an early specialisation branch.

Limitations

The current study has the following limitations:

(1) Twenty female and twelve male gymnasts participated in this study.

(2) The kinematic analysis consisted only of Take-off (TO) angles, penultimate CT, TO Foot CT, Hand CT variables.

(3) Only nine markers were put on gymnasts' anatomical landmarks.

CONCLUSIONS

In this study, similarities and differences between genders were determined. The results show that CMJ, DJ-40 cm and 20m speed velocity variables were found to be higher for male than female gymnasts. Furthermore, the 0-20m speed and the hand-CT were higher for female gymnasts. According to the results of our study, the approach run and speed tests did not show any significant correlations for female gymnasts. However, a high correlation was found between the approach run and the 20m speed test for male gymnasts. This may be a proof that male gymnasts use their potential speed in the approach run better than female gymnasts.

Additionally, the relationships among the handspring vault performance components in terms of training elements were determined. In this way, priorities can be set for tests that are used in bio-motor and technical applications that can be conducted by trainers and gymnasts in vault training. In addition, by means of this study, it will be helpful for trainers to evaluate the top performance potential level in gymnasts in relation to their biological age and maturity level.

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SHORT HISTORICAL NOTES XXI

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.

MEMORY ON OLYMPIC GAMES IN TOKYO 1964

The first Olympic Games in Asia were in Tokyo (Japan) in 1964. Competition as never seen before. Modern technology everywhere.

Male gymnasts from Japan won the second consecutive team title. Japan team represented: Yukio Endo, who also won all around, parallel bars, silver on floor; Takuji Hayata who also won rings, Haruhiro Yamashita who also won vault , Shuji Tsurumi who was second in all around, parallel bars and pommel horse, Takashi Mitsukuri and Takashi Ono. Three gold medals went to other countries. Miroslav Cerar (Slovenia, ex.Yougoslavia) won pommel horse, Franco Menichelli (Italy) won floor and Yuri Titov (Russia, ex. Soviet Union) won horizontal bar. Gold medals were really gold medals, not just covered with gold film.

In women gymnastics Soviet Union dominated as a team, which was represented Larisa Latinina, who won on floor, was second in all around, vault and third on beam and uneven bars; Polina Astakhova who won uneven bars, was second on floor and third in all around; Tamara Manina was second on beam; Elena Voltchetskaya, Tamara Gromova and Tamara Zamotaylova. The most decorated gymnast was Vera Caslavska (Czech, ex. Czechoslovakia) who won all around, beam and vault, and second with team.

At the end the most successful country Japan had (5 gold, 4 silver and 1 bronze medal), Soviet Union had most medals, but less gold ones (4 gold, 10 silver, 5 bronze medals). Medals had also Czechoslovakia, Italy, Yougoslavia, Hungary, United team of Germany and Finland.

Diploma from OG 1964 for Miroslav Cerar – 3rd place horizontal bar (Archive M.Cerar)

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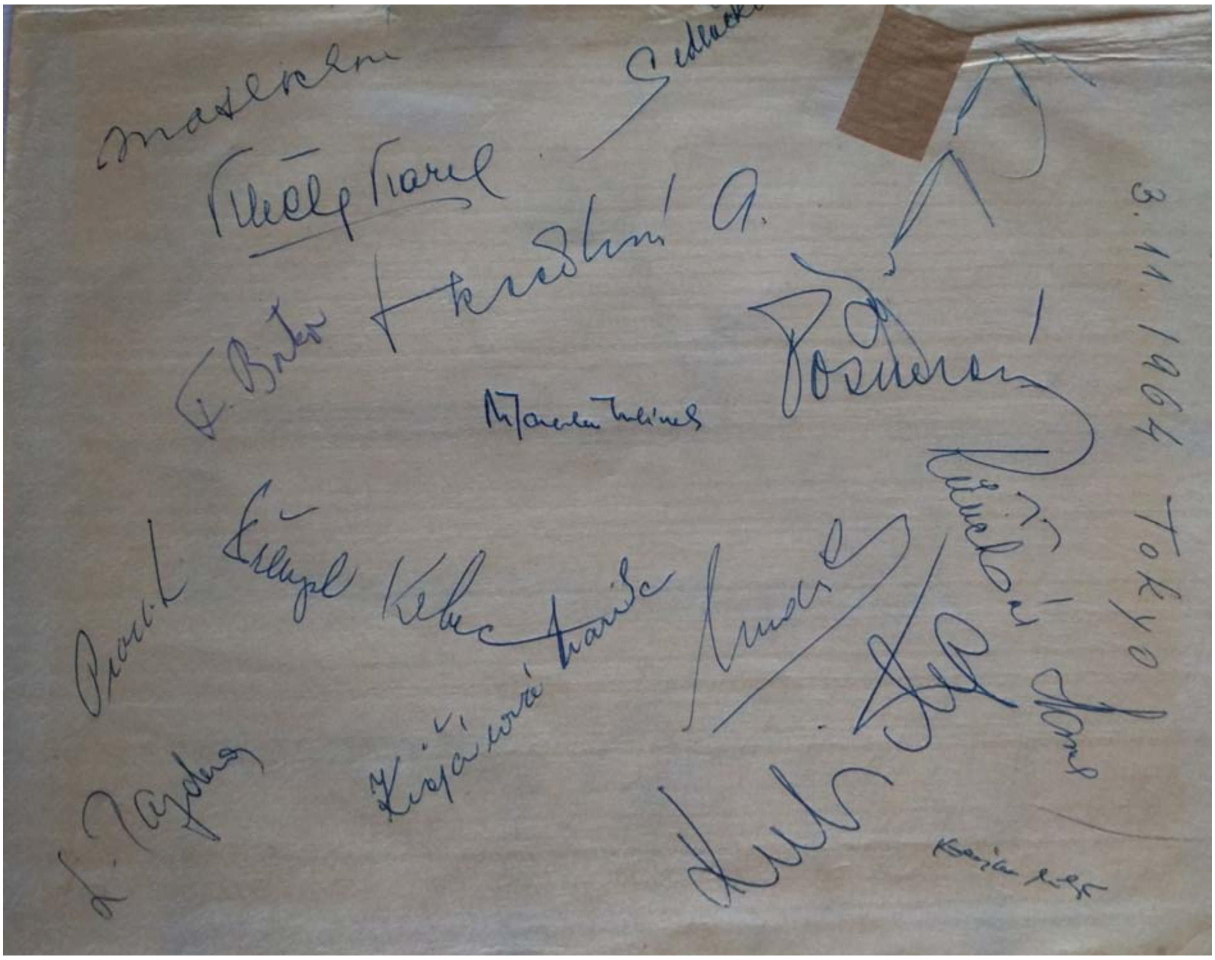
Gift from the Embassy of Japan in Slovenia, a newspaper excerpt on Miroslav Cerar victory, on photos are also Franco Menichelli, Vera Caslavska, and Polina Astakhova in Tokyo in 1964 (Archive M.Cerar)



Autographs of Czechoslovakia teams - men and women at Olympic Games in Tokyo 1964 on napkin. From left: Matlochová Jaroslava-coach, Klečka Karel, Sedláčková Jaroslava, František Bočko -reserve, Tkačíková Adolfína, Vera Čáslavská, Posnerová Jana, Germany-wife of Kubička Václav, Prorok Vladimír- coach, Přemysl Krbec, Ladislav Pazdera, Krajčírová Marika, Mudřík Bohumil, Ružičková Hana, Kubička Václav, Kolejka Miloš - judge

Slovenski izvlečki / Slovene Abstracts

Michal Bábela, Josef Oborný

»SPARTAKIADA« – DRUŽBENO-TELESNO KULTURNI POJAV NA OZEMLJU ČEŠKOSLOVAŠKE

Namen članka je bil opisati nastanek »Spartakiade« na ozemlju nekdanje Češkoslovaške. V članku smo se osredotočili na nastanek in razvoj množičnega športa na Češkoslovaškem od leta 1918, na nastanek »Spartakiade« ter opredelitev izraza "Spartakiade". V tem prispevku predstavljamo tudi kronološki seznam imen in kratek potek posameznih »Spartakiad«, ki so potekale na ozemlju Češkoslovaške v obdobju 1955 - 1985.

Ključne besede: zgodovina, fizična kultura, narod.

Thomas Lehmann, Alexander Winter, Alexander Seemann-Sinn, Falk Naundorf

UPORABA STVARNIH POSTOPKOV ZA DOLOČANJE ČASA TRAJANJA DRŽ NA KROGIH

Trajanje drže je ključni dejavnik za presojo sestav na krogih pri orodni telovadbi. Telovadce lahko kaznujejo z nepriznavanjem prvine, če je čas trajanja prekratek. Dinamometrični in kinematični merilni postopki omogočajo podporo sodnikom pri ocenjevanju trajanja drže. V tej raziskavi sta predstavljena dinamometrična postopka z dvema različicama (dms10 in dms5) ter kinematični postopek (kms), ki temeljijo na usposobljeni nevronski mreži in je bila proučena njihovo skladnost z ocenami sodnikov pri določanju časa drže. Za preverjanje skladnosti so bili izračunani Cohenove kappa (k) ter izračunani a) odstotno skladje in b) zanesljivost postopka. Dve dinamometrični metodi sta pokazali odstotno soglasje 83,5% (dms10) in 51,7% (dms5) s sodniško oceno časa drže. Odstotek soglasja km je bil 38,8%. Zanesljivost postopka je pokazala za dms10 zmerno (k = 0,58) in za dms5 primerno (k = 0,23) skladnost, medtem ko je kms pokazal slabo (k = 0,02) ujemanje. Rezultati so podprli dms10 za njegovo morebitno uporabo kot izvedljivo in zanesljivo metodo za pomoč sodnikom pri ocenjevanju časa drže na krogih. Dms5 in kms (v trenutnem razvoju) nista bila primerna za podporo sodnikov.

Ključne besede: moška orodna telovadba, krogi, ocenjevanje, čas, drže, merilni sklopi.

Stefan Kolimechkov, Iliya Yanev, Iliya Kiuchukov, Lubomir Petrov

KINEMATIČNA RAZČLENITEV DVOJNEGA SALTA NAZAJ STEGNJENO IN DVOJNEGA SALTA NAZAJ STEGNJO Z OBRATOM NA KROGIH

Krogi so disciplina znotraj telovadnega mnogoboja. Zadnja prvina na krogih – seskok - je v mnogih primerih ključna končno sodniško oceno. Večina osvajalcev odličij na krogih z olimpijskih iger in svetovnih prvenstev v zadnjih 20 letih je izvedla bodisi dvojni salto nazaj stegnjeno ali dvojni salto nazaj stegnjeno z obratom. Namen te raziskave je bil izvesti kinematično analizo obeh prvin. Merjenca, ki sta bila izbrana za to študijo, sta bila telovadca svetovnega razreda Filip Yanev in Jordan Jovchev iz Bulgarije. Seskoki so bili posneti z DV kamero po standardnem postopku kinematične razčlenitve. V delu izvedbe je hitrost gležnja pri Yanevu dosegla 11,11 m / s, pri Jovčevu pa 11,29 m / s, kotna hitrost pa se je znatno povečala na 10,0 rad / s in 9,05 rad / s za Yaneva oziroma Jovčeva . Vrtilna količina je zadostoval za uspešno izvedbo obeh seskokov. Dejanja Jovčeva, potrebna za popoln obrat, vključno z majhno nesočasnost gibanja roke, so se začela tik pred sprostitvijo obročev. Uspešno vleknjenje in sklanjanje pod krogi in močan zamah nog so ključnega pomena za uspešno izvedbo seskoka.

Ključne besede: orodna telovadba, krogi, seskok, salto nazaj.

Deborah Cecilia Navarro Morales, Eduardo Palenque in Jorge Deheza Justiniano

VPLIV KOTA V KOLKU NA UČINKOVITOST SALTA NAZAJ SKRČENO

Salto nazaj skrčeno je osnovna prvina telovadbe; na njegovo delovanje močno vpliva odriv. Namen tega dela je bil preučiti, kako kot v kolku pri odrivu vpliva na hitrost vrtenja in višino salta. V ta namen smo skupaj zabeležili 60 saltov 4 telovadcev (vsak po 15 saltov). Obstajale so tri skupine saltov, ki so temeljile na navodilih, ki so bile dane telovadcem: nobenih posebnih navodil, salto je bilo potrebno izvesti čim višje in salto je bilo potrebno izvesti čim hitrije. Nato so bili zapisi analizirani, da so bile izmerjene naslednje spremenljivke: največja višina masnega središča in največja kotna hitrost telesa med saltom, kot kolka in kot kolena pri odrivu. Zdi se, da so telovadci nagnjeni k upogibanju kolen, namesto da bi iztegnili boke, da bi lahko izvajali salto po navodilih.

Ključne besede: kot kolka, kotna hitrost, salto nazaj.

Sebastian Möck, Alina Korrmann, Petra Nissinen in Klaus Wirth

VPLIV NAJVIŠJEGA EKSCENTRIČNEGA NAVORA UPOGIBALK IN IZTEGOVALK KOLENA NA VIŠINO SALTA NAZAJ PRI TELOVADKAH

Orodna telovadba je sestavljena iz velikega števila skokov z vrtenjem okoli ene ali več osi. Da bi dosegli najbolj primerno višino leta za izvedbo želenega števila vrtljajev, je treba vzorec gibanja in značilnosti Parterja. Da bi upoštevali potrebno togost nog, da bi izkoristili elastičnost parterja, morajo mišice nog ekscentrično ustvarjati velike sile med stikom s parterjem. Tako bi lahko imela ekscentrična moč mišic kolena pomembno vlogo za višino salta in hitrost zaleta na preskoku. Raziskovali smo povezanost ekscentričnega najvišjega navora upogibalk in iztegovalk kolena ter višino navpičnega leta z višino salta in hitrostjo teka pri mladih telovadkah. Rezultati so pokazali srednje do močne, pomembne povezave med ekscentričnim najvišjim navorom in višino salta nazaj ter hitrostjo teka. Navpična višina leta je pokazala pomembne povezave z višino salta in hitrostjo teka. Zdi se, da ima ekscentrična mišična dejavnost pomembno vlogo pri uravnavanju togosti sklepov pri uporabi elastičnega odriva s parterja in odrivnih desk. Pri teku, na preskoku, se zdi enak mehanizem očiten in je v skladu z ugotovitvami glede teka v različnih športih.

Ključne besede: orodna telovadba, hitrost, moč.

Merve Koca Kosova, Sercin Kosova

PRIMERJAVA ČASA LETA IN OCEN POTOVANJA V VODORAVNI SMERI PRI AKROBATIH NA VELIKI PROŽNI PONJAVI

Pri prvi sestavi na ponjavi imajo skoki z nizkimi težavnostnimi vrednostmi večjo pojavnost v skladu z mednarodnimi pravili tekmovanja. V drugi sestavi, kjer je težavnost skokov pomembna za razvrstitev akrobata, imajo prednost skoki z visoko težavnostjo. Ta razlika lahko vpliva na druge ocenjevalne dejavnike v sestavi. V skladu s tem je bil cilj primerjati čas leta in rezultate vodoravnega potovanja v prvi in drugi sestavi. Podatki so bili rezultati turškega prvenstva v letu 2019-2020. Na obeh tekmovanjih sta bili ocenjeni tako celotna skupina akrobatov, kot ženska in moška skupina. Ugotovljeno je bilo, da so bili časi letenja in vodoravna potovanja za vse skupine leta 2019 statistično značilno nižji pri drugi sestavi v primerjavi s prvo sestavo ($p <0,05$). Glede na te rezultate so akrobati raje imeli bolj zapletene in težje elemente, da bi v drugi sestavi dosegli visoko težavnost v skladu z mednarodnimi pravili, zaradi katerih so lahko dosegli nižji čas leta in vodoravno potovanje v primerjavi s prvimi . Vaditelji in akrobati si morajo prizadevati za povečanje težavnosti, ne da bi zmanjšali skupni rezultat, medtem ko izbirajo skoke za drugo sestavo. Da bi našli to težavnostno stopnjo, lahko vadbo in poskusna tekmovanja izvajamo s sestavami z različnimi težavnostmi.

Ključne besede: velika prožna ponjava; čas leta; vodoravno potovanje; težavnost.

Alena Kašparová, Kateřina Doležalová in Viléma Novotná

USTVARJANJE MERSKIH POSTOPKOV ZA VREDNOTENJE RITMIČA PRI ŠTUDENTIH

Dobro razviti vzorci ritma gibanja imajo pomembno vlogo pri uspešnem učenju različnih telesnih dejavnosti in tudi pri športni uspešnosti. Univerzitetni študentje - bodoči učitelji športne vzgoje in športa - bi morali med študijem izboljšati svoje ritmične sposobnosti, da jih bodo lahko kasneje uporabljali pri svojem delu. To zahteva ustvarjanje merskih postopkov za ocenjevanje spretnosti ritma z glasbo. V prispevku so predstavljeni rezultati meritev, ki jih je opravilo 121 univerzitetnih. Merski sklop se je osredotočila na tri vrste glasbeno-gibalnih veščin: spretnosti in dejavnosti zaznavanja (postavke 1-18), spretnosti in dejavnosti ponavljanja (postavke 19-27) ter proizvodne spretnosti in dejavnosti (postavka 28). Podatki so bili statistično obdelani s klasično faktorsko analiza in teorijo odzivov spremenljivk (dvo parametrski model). Izračunane so bile zanesljivosti in veljavnosti merskih postopkov. Pričakovana zavrnitev predlagane hipoteze je bila potrjena tako za klasični sklop kot za sklop odziva. Edina izjema je bil model 4, kjer pa so indeksi primernosti (zlasti TLI = 0,537) bolj opozorili na pomanjkanje dokazov za zavrnitev hipoteze kot na popolno skladnost modela in podatkov. Namen je bil ustvariti in preizkusiti modele z najboljšo skladnostjo podatkov. Najboljša skladnost podatkov je bila ugotovljena pri modelih št. 1 in 5. Model 5 je bil enodimenzionalen in njegovi indeksi ustreznosti so pokazali boljšo skladnost modela in podatkov. Na podlagi teh modelov bi bilo treba razviti najprimernejši merski sklop, čemur bi sledila nova preveritev veljavnosti.

Ključne besede: glasbeno-gibalne spretnosti, ritem, faktorska analiza, teorija odziva.

Anita Lamošová, Oľga Kyselovičová, Petra Tomková

SPREMEMBE TELESNIH ZNAČILNOSTI IN GIBALNIH SPOSOBNOSTI PO ENOLETNI VADBI TELOVADNIH PLESOV

Namen raziskave je bil raziskati učinek enoletne vadbe telovadnih plesov na izbrane telesne in gibalne spremenljivke pri 6-11-letnih deklicah. V raziskavi sta sodelovali dve športni društvi s telovadnimi plesi na Slovaškem, skupaj je sodelovalo 23 deklet (povprečna starost na začetku študije je bila 8,04 ± 1,22 leta). Izbrana skupina je zaključila redno vadbo in tekmovanja v obdobju enega leta. Meritve so bile opravljene januarja 2019 in januarja 2020, sredi pripravljalnega obdobja. Normalnost porazdelitve lastnosti smo preučili s pomočjo Shapiro-Wilkovega postopka. Podatki so bili razčlenjeni z uporabo Wilcoxonovega testa s podpisanim rangom. Telesne značilnosti so se bistveno spremenile ($p \leq 0{,}01$) telesna višina, telesna teža in ITM. Gibalne sposobnosti so se znatno povečale na raven $p \leq 0{,}05$. Pri preskusu vesa v zgibi in vesi skrčno ni bilo napredka. Pri stoji na eni nogi z zaprtimi očmi in 2-minutnem vzdržljivostnem teku so se rezultati neznatno zmanjšali.

Ključne besede: telovadni plesi, telesne značilnosti, gibalne sposobnosti, vadba, dekleta.

Siahkouhian Marefat, Bahram Mohammad Ebrahim, Mogharnasi Mehdi

GBLJIVOST IN HIPNA MOČ MLADIH TELOVADCEV RAZLIČNIH RAVNI

Telovadec ne more uspeti brez dovolj mišične moči in gibljivosti. Cilj te raziskave je bil ugotoviti razlike med hipno močjo in gibljivostjo pri mladih telovadcih na različnih stopnjah uspešnosti. Petindevetdeset mladih fantov, ki so sodelovali v tej študiji, je bilo razdeljenih v tri skupine: dve skupini orodnih telovadcev (N = 53) in sedečo skupino (N = 42). Orodni telovadci so bili po svoji uspešnosti in športni zgodovini razvrščeni v vrhunsko (E, N = 15) in / ali nevrhunsko skupino (Ne, N = 38). Eksplozivno moč preiskovancev so določili z navpičnim skokom in skokom v daljino. S meritvijo predklona v sedu smo določili gibljivost spodnjih okončin. Naši rezultati so pokazali, da so se tri skupine bistveno razlikovale (P≤0,001). Prišli so do zaključka, da je vadba sočasno izboljšala hipno moč in gibljivost mladih telovadcev.

Ključne besede: hipna moč, gibljivost, telovadci.

George Dallas, Panagiotis Pappas, Costas Dallas, Giorgos Paradisis

HIPNI UČINKI DINAMIČNEGA IN PNF RAZTEZANJA NA NOGO IN NAVPIČNA TOGOST TELOVADK

Namen je bil raziskati hipni učinek dinamičnega raztezanja (DS) in PNF raztezanja na nogi (Kleg) in navpične togosti (Kvert) pri telovadkah. V tej študiji je sodelovalo enaintrideset telovadk iz različnih vrst telovadbe (orodne, ritmike, skupinskih akrobatskih sestav) ([povprečje ± SD] starost: 22,32 ± 3,35 leta, višina: 164,87 ± 4,96 cm, telesna masa: 57,20 ± 6,54 kg) izvedli 30-sekundne teka pri 4,44 m * s-1, pod 3 različnimi postopki raztezanja (PNF, DS in brez raztezanja [NS]). Skupno trajanje vsakega razteznega stanja je bilo 6 minut in vsaka od 4 mišičnih skupin je bila raztegnjena 40 sekund. Vrednosti togosti nog in navpične togosti so bile izračunane po metodi "sinusnega vala". Po DS in PNF raztezanju niso ugotovili pomembnega vpliva vrste raztezanja na Kleg in Kvert. Vendar so bile po postopku raztezanja DS in PNF ugotovljene pomembne spremembe v Fmax, Dy, času leta (tf), stopnji koraka (SR) in dolžini koraka (SL), kar kaže, da je DS povzročil večje spremembe v primerjavi s postopkom PNF.

Ključne besede: ogrevalne dejavnosti, raztezanje, tek, sila.

Berfin Serdil Örs, Işık Bayraktar, Emre Bağci, Mustafa Altunsoy, H. Ahmet Pekel

ZALET NA PRESKOKU GLEDE NA STAROST, SPOLU, SPOSOBNOSTI IN TEHNIČNE ZNAČILNOSTI PRESKOKA

Preskok je ena od disciplin moškega in ženskega mnogoboja v orodni telovadbi. Najprimernejša tehnika preskoka je odvisna od številnih spremenljivk, kot je zalet. Za telovadbo je značilno zgodnje usmerjanje, saj je treba z vadbo začeti že v zgodnji mladosti. Iz tega razloga je bil cilj raziskati razmerje med starostjo, gibalnimi in tehničnimi deli glede na hitrost zaleta in drugih spremenljivk orodne telovadbe. Poleg tega so bile raziskane podobnosti in razlike med spoloma. V raziskavi je sodelovalo dvajset telovadk in dvanajst telovadcev. Izmerjene so bile hitrost, gibčnost, hipna moč, hitrost zaleta. Poleg tega so bili izračunani indeks reaktivne moči (RSI) in največje hitrostne razdalje (PHV_Distance). Kinematične spremenljivke roke so bili izračunani z dvodimenzionalno video analizo. Statistično primerjavo med spoloma smo izvedli z izračunom Mann Whitney U. Povezanost je bila izračunana Spearmanovim korelacijskim koeficientom (r). Anaerobna moč, hitrost 0-20 m, hitrost 20 m in čas stika z roko so se med spoloma bistveno razlikovali ($p < 0,05$). Potek zaleta je bil pomembno povezan s kronološko starostjo ($r = 0,66$; $p = 0,002$ za ženske in $r = 0,96$; $p < 0,001$ za moške), PHV_Distance ($r = 0,69$; $p = 0,001$ za ženske in $r = 0,97$; $p < 0,001$ za moške) in biološko starost ($r = 0,69$; $p = 0,001$ za ženske in $r = 0,97$; $p < 0,001$ za moške). Ko se hitrost zaleta poveča, se poveča kakovost preskoka. Medtem ko so bili preizkusi hitrosti pomembno povezani z zaletom pri moških, pri ženskah ni bilo povezanosti. Poleg tega bi morali vaditelji upoštevati, da je v načrtih vadbe pomembno razmerje med gibalnim razvojem in biološko starostjo telovadcev.

Ključne besede: preskok, največja hitrostna razdalja, stopnja zrelosti, kinematika.