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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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EDITORIAL

Dear friends,

We are all eagerly waiting the Olympic Games in Tokyo. In the meantime, you can enjoy our first issue of Science of Gymnastics Journal this year. We have entered the thirteenth year of publication. Let's hope this number will bring us good luck!

In this issue we have many interesting articles. The first is by William Sands and his colleagues. They tried to answer the big question whether gymnastics is rising or sinking. It opens questions we need to consider, including whether to pursue the Olympic motto Faster, Higher, Stronger or perhaps "a healthy mind in a healthy body" is a worthy goal too.

There is a wide spectrum of other important research projects that our authors from many different parts of the world contributed. We are proud of our diversity and the range our authors cover.

We also have a small anniversary, i.e., this issue presents Anton Gajdoš's 20th short historical note, introducing two German gymnasts, Alfred Schwarzmann (Olympic all-around champion) and Walter Stefans, who were both members of the winning team at the OG in Berlin 1936.

From our June issue onward, we will add a DOI number to each article as the University of Ljubljana and our Faculty of Sport have been authorized to generate DOI.

We strongly recommend all authors to use Grammarly or Instatext (you can find them using any search engine on the internet) before sending their manuscript to the editor. Both tools are free and can improve your writing.

Just a reminder that if you cite the journal, its abbreviation in the Web of Knowledge is SCI GYMN J.

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

Ivan Čuk
Editor-in-Chief

ASSESSING INTEREST IN ARTISTIC GYMNASTICS

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Original article

Abstract
Despite information from world media, worldwide interest in artistic gymnastics has never been assessed. Memberships, equipment and apparel purchases, subscriptions, and other data have been used as indirect substitutes for gauging interest and participation in gymnastics. A readily available tool for assessing gymnastics interest could be of use in uncovering myriad trends. Aim of Study: This study sought to use a relatively new internet search tool called Google Trends™ (GT) to assess gymnastics interest by records of search terms used in Google™. Methods: Google™ searches involve the use of search terms that are recorded and then accessible by GT. As GoogleTM searches provide access to topics of interest nearly anywhere in the world, by anyone with internet access, then using Google Trends™, then GT could be used to harvest the number and types of searches involving the search-terms "men's gymnastics" and "women's gymnastics." The tally of the search terms was obtained using filters such as country, region, and others. GT reports the search-term trends by calculating a relative percentage based on a sample of the largest number of specific search-term use during a particular time. Although the relative percentage approach is somewhat awkward, processing large amounts of data may be considered valuable and otherwise unattainable. Results and Conclusions: Results should be interpreted cautiously. However, the analysis revealed a litany of important trends in the worldwide interest in gymnastics.

Keywords: *Media, Internet, Google.*

INTRODUCTION

When a physician seeks quick and easily obtained information about the overall health of a patient, the physician will usually take the patient's temperature. Parents have used the same approach by touching a youngster's forehead to assess whether a youngster is sick. Also, body temperature can indicate the severity of an illness based on the temperature value. Is there a metric like body temperature that one can use to get an idea of artistic gymnastics' current health? The level of interest and participation may be such a metric.

The worldwide sport of artistic gymnastics has a long history but remains enigmatic regarding interest and participation statistics (Bogage, 2017; Brown, Clark, Ewing, & Malina, 1998; Carlson, Scott, Planty, & Thompson, 2005; Petlichkoff, 1992). Numerous questions arise when assessing the interest and

healthy participation of young athletes. Questions of injury incidence and frequency are important, but a denominator's inclusion is even more helpful. For example, injury research usually includes a rate value, such as the number of injuries per 1000 participants or per exposure to training. Ratios of such information provide incidence and rate, thereby enhancing the overall understanding of the phenomenon of interest. There does not appear to be a simple metric indicating the overall status of artistic gymnastics. Moreover, even participation statistics are usually single "snapshots" of a particular condition at a specific time. Assessing the global interest in artistic gymnastics presents numerous challenges, such as accuracy of a particular statistic, whether individual countries have artistic gymnastics data, the purpose for which the data and statistics were acquired, and many others.

National and international governing bodies for gymnastics should have indicators that allow each associated entity to determine the history, current state, and predicted future artistic gymnastics status. Business entities such as gymnastics equipment and apparel companies have vested interests in gymnastics' growth or decline. Most countries that want to be contenders for competitive world honors also need an idea of other contenders' current status and overall development. Unfortunately, there is no central or easily accessible data to obtain such information. In business, sales figures and memberships are relatively easy to gather within each company or enterprise, but sharing these values may be difficult because of proprietary concerns, costs of collection, different collection methods, and varying data assumptions. For example, the price of a gymnastics participation report from the Sports and Fitness Association (SIFA) is USD 295.00 (Kerman, 2020) and covers only United States participation.

The use of "Big Data" has become ubiquitous in business and medicine (Albert, Glickman, Swartz, & Koning, 2017; Hand, 2020; Lewis, 2003; Mavragani & Ochoa, 2019; Morgulev, Azar, & Lidor, 2018; Sagiroglu & Sinanc, 2013; Schneier, 2015; Siegel, 2016; Stein et al., 2017). The worldwide sport of gymnastics could use a big data approach to assess interest and popularity trends. Moreover, the current problems (as of this writing) with the COVID-19 pandemic is devastating the small but important industry of gymnastics schools and clubs. Gymnastics could use a metric to assess the past, current, and potential future state of gymnastics interest. A robust tool that puts access to big data into the hands of ordinary citizens, scientists, medical personnel, coaches, and others could be a breakthrough for gauging interest in many aspects of modern life, including gymnastics. Google Trends™ may be such a tool that is easily accessible and offers the opportunity to quantify gymnastics interest.

Google Trends™ (GT) is an online service offered by Google, LLC. GT samples search-terms from its worldwide search engine and its log of the use of terms as indicators of searchers' interests over time. "Where there is sufficient data available, GT awards a score of between 0 and 100 to inputted search-terms on a month-by-month / day-by-day basis and on a geographical basis." (Trends, 2013) The scores provided by GT are somewhat awkward in that the scores have no direct quantitative meaning. "For example, two different terms could achieve scores of 100 in the same month, but one received 1,000 search requests, whilst the other received 1,000,000. This is because the scores have been scaled between 0 and 100. A score of 100 always represents the highest relative search volume." (Trends, 2013) GT's output or reporting includes a line graph that follows relative general search use of specific terms. As such, a rising line may not indicate that the search-term has increased over time, or a decreasing line or track may not indicate a decline of search-

term use. The scores generated are relative to an overall change in the search-term use based on internet use. Scaling the scores between 0 and 100 would depend on how the relative search volume for the terms on the day compares to the highest relative search volume within the time range. Google Trends provides its scores based on an analysis of a portion of search volume. Thus, scores are obtained from a sample of available data rather than all available data. Although these limitations may seem crippling, GT has entered extensive use within business, epidemiology, medicine, and others (Garrison, Dormuth, Morrow, Carney, & Khan, 2015; Hunter et al., 2017; Mavragani & Ochoa, 2019; Nuti et al., 2014; Sagiroglu & Sinanc, 2013; Tran et al., 2017; Trends, 2013; Wiley, Steffens, Berry, & Leask, 2017; Zhou, Ye, & Feng, 2011).

GT has been analyzed for reliability and validity with mixed results (Arora, Stuckler, & McKee, 2016; Cervellin, Comelli, & Lippi, 2017; Hunter et al., 2017; Nuti et al., 2014; Tran et al., 2017; Wiley et al., 2017; Zhou et al., 2011). "Google Trends is being used to study health phenomena in various topic domains in myriad ways. However, poor documentation of methods precludes the reproducibility of the findings. Such documentation would enable other researchers to determine the consistency of GT results for well-specified queries over time. Furthermore, greater transparency may improve GT's reliability as a research tool (Nuti et al., 2014). Despite GT's limitations, a search of PubMed.gov showed 484 records for the term "Google Trends," indicating that the service is used in medical settings. Sports- or athletic-related uses of GT resulted in six citations covering interval training (Rynecki, Siracuse, Ippolito, & Beebe, 2019), sports supplement usage (Catalani et al., 2018), forecasting sports popularity (M. Ryan, Harrison, & Ismael, 2017), the Ironman Triathlon (Mnadla et al., 2016), anabolic steroid use (Tay Wee Teck & McCann, 2018), and nocturnal leg cramps (Garrison et al., 2015).

Despite methodological shortcomings, the use of GT to ascertain interest in gymnastics merits consideration. However, there are caveats; one must be willing to tolerate the fact that GT results are estimates. As yet, the investigator cannot peer inside the "black box" of GT's internal calculations and specific data. Judging the time-line of interest in artistic gymnastics and a cautious willingness to use GT as a simple, available, and perhaps brittle tool for assessing such interest may be an important initial step that has not been used in the past.

The purpose of this paper was to assess worldwide interest in men's and women's artistic gymnastics based on an online search engine and participant data. The data were obtained from Google Trends™ on 30 June 2020 and were stored for further analyses using GT functionality (i.e., reports, graphics, and comparisons). Also, other sources, such as the International Gymnastics Federation participation statistics, were included.

METHODS

Search-terms were used to obtain the desired data from GT. Searches of GT for this project involved the selection and use of search-terms that would be logically used by others. In short, we performed a search using search-terms about search-terms. Search-terms' choice was essential, mainly when multiple search-terms could be synonymous but may not garner similar usage in the worldwide application for Google™. The approach of using specific keywords or search-terms is called "filtering" in much the same way that a filter stops some things from carrying on while permitting others (Dewan & Sur, 2018; Mavragani & Ochoa, 2019; Nuti et al., 2014).

When using GT, there are several filter choices. These choices include:

1. time-line, beginning from 2004 to the present,
2. worldwide, region of the world, and/or country,
3. categories such as arts and entertainment, news, sports, or travel, and
4. an additional filter to search for images, news, shopping, or YouTube™ material.

Our primary search attention involved to the period from January 2004 to 20 June (Cervellin et al., 2017; Dewan & Sur, 2018; Mavragani & Ochoa, 2019)20, worldwide artistic gymnastics, and all Google™ searches involving "women's gymnastics" and "men's gymnastics." This time-line represented the complete search analyses available from GT for men's and women's gymnastics. We did not include news, shopping, or video data after checking them for relevance to the study's purpose.

GT searches of the search-terms *women's gymnastics* and *men's gymnastics* resulted in finding the highest number of "hits." Other terms, such as "artistic women's gymnastics," resulted in reports that were inadequate and uncertain, such as no results or results so low that GT could not provide a trend.

In addition, data on participation were obtained from the International Gymnastics Federation website (F.I.G., 2020) from U.S. data when making some comparisons. Participation is an obvious indication of interest, and therefore these data were also included to enhance the study's scope.

Bias: a limitation of this study is the unknown characteristics of the GT algorithms. Bias in these data may arise as a result of this limitation. Other search engines were queried using the search term "trends." The search engines were DuckDuckGo.com, Bing.com, TrendHunter.com, DogPile.com, Yippy.com, GoogleScholar.com, Webopedia.com, Yahoo.com, and Archive.org. None of these search engines had a function similar to GT, all but one of these search engines listed Google Trends as the top search result. The closest results involved business, merchandise, and fashion trends.

Given that gymnastics is a worldwide activity, a language may have been a factor in search results. Unfortunately, GT appears to be the only search engine that supports keyword use over time. Thus, we were forced to engage in a near "circular" approach by using GT to determine the prevalence of different languages used in GT. The term "gymnastics" (English) is also "gymnastique" (French), ginnastica (Italian), and gymnastik (German). A GT search involving all of these terms showed that they are rarely used in GT searches (Figure 1).

In practice, medical studies of disease and injury epidemiology often use GT (Arora et al., 2016; Avilez, Zevallos-Morales, & Taype-Rondan, 2017; Cervellin et al., 2017; Cha, Hwang, & Yang, 2019; Dewan & Sur, 2018; Garrison et al., 2015; Mavragani & Ochoa, 2019; Mnadla et al., 2016; Nuti et al., 2014; Rynecki et al., 2019; Tran et al., 2017; Trends, 2013; Zhou et al., 2011) and other sources such as social media and other electronic health records.

Data analysis. This study was exploratory and hypothesis-generating rather than hypothesis testing study (Biesecker, 2013; Huberty & Morris, 1989; Porter, 1993). Data and information obtained were entirely from Internet sources with all of the attendant cautions that accompany such data (Cervellin et al., 2017; Nuti et al., 2014; Shenk, 1997; Stoll, 1995; Tran et al., 2017). Data were obtained and analyzed from GT using descriptive statistics and linear and natural logarithm regression trends (Microsoft Excel).

RESULTS

The data were extracted from GT and binned by months. A total of 185 months was surveyed. Figures 2 (women) and 3 (men) show the relative percentages of Google™ search interest for *women's gymnastics* and *men's gymnastics*. These two search-terms were used because the use of the term "artistic" for men's and women's gymnastics was clearly not the generally used search-term and produced distorted results.

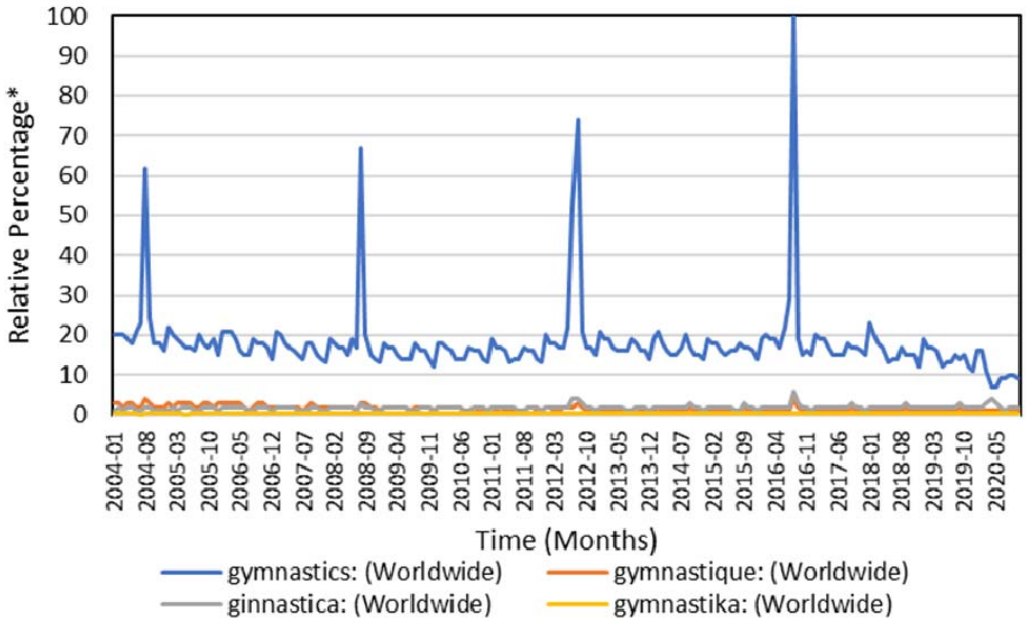

Figure 1. Comparison of common translations of the term "gymnastics" with terms from other languages in search queries with GT.

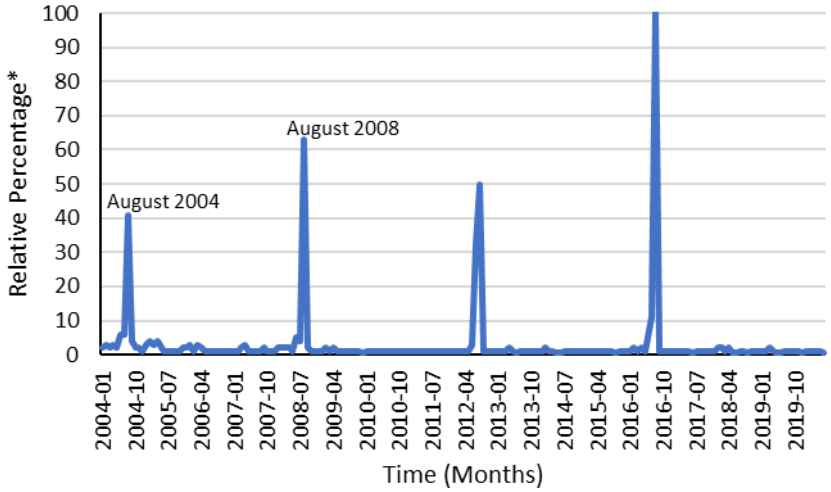

Figure 2. GT search results for "women's gymnastics" 2004 to 2020. *Relative percentage calculated from a sample from the largest volume of search-term use (August 2016).

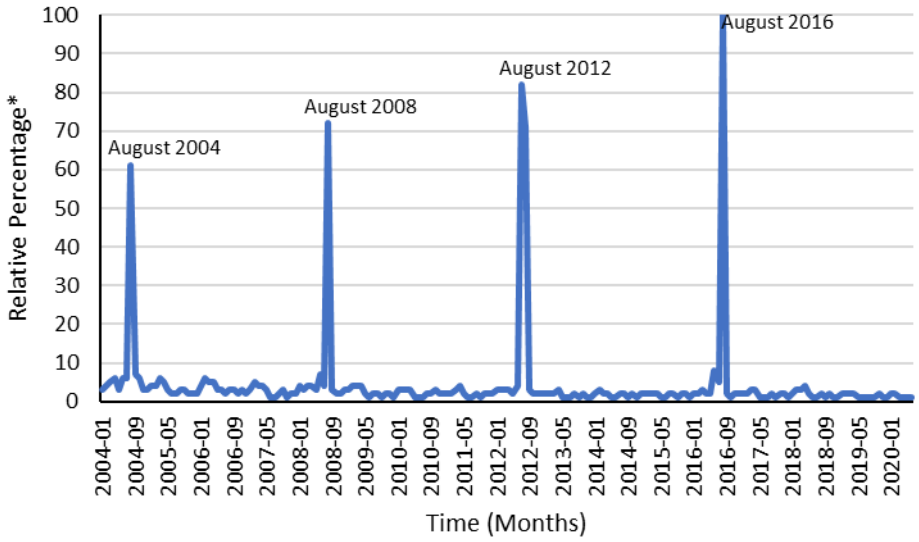

Figure 2. GT search results for "men's gymnastics" 2004 to 2020. *Relative percentage calculated from a sample from the largest volume of search-term use (August 2016).

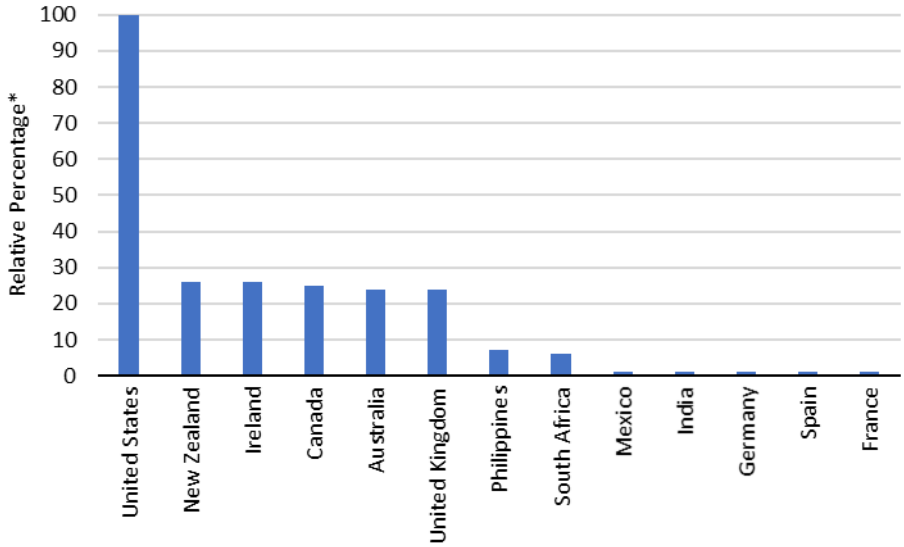

Figure 4. Women's gymnastics GT search interest by country. *Relative percentage calculated from a sample from the largest volume of search-term use (August 2016)..

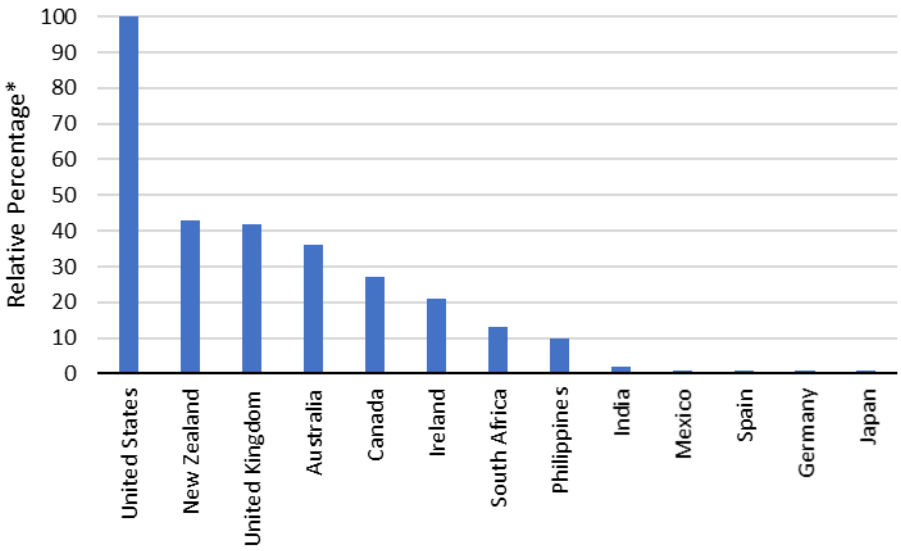

Figure 5. Men's gymnastics GT search interest by country. *Relative percentage calculated from a sample from the largest volume of search-term use (August 2016).

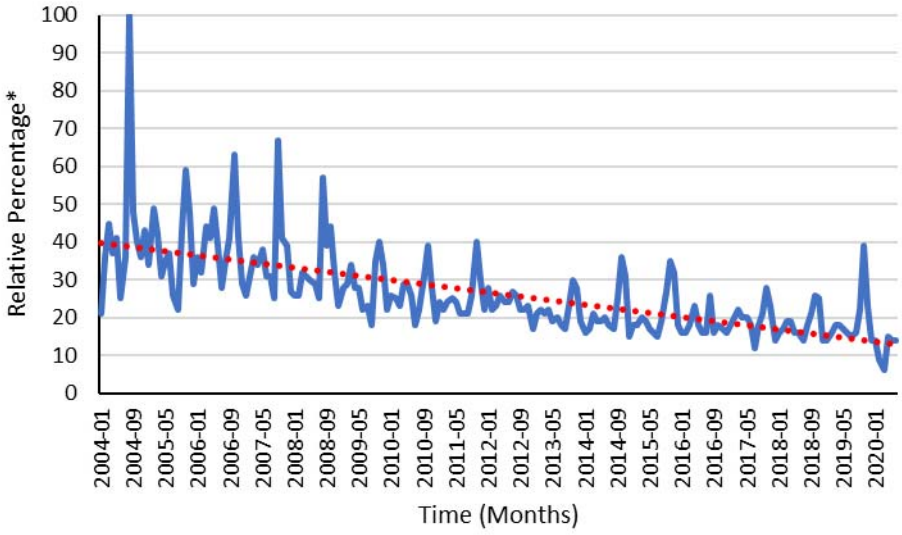

Figure 6. Trend of Google Trends™ searches using "International Gymnastics Federation" as the search-term. *Relative percentage calculated from a sample from the largest volume of search-term use (August 2016).

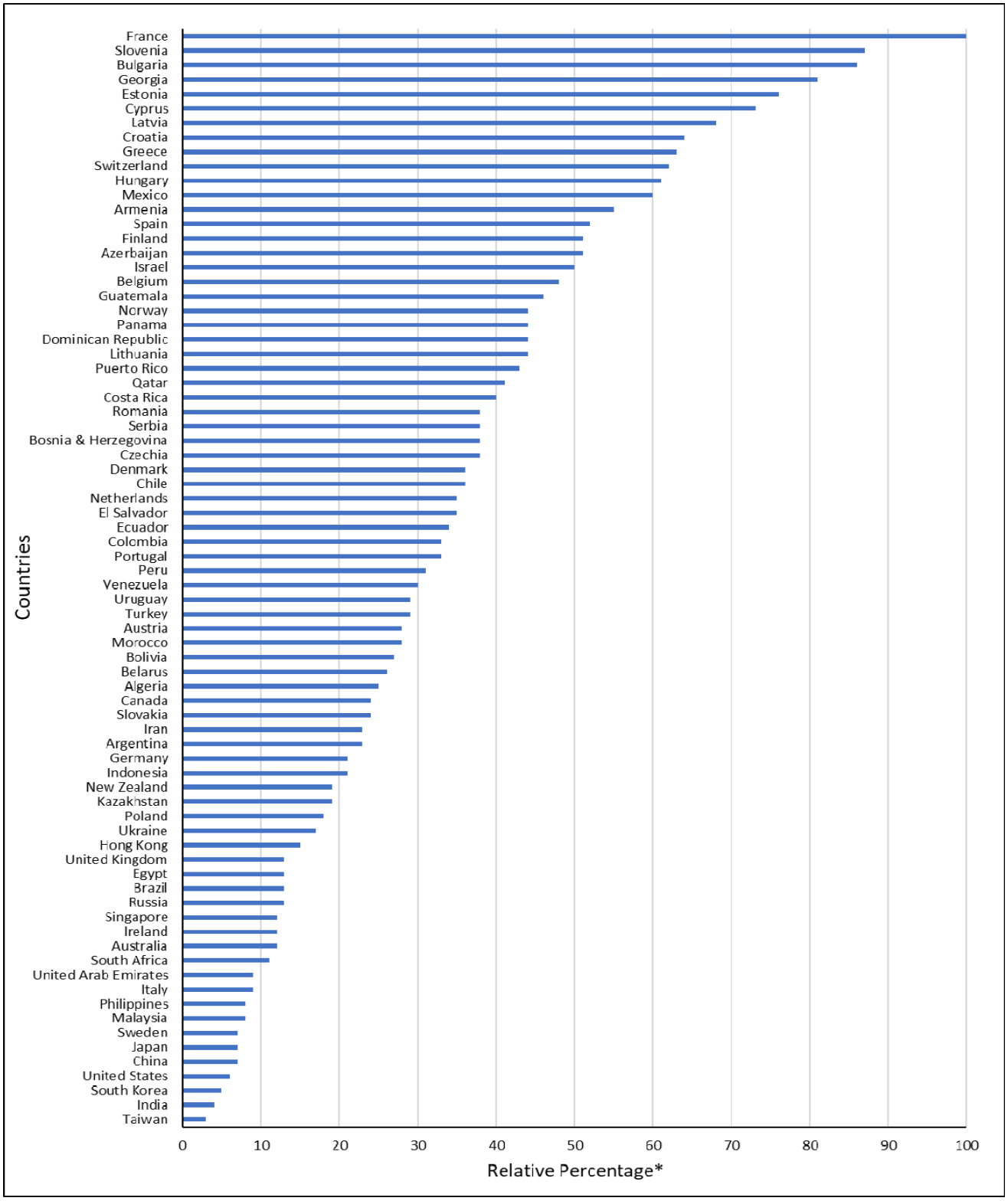

Figure 7. GT searches using the search-term "*International Gymnastics Federation"* by country. *Relative percentage calculated from a sample from the largest volume of search-term use (August 2016).

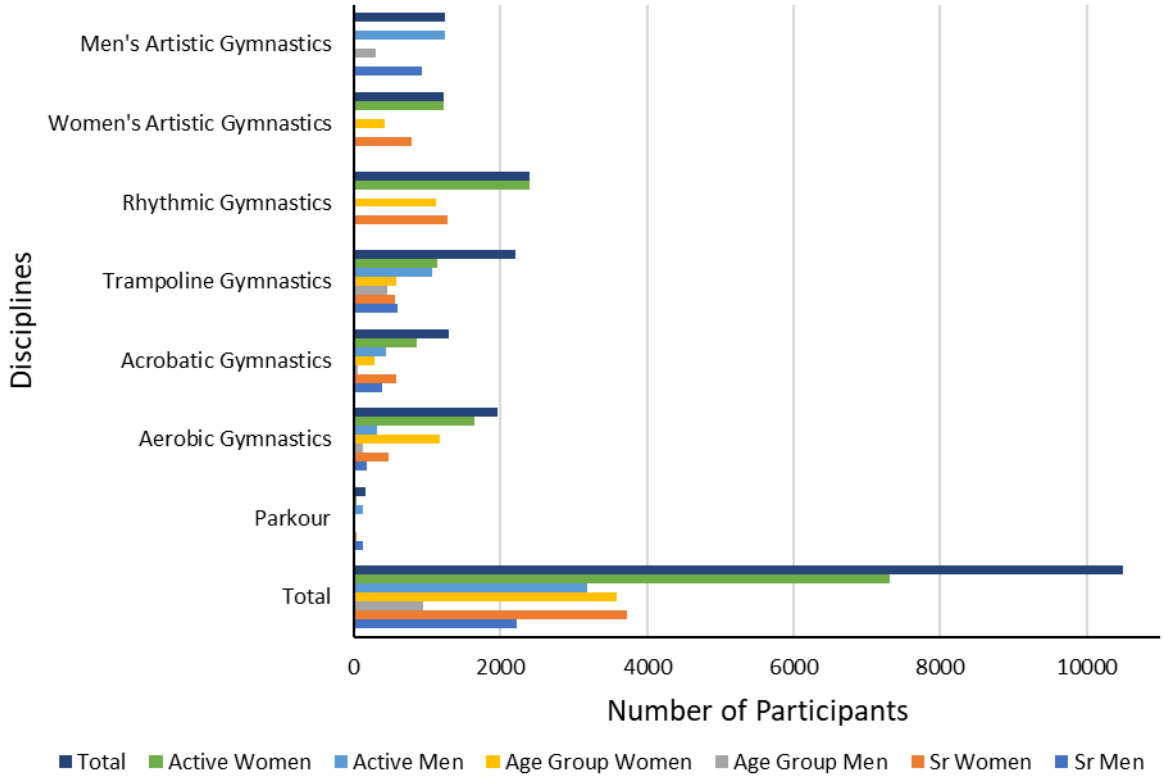

Figure 8. Athlete participation data from the FIG by gender and discipline (Sr = Senior).

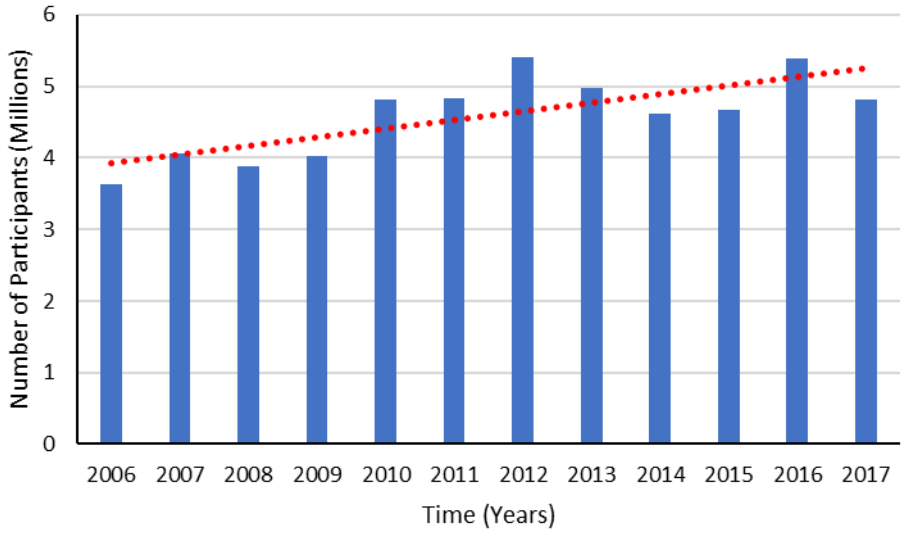

Figure 9. U.S. Gymnastics participation 2006 to 2017.

Information regarding the search interest of various countries was also considered valuable. Figures 4 and 5 show the frequencies of the relative percentages of searches from countries showing an interest in *women's gymnastics* (Figure 4) and *men's gymnastics* (Figure 5).

The world governing body for gymnastics is the International Gymnastics Federation (FIG) headquartered in Lausanne, Switzerland. The FIG is the oldest Olympic sport governing body (founded in 1881), having participated in the Olympic Games since 1896. There are 148 members of national governing bodies served by the FIG. The FIG governs eight sports, including Gymnastics for All, Men's and Women's Artistic Gymnastics, Rhythmic Gymnastics, Trampoline - including Double Mini-trampoline and Tumbling, Aerobics, Acrobatics, and Parkour. Figure 5 shows the time-series distribution of Google™ searches on the FIG. It is noteworthy that the majority of peaks of search interest correspond to men's and women's artistic gymnastics World Championships and Olympic Games. The cyclicity of these peaks is evident during the autumn period when most World Championships are conducted and August's month when the Olympic Games occur. Figure 6 also shows the trends of Google™ searches on the title "International Gymnastics Federation" via a linear regression that was applied to the search-term data to characterize the visual direction of declining use of the term ($y = -0.136(x) + 39.999$, $R = .68$, $R^2 = .46$).

The distribution of countries using the *International Gymnastics Federation* search-term (men's and women's gymnastics combined) is shown in Figure 6. Seventy-six countries are represented in Figure 6, approximately half of the total FIG nation memberships.

Gymnastics participation among the FIG disciplines is shown in Figure 8. These data from Figure 8 represent the peak of the participation pyramid in terms of the world's top athletes, male and female, from all countries. (F.I.G., 2020). The term "Senior" refers to an age eligibility requirement. The required age for women's artistic gymnastics is 16 y as of 1997. The men's age requirement is 16 y. The term "active" means that they have not retired or are not ineligible for competition.

Worldwide participation of athletes in men's and women's artistic gymnastics is unknown. However, there have been various estimates of this population. Unfortunately, the 148 countries who are members of the FIG may not keep uniformly accurate statistics of their members and non-members within their country. For example, even in the U.S., there are various artistic gymnastics-related groups and a range of organizations, goals, and histories within the sport. Figure 9 shows data acquired by a private source that provides a historical trend from 2006 to 2017 (Lock, 2020). The upward trend of participation shown in Figure 8 resulted in a linear regression equation of $y = 0.1202(x) + 3.8109$, and an R of .75, R^2 of .57. According to the Sporting Goods Manufacturers Association, in the U.S. in 2019, the total number of gymnastics participants was 4,699,000. There were 1,695,000 core gymnastics participants. Of the approximately 4.5 million gymnastics participants in the U.S., 71% of the participants are female. Of the 71% of the participants who are female, about 67,000 compete in the US Junior Olympic program, while others participate in AAU, YMCA, or other programs (Lock, 2020).

DISCUSSION AND CONCLUSION

Perhaps one of the most apparent and common assertions in gymnastics is that interest increases enormously near the Olympic Games and World Championships. A study by the Sporting Goods Manufacturers Association (SGMA) showed that at least seven sports with links to the Olympics increased

participation from 2008 to 2009 (T. J. Ryan, 2012). Gymnastics' increased participation amounted to a 3.6% "bump" in the U.S. from 3,883,000 to 4,021,000 participants (T. J. Ryan, 2012). The regression equation from Figure 8 shows an annual increase of approximately 120,000 participants per year. The dramatic increase in gymnastics interest is demonstrated by the startling spikes of GT searches in Figures 2 and 3 and the cyclic nature of searches for the International Gymnastics Federation near Olympic Games and World Championships (Figure 6).

The overall interest in men's gymnastics showed a relative percentage increase across the four Olympic Games (Figure 3). Women's gymnastics also showed an overall relative percentage increase with a decline during the 2012 Olympic Games (Figure 2).

Examining the relative percentages of GT searches by country provided some insight into countries' ranks associated with their world competitive rankings with some startling exceptions. For example, neither China nor Russia appears in the list of countries with enough GT data to be included in the relative percentage analyses (Figures 3 and 4). It is unclear if the non-inclusion of China and Russia in Figures 3 and 4 is perhaps because of an actual lack of search-term interest, government-based internet policies and access, or some other factor (Dowell, 2006). The Chinese government's role in internet access and use is suppressive, but the magnitude of government censorship is less clear (D 'Jaen, 2007). Much the same can be said about Russia (Khurshudyan, 2020). However, there does not appear to be direct evidence of censorship in the specific instances of search-terms related to the information presented in this document. Therefore, the potential influence of censorship and suppression of both countries remains unclear. Moreover, Figure 6 shows that the use of the search-term *International Gymnastics Federation* includes both Russia and China. Other countries with lower competitive rankings such as Ireland and New Zealand showed considerable interest in gymnastics based on the number of searches, thereby indicating that world competitive rank is unlikely to be a powerful predictor of gymnastics interest.

The FIG shows a relative percentage decline in Google™ searches over the 2004 to 2020 time-line (Figure 5). Despite the FIG's international gymnastics governance, the Olympic Games are not the FIG's responsibility and lie within the purview of the International Olympic Committee (IOC). Although the "flagship" disciplines, at least in terms of Western television of the FIG, are men's and women's artistic gymnastics, artistic gymnastics has the lowest level of participation within the FIG except for Parkour (Figure 7). There is considerable potential for a United States bias based on Western television toward artistic gymnastics when Europe and Asia may present more public interest in Rhythmic and Acrobatic gymnastics (North, 2012). Such regional biases in sports interests may also hinge on the competitive ranking of a given country in Olympic and World contests based on the world medias' tendency to follow winners – primarily if the media represents the country of the champions.

Although a worldwide trend in artistic gymnastics interest appears to be increasing (Figures 2 and 3), overall participation trends are unclear. In the U.S., youth sport seems to be in decline (Bogage, 2017). A participation model of gymnastics participation has been critical of the emphasis on competitive gymnastics at the expense of "casual" gymnastics emphasizing the health and fitness benefits of gymnastics rather than a medal count, technique development, command style teaching and coaching, and skill difficulty escalation (North, 2012). Even among those disciplines that garner a large share of television coverage, the scoring systems

are almost impossible for the public to interpret and understand (Governali, Gustafson, & Yelton, 2013; Hudson, 1988; Meyers, 2016; Pajek, Cuk, Pajek, Kovac, & Leskosek, 2013). The change from the 10.0 scoring system to an open-ended scoring system was undertaken for good reasons but has left the general public scratching their collective heads trying to determine why one athlete wins over another (Governali et al., 2013). Despite the obtuse scoring systems, artistic gymnastics remains a highly popular Olympic sport.

In conclusion, GT does not support the premise that worldwide gymnastics interest is declining. In essence, artistic gymnastics is not "running a temperature." It appears that artistic gymnastics is healthy and growing slowly. The recent Covid-19 pandemic has devastated the Olympic Games, world gymnastics, and the long-term training of gymnasts. Whether the athlete's goal is competitive prowess or health and fitness, neither can be achieved while sequestered in a home or apartment. Future investigations of artistic gymnastics interest will likely find the current period an inflection point in the sport's history. What will happen to gymnastics following this inflection point is unclear. The future direction of artistic gymnastics demands careful planning and governance to maintain current interest and long-term training safety.

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ANALYSIS AND COMPARISON OF TRAINING LOAD BETWEEN TWO GROUPS OF WOMEN'S ARTISTIC GYMNASTS RELATED TO THE PERCEPTION OF EFFORT AND THE RATING OF THE PERCEIVED EFFORT SESSION

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Original article

Abstract

The aim of this study was to assess the internal training load in female artistic gymnastics through subjective perception of effort (PSE) by calculating the sRPE variable and different associated variables. Ten gymnasts participated (age: 14.4 ± 2.9 years; height: 1.5 ± 0.1 m; mass: 43.3 ± 12.2 kg) and were divided into two groups according to their competitive level and weekly training volume: High Level Gymnasts (HLG) and Medium Level Gymnasts (MLG). The PSE of each gymnast was recorded daily for four weeks after the end of each training block. The HLG group recorded a significantly higher RPE and sRPE value in the specific physical preparation (SST) and in the parallel technical training (UB) contents ($p < 0.05$) compared to MLG. Statistically significant differences were also obtained from the registered mean values of RPE and sRPE when comparing training content. Furthermore, a direct relationship between volume and workload was observed. Finally, the variables associated with injury risk control provided relevant information to determine that the HLG group had a higher risk of injury than the MLG group. Therefore, the sRPE has been a useful tool to assess the internal training load in women's artistic gymnastics. Such information may help quantify the load in this sport in the future.

Keywords: *training load, internal load, gymnastic.*

INTRODUCTION

Training load is defined as the set of stimuli that cause certain effects on the organism (Mujika, 2013; Navarro, 1999; Zintl, 1991). In order to identify the effects of training on athletes, observe whether specific adaptations are achieved, understand individual responses to training, and evaluate fatigue and the need for associated recovery processes, it is necessary to quantify and monitor the training load of athletes (Bourdon, et al., 2017; Mujika, 2013).

Training load measurements can be classified as internal and external. Internal load can be defined as biological stimuli (physiological and psychological) applied to the athlete during training or competition (Bourdon et al., 2017); while the external load is an objective measurement, exercised by the athlete

regardless of the internal characteristics, and usually measured through the power output, speed, acceleration, analysis of movement as a function of time, measurements through GPS systems or parameters derived from measurements with accelerometers (Bourdon et al., 2017).

Internal load is mainly measured by four internal variables: heart rate (HR), maximum oxygen consumption (VO2 max), blood lactate concentration (BLC) and subjective perception of effort (SPE), (Bourdon et al., 2017; Mujika, 2006). In general, if the effort is controlled with several of these variables simultaneously, we have a valuable and useful tool available to control and plan training (Achten & Jeukendrup, 2003; Hopkins, 1991; Viru &Viru, 2000).

More and more studies are paying attention to the sensations that athletes experience during training (Foster, 1998; Gabbett, 2016; Gabbett, 2020; Hulin & Gabbett, 2019; Malone, Hughes, Doran, Collins, & Gabbett, 2019). Cognitive awareness of these sensations considers a form of feedback in which central, peripheral, and metabolic changes that occurred during exercise are integrated (Pfeiffer, Pivarnik, Womoc, Reeves, & Malina, 2002). The most widely used indices controlled in the athlete's perception to observe and control these psychological variables include: the profile of mood states (POMS) and its derivatives (McNair, Loor & Droppleman, 1971), the RPE (Rating of Perceived Effort) or Borg scale (Heath, 1998), the session-RPE (sRPE) (Foster et al., 1996) and the Recovery Stress Questionnaire for athletes (Bourdon et al., 2017).

Currently, the RPE scale is frequently used during physical exercise, and the subject is instructed to verbally express a numerical value for their RPE with the help of text descriptors on the scale (Pereira, Souza, Reichert, & Smirmaul, 2014). Foster et al., (1996), in an attempt to simplify the quantification of training load, introduced the term “Session-RPE” (sRPE). The session load is calculated by multiplying the session RPE by the exercise session duration (in minutes), (Borresen & Lambert, 2009; Foster et al., 2001). One of the main benefits of this index is that it caters for the different modalities that a training has, in addition to the fact that it is favorably related to the objective and to other tools for quantifying internal load (Williams et al., 2017). It is also an economical and very practical tool.

The variables that can be calculated from the sRPE measurement are: weekly load accumulation (weekly sum of daily load values) (Colby, Dawson, Heasman, Rogalski, & Gabbett, 2014; Gabbett et al., 2017; Rogalski, Dawson, Heasman, & Gabbett, 2013), changes between training weeks (absolute difference between training load totals for the current and previous week) (Cross, Williams, Trewartha, Kemp, & Stokes, 2016; Rogalski et al., 2013), monotony of workouts (average weekly load x standard deviation between the daily values of week load) (Foster, 1998), training stress (weekly training load × training monotony) (Foster et al., 2001) and chronic acute workload, which is calculated by expressing player's acute workload as a percentage of their chronic workload (Hulin et al., 2014) and the exponentially weighted moving average (Holt, 2004; Keskin, Kıraç, Kara, & Akarun, 2013).

The purpose of measuring monotony, load and stress is to increase the quality of work and reduce injuries. Training monotony is a metric that assesses load fluctuations at the repetition site of the exercise (Comyns & Flanagan, 2013). Stress refers to how hard someone is working based on the backlog of work done over time, usually per week (Comyns & Flanagan, 2013). Many sports scientists are currently investigating how the daily load, the periodic monotony and the stress that results from the relationship of the two services effect (Comyns & Flanagan, 2013; Colby, Rogalski, Dawson, Heasman, & Gabbett, 2013; Dawson, Heasman,

Rogalski, & Gabbett, 2014; Gabbett et al., 2017). Studies have shown that gymnastics is a very complex sport due to high demand for technical perfection (Cavallerio, Wadey, & Wagstaff, 2016). Hence, obtaining indices that control the risk of injury can be of great help to improve gymnasts' performance.

There are several studies that provide reliable data on how to consider the subjective perception of effort, a useful method to quantify the training load in women's artistic gymnastics (WAG), (Minganti, Capranica, Meeusen, Amici, & Piacentini, 2010; Sartor, Vailati, Valsecchi, Vailati, & De La Torre, 2013).

The objectives of this study were: (1) to assess the internal training load in WAG using the sRPE and different associated variables (accumulation of weekly load, accumulation of load of a training cycle (4 weeks), monotony of workouts, training tension and chronic acute workload); (2) to compare the differences in the variables analysed between two groups of gymnasts (High Level Gymnasts (HLG) vs Medium Level Gymnasts (MLG)) of different age, level of competition and volume of training, and (3) to compare the existence of differences in the perception of effort and training load between different contents of training in women's artistic gymnastics (WAG).

The analysis was performed using data from the sessions and differentiates the training content in order to analyse whether there are differences between the training load of the physical preparation contents used in sessions, and the technical contents in the four-competition apparatus (vault, uneven bars, balance beam and floor exercise). In this way we are able to assess whether the effort perceived by gymnasts in the diverse work contents is different. In addition, we can observe the evolution of the effort perceived during the four weeks of training and obtain certain indexes that help control the risk of injury.

METHODS

Ten gymnasts at the national competitive level (age: 14.4 ± 2.9 years; height: 1.5 ± 0.1 m; mass: 43.3 ± 12.2 kg) participated in the study. According to their competitive level and weekly training volume they were divided into two groups, into high level gymnasts (HLG) (n = 5) (Age: 17.25 ± 0.95 years; Level 7-8; 20 h / week) and medium level gymnasts (MLG) (n = 5) (Age: 13.25 ± 0.98 years; Level 4-6; 17 h / week). The HLG training week consisted of 4 sessions of 3 hours (Monday, Tuesday and Wednesday) and 2 sessions of 4 hours (Friday and Saturday) (Rest day: Sunday). The MLG training week consisted of 3 sessions of 3 hours (Monday, Tuesday and Wednesday) and 2 sessions of 4 hours (Friday and Saturdays) (Rest days: Thursday and Sunday). Training sessions were divided into 30-minute blocks with different training content. As there are transition times between each block, the start and end time of each block was recorded in a spreadsheet to have a more precise reference of the duration of each. The subjective perception of effort (RPE) for each gymnast was recorded daily for four weeks after completing each training block and just after the transition time and the start of the next block. The gymnasts became familiar with the use of this instrument for three days in the week prior to the start of data collection. Gymnasts recorded RPE values on a computer located in the training room with the adapted Borg scale of values right in front of them (Heath, 1998). This ten-item scale ranges from 1 (rested; effortless) to 10 (maximum effort). The RPE data was used to calculate the variable "session-RPE" (sRPE), which was calculated by multiplying each gymnast's CR-10 RPE score by the duration of each block (Foster, 2001). With the control of time and the RPE value for each content, the specific value of sRPE was calculated as the sum of 6 or 8 training blocks comprising the total

load of the session. The training contents that were differentiated were: General Strength Preparation (GST), Specific Strength Preparation (SST), Vault Technique (VA), Uneven Bars Technique (UB), Balance Beam Technique (BB), Floor Technique (FX), Preparation Physical Resistance (END), Physical Preparation Flexibility (FLEX) and Trampoline (TRP). The contents of warm-up and return to calm were not analysed.

The variables used in the study were: total load (4-weeks) (sRPE); total load per content (4-weeks) (sRPEGST, sRPESST,…); relative load of cycle per content (% sRPEGST,% sRPESST ,. .); training monotony (Tm) (Foster, 1998); training strain (Ts) (Foster, 1998), and acute: chronic workload (ACW) (Hulin, Gabbett, Blanch, Chapman, Bailey & Orchard, 2014).

The variable Tm was noted by Foster (1998) as a training variability index that can be defined as the daily mean / standard deviation calculated over a period of time. Ts is defined by this same author as the product of training load and training monotony (Foster, 1998). Both variables give information about negative adaptations to training. Table 1 shows schematically the calculations of variables Tm and Ts.

The variable Acute: chronic workload (ACW) was defined by Hutlin et al. (2012) as a parameter that would help quantifying the risk of injury to the athlete. It is calculated by exposing the acute training load (accumulation of load in one week) in relation to the chronic training load (average of the load registered during the last 4 weeks of training (Table 1). The risk of injury is very low (ACW <0.49), low (0.50 <ACW <0.99), moderate (1.00 <ACW <1.49), high (1.50 <ACW <1.99) or very high (ACW> 2.00) (Hutlin et al., 2014).

Table 1
Schematic evaluation of the Training monotony (Tm) and Training strain (Ts) variables from the sRPE values of the high-level gymnasts (HLG) at week 1 of registration.

WEEK 1 (HLG)			
Day	Duration (min)	RPE	Load
Monday	110	4.6	504.2
Tuesday	117	3.8	443.6
Wednesday	108	6.7	720.0
Thursday	109	5.7	617.7
Friday	165	5.2	849.8
Saturday	174	5.0	870.0
Daily Mean Load			667.5
Daily standard deviation of load			176.8
Monotony (Daily mean/standard deviation)			3.8
Weekly load (daily mean load x 6)			4005.2
Strain (Weekly load x Monotony)			1060.7

The data analysis was performed with version 25.0 of IBM SPSS for Windows (IBM Corporation, Armonk, NY, USA). Descriptive statistics mean and standard deviation of all data sets were calculated. To check the normality and homogeneity of the variables used for the comparison between the two groups of gymnasts (HLG vs. MLG), the Kolmogorov-Smirnov (K-S) test and the Levene test (homogeneous variances) were applied respectively. However, considering the size of the sample, it was decided to apply non-parametric statistics. To identify the existence of differences between the two groups of gymnasts, the nonparametric Mann-Whitney U test was calculated. To observe the differences between the perceptions of each content and determine how different content is perceived compared to the others, as well as to observe if there are contents that imply a greater load, the Kruskal Wallis test was carried out. η^2 was used as the effect size index (Morse, 1999). The Mann-Whitney U post-hoc test was applied in pairs to compare data between the two groups. The interpretation for η^2 was categorized as small for effect sizes 0.01 - 0.06, medium for 0.06 - 0.14, and large for $\geq$ 0.14 (Cohen, 1988). The significance level for all procedures was established at 0.05.

All gymnasts voluntarily participated in the study, and were informed about its design, implications, and characteristics. After receiving detailed information, they signed an informed consent. Ethical standards for human study were met as recommended by the Declaration of Helsinki, and the study was conducted in accordance with international ethical guidelines for research in the sciences of physical activity and sport (Harriss, Macsween, & Atkinson , 2020).

RESULTS

Table 2 represents the descriptive statistics of RPE and sRPE for each content of the two groups of gymnasts analysed. The HLG group registered a significantly higher RPE value in the SST content ($Z=3.03$; $p=0.002$) and in the uneven bars technical training (UB) ($Z=3.05$; $p=0.002$), compared to MLG (Figure 1). No significant differences were observed in other analysed training contents.

The SST contents ($Z=2.03$; $p=0.04$) and the UB training ($Z=3.17$; $p=0.001$) also show a statistically significant difference in the quantification of the training load using the sRPE (Figure 1).

Statistically significant differences were obtained from the recorded mean RPE values in the comparison by training content. The results of the Kruskal-Wallis test calculated with the RPE results of the HLG group ($x^2(5)=69.63$; $p < 0.001$; $\eta^2=0.458$), and MLG group ($x^2(5)=46.26$; $p < 0.001$; $\eta^2=0.458$), show differences between analysed contents.

In the HLG group, the contents of GST (5.2 ± 1.0) and FLEX (1.8 ± 0.6) showed RPE values significantly ($p < 0.05$) lower than the rest of the training contents (Figure 2). However, there were no significant differences regarding the RPE of the HLG group among the technical contents for different apparatus ($p > 0.05$) (Figure 2).

Regarding the MLG group, the FLEX content (2.2 ± 0.9) continued to show a significantly lower value ($p <0.05$) than the rest of the training content. As also happened with the HLG group, the MLG group did not show significant differences among the technical contents carried out on different apparatus (Figure 2). The GST content showed a significant difference ($p < 0.05$) in comparison to the technical work on balance beam (BB). In addition, the SST content showed significant differences ($p < 0.05$) between the balance beam (BB) and ground (FX) contents. No significant differences were found among the contents of technical training on different apparatus.

Comparisons in the case of the sRPE variable were made by calculating the

relative value in relation to each training content block. The training time of the HLG group was greater than that of the MLG, therefore, the absolute values of sRPE were superior with a higher training volume.

Table 2

Results (MD ± SD) of rating of perceived exertion (RPE) and session-RPE (sRPE) by training content in the groups of high-level gymnasts (HLG) (n = 5) and medium-level gymnasts (MLG) (n = 5).

	HLG (n=5)		MLG (n=5)	
	RPE	sRPE	RPE	sRPE
GST	5.17±0.96	97.90±15.63	5.37±0.94	103.64±18.07
SST	6.57±0.79 ***	125.04±27.14 **	5.57±1.30 ***	103.95±35.08 **
VA	5.71±0.68	118.38±22.28	5.68±0.28	112.74±11.14
UB	6.56±1.13 ***	134.23±24.12 *	5.82±0.91 ***	117.91±20.45 *
BB	6.16±0.82	123.09±18.50	6.13±0.34	128.78±14.04
FX	6.85±1.50	135.33±29.22	6.49±0.89	130.39±19.61
END	8.70±0.36	123.23±12.67	8.93±0.45	133.42±19.86
FLEX	1.83±0.64	36.66±14.78	2.17±0.91	44.99±20.11
TRP	3.34±1.92	67.43±41.17	3.81±0.72	80.31±10.22

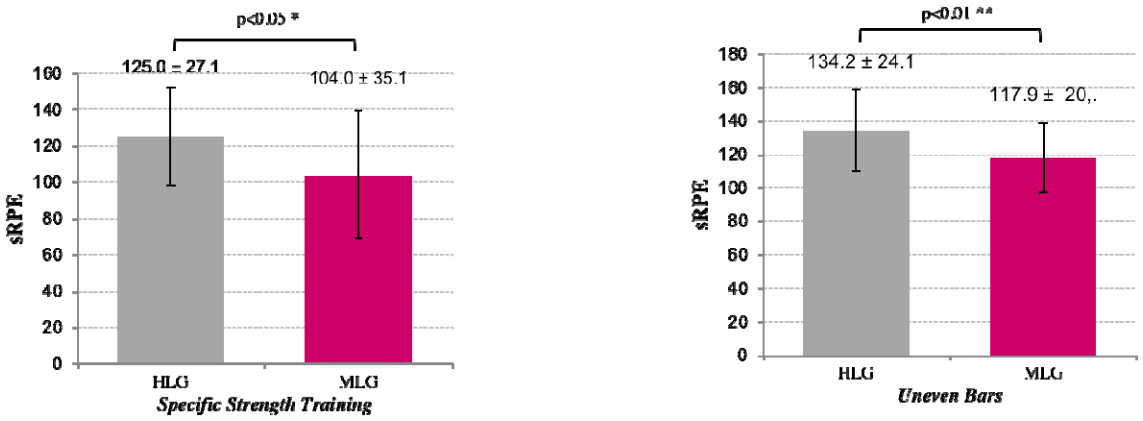

Figure 1. Statistically significant differences in the mean session-RPE (sRPE) value found between high-level gymnasts (HLG) and medium-level gymnasts (MLG) in the contents of Specific Physical Preparation (SST) training and technical training in uneven bars (UB) .

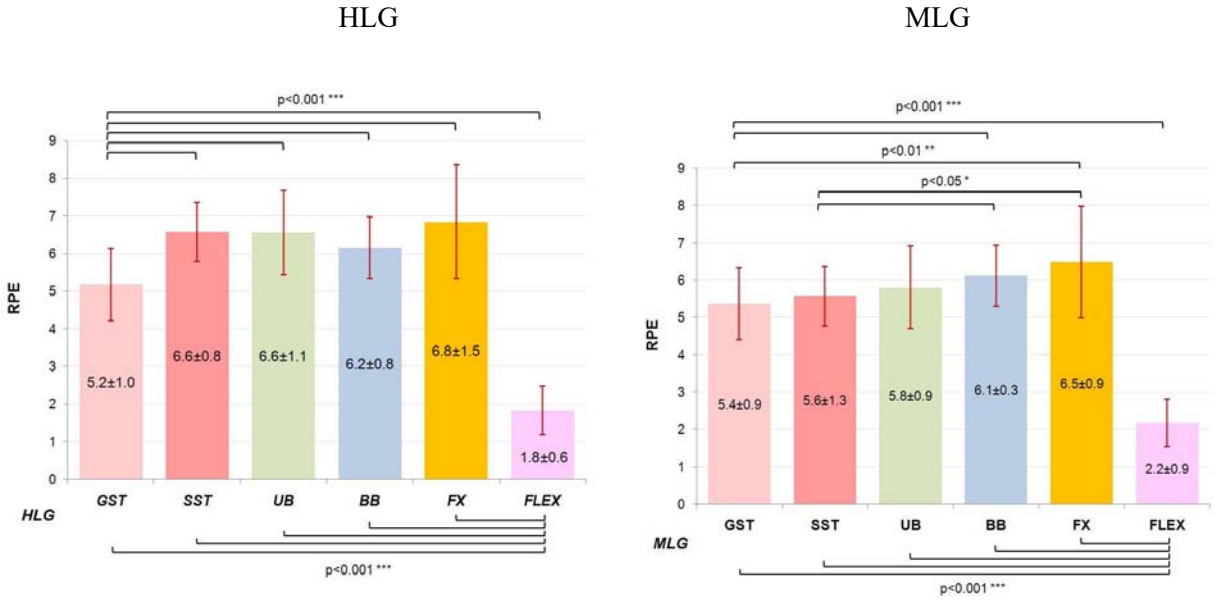

Figure 2. Statistically significant differences in the mean rating of perceived exertion (RPE) value found between the contents (HLG = high level gymnasts; MLG = medium level gymnasts). Statistically significant differences at 0.05 level.

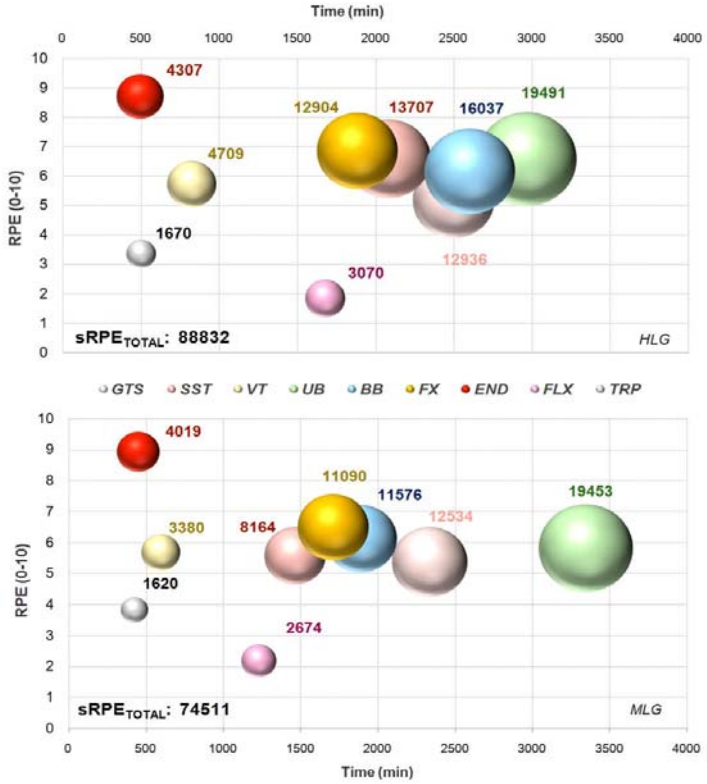

Figure 3. Results of the amount of training load (sRPE) by training content in the HLG and MLG groups as a function of the volume (Time) and Intensity (RPE) of the load (sRPE = session rating of perceived exertion; RPE = rating of perceived exertion; HLG = High Level Gymnasts; MLG = Medium Level Gymnasts; GST = General Strength Training; SST = Specific Strength Training; VT = Vault; UB = Uneven Bars, BB = Balance Beam; FX = Floor; FLEX = Flexibility; TRP = Trampoline).

Figure 4. %SRPE values per content (HLG = High Level Gymnasts; MLG = Medium Level Gymnasts; GST = General Strength Training; SST = Specific Strength Training; VT = Vault; UB = Uneven Bars, BB = Balance Beam; FX = Floor; FLEX = Flexibility; TRP = Trampoline).

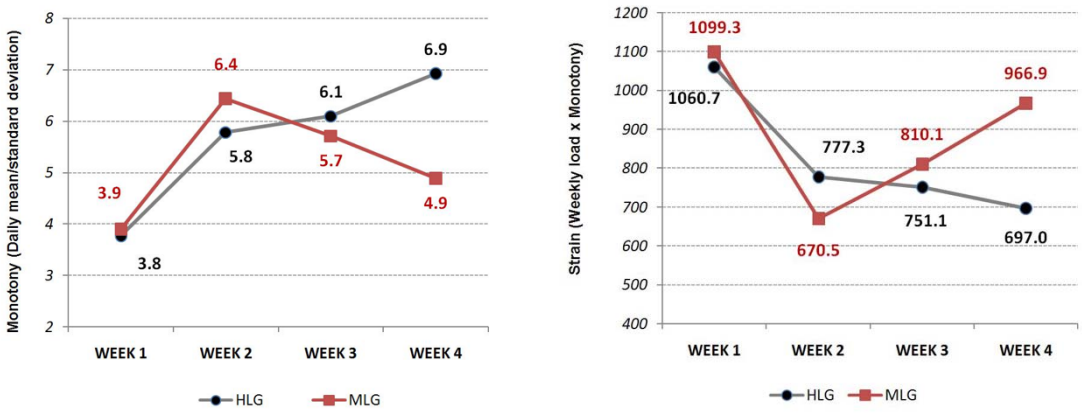

Figure 5. Comparison of the monotony and tension curves of the gymnasts during the four weeks of training (HLG = High Level Gymnasts; MLG = Medium Level Gymnasts).

Table 3
Results of the variable Acute: chronic workload (ACW) of all the gymnasts analyzed.

Week Total Load sRPE (Acute load)						
HLG	Week 1	Week 2	Week 3	Week 4	*CW*	*ACW*
Gymnast 1	4674	5075	5061	5299	5027.3	*1.05*
Gymnast 2	4024	3406	3544	4487	3865.3	*1.16*
Gymnast 3	3204	4993	3472	5442	4277.8	*1.27*
Gymnast 4	4139	4591	4565	4611	4476.5	*1.03*
Gymnast 5	4160	4666	4309	5110	4561.2	*1.12*
MLG	Week 1	Week 2	Week 3	Week 4	*CW*	*ACW*
Gymnast 1	3438	3642	3789	3534	3600.8	*0.98*
Gymnast 2	3458	3871	3736	4258	3830.8	*1.11*
Gymnast 3	3583	3830	3727	3630	3692.5	*0.98*
Gymnast 4	3738	3742	2678	4357	3628.8	*1.20*
Gymnast 5	3684	3771	3887	4158	3875.1	*1.07*

**CW: chronic workload; ACW: acute chronic workload*

The mean load volume (sRPE) per content block also showed statistically significant differences in the Kruskal-Wallis test results when comparing different working contents, both in the HLG group ($X^2(5) = 73.90$; $p < 0.001$; $\eta^2 = 0{,}458$) as in that of MLG ($X^2(5) = 51.60$; $p < 0.001$; $\eta^2 = 0{,}458$).

The differences between the training contents in terms of sRPE per block presented the same differences in the HLG group as those shown in the case of RPE, except for the significant difference between the content on uneven bars (UB) and balance beam (BB), being significantly higher on the uneven bars apparatus (UB) ($p < 0.005$). In the HLG group, the contents of SST (97.9 ± 15.6) and especially the FLEX (36.7 ± 14.8) revealed a load volume per block significantly lower ($p < 0.05$) than the rest of the contents. No statistically significant differences were found among the rest of the training contents under comparison.

The same trend was observed in the MLG group with respect to the contents, i.e., the lowest volume of load per block presented significantly ($p < 0.05$) with the rest of the contents (GST: 103.6 ± 18.1; FLEX: 45.0 ± 20.1). In this case, it is observed that the technical contents in BB (128.8 ± 14.0) and FX (130.4 ± 19.6) show a significant difference ($p < 0.05$) due to their load value of training higher than GST (103.6 ± 18.1) and SST (104.0 ± 35.1). In addition, there is another significant difference between the content on uneven bars (UB) (mean / ds) and balance beam (BB) (mean / ds).

In a single graph, Figure 4 presents the results of load volume (Time (min): horizontal axis X), intensity of load (RPE: vertical axis Y) and amount of training

load (sRPE: volume of sphere) of the two groups of gymnasts.

It points out out that the technical content of UB is the one with the highest total training volume (HLG: 2970 min; MLG: 3345 min) and relative training volume (HLG: 21.9%; MLG: 26.1%); whereas the two groups of trampoline gymnasts (TRP) recorded lower total training volume (HLG: 1670 min; MLG: 1620 min) and relative training volume (HLG: 1.9%; MLG: 2.2%).

Regarding the perceived intensity of each training content (RPE), the END obtained in both groups the highest values (RPE_{HLG}= 8.70±0.36; RPE_{MLG}= 8.93±0.45). The content in which the gymnasts showed a lower intensity value was FLEX (RPE_{HLG}=1.83±0.64; RPE_{MLG}= 2.17±0.91), (Figure 3).

In both groups, it was agreed that the UB technical training content registered the highest training load (sRPE) ($sRPE_{HLG}$= 19491; $sRPE_{MLG}$= 19453) and that the lowest training load was found in trampoline ($sRPE_{HLG}$= 1670; $sRPE_{MLG}$= 1620), (Figure 3).

The total sRPE was higher for the HLG group ($sRPE_{HLG}$= 88832; $sRPE_{MLG}$= 74511). For a more reliable comparison, the relative value (%) of sRPE by content is also taken into account, with UB training being the content with the highest % sRPE ($\%sRPE_{HLG}$ = 21.9%; $\%sRPE_{MLG}$ = 26.1%) (Figure 4).

Figure 5 shows the results of monotony (Tm) and tension (Ts) calculated from the training load recorded by gymnasts from their weekly sRPE values. The HLG group showed a constant increase during the 4 weeks of training of the value of Tm, registering the maximum peak in the fourth week (Tm_{HLG} = 6.9). The MLG group obtained their maximum peak in the second week of training (Tm_{MLG} = 6.4), decreasing the value in the third and fourth week. For both groups, the lowest Tm result was obtained in the first week (Tm_{HLG}= 3.8; Tm_{MLG}= 3.9).

The evolution of Ts was different; the maximum values were obtained for both groups in the first week (Ts_{HLG}= 1060.7; Ts_{HLG}= 1099.3). The HLG group experienced a decrease in Ts during the following weeks of training, obtaining the minimum value in the fourth week (Ts_{HLG}= 697.0). The MLG group obtained the minimum tension result in the second week (Ts_{MLG}= 670.5), subsequently registering an increase during the third and fourth week.

Finally, the ratio between chronic and acute workload (ACW) was calculated (Hulin et al., 2014). Every high-level gymnast was observed to have a moderate risk of injury (ACW> 1.0) and only two medium-level gymnasts had low risk of injury (ACW <1.0) results (Table 3).

DISCUSSION

The main objective of this study was to assess the internal training load in WAG, based on the RPE record, by calculating the sRPE variable and applying different variables associated with measuring training load, in order to assess the risk of injury for gymnasts.

The RPE values of the different training contents showed statistically significant differences between both analyzed groups (HLG vs. MLG). The HLG group expressed a higher RPE in 5 of the 9 training contents evaluated. The difference between the RPE of the SST contents (Z=3.03; p=0.002) and the UB (Z=3.05; p=0.002) was higher and statistically significant in the HLG group. No other differences were found between the two analysed groups regarding their RPE of the training contents.

To a certain degree these results coincide with the study by Burt, Naughton, Higham, & Landeo (2010), in which they affirm the perceptions that training load is greater for gymnasts at a higher level of competition. In our case, a higher evaluation of the RPE was observed for the HLG group. This aspect is evident in the

four-competition apparatus. This difference may be due to the difficulty of the technical elements worked on, which can directly influence the assessment of intensity in the technical work blocks. In the future, it would be interesting to analyse the possible relationship between the technical difficulty of the trained elements (A, B, C, D, etc.) and the associated RPE recorded. Determining a greater perception of effort depending on the difficulty of the elements carried out could be very useful when designing the training loads involved in technical work on the different apparatus.

It should be noted that the SPE scores for the technical work contents on the different apparatus were found in the range of 5.7 to 6.8, a range of values that are considered on the RPE scale as moderate perceived efforts. The study by Sartor et al. (2013) demonstrates that obtaining moderate results in relation to the perceived effort could be due to the fact that gymnasts were asked to rate the RPE during the entire training session, as well as after effective work on each apparatus. In the present study, the intention was to solve the first problem raised by Sartor et al. (2013), i.e., to record the RPE after each training block. Despite recording after each content-specific training period, assessment of the technical work on apparatus continued to be considered as a moderate perceived effort. An attempt was made to get as close as possible to the effective work on each apparatus by noting the specific start and end of each block; this aspect is closer to the calculation of the sRPE but is not a reflection of the actual work done by the gymnast on the apparatus due to the intermittent nature of gymnast's performance on the training apparatus.

Another aspect to analyse is the relationship exposed by Burt et al. (2010) between the gymnasts´ perception of effort and working time. The contents with the highest volume of work had higher perceptions (Burt et al., 2010). This direct relationship between volume and workload is also observed in the present study (Figure 4), the UB content being the one with the highest volume and training load, both in the HLG and MLG group; whereas the TRP content was the one with the lowest volume and training load in both groups.

It should be noted that the content considered to be the most intense was END, characterized by interval aerobic work with hardly any recovery time. On the other hand, the content considered to be less intense was the FLEX content, work in static and with hardly any fatigue production.

The amount of training load (sRPE) showed differences quite similar to those reported in the case of RPE. A higher total training load was observed in the HLG group ($sRPE_{HLG}$ = 88832) versus the MLG group ($sRPE_{HLG}$ = 88832). This difference was influenced both by the longer training time of the HLG gymnasts (T_{HLG} = 15545 min; T_{MLG} = 13445 min) and by the greater average perception of effort in this group (RPE_{HLG} = 5.7±2.0; RPE_{MLG} = 5.5±1.8).

In both cases the highest volume load was recorded on uneven bars (UB: $sRPE_{HLG}$ = 19491; $sRPE_{HLG}$ = 19453). In this case, such a high load value is directly related to the content with the highest load volume (UB: T_{HLG} = 2970 min; T_{HLG} = 3345 min) since, as we have previously indicated, it is not the apparatus that registers the higher values of RPE.

The most notable differences between the amount of load (sRPE) by content were found in the GST and FLEX contents, which showed statistically significant differences ($p < 0.05$) in comparison to other contents, both in the HLG group and in the MLG group.

Regarding the validity of this method to quantify the load in gymnasts, the study by Minganti et.al (2010) stands out. This analysis set out to relate methods of quantifying the internal load of a team of gymnasts from the record of RPE and HR. Positive evidence was found regarding the

relationship between the two methods, and they observed that the higher HR values, reflecting a higher intensity of training, generated perceptions of more intense effort. The validation of the sRPE method as a way to quantify the training load in gymnasts is established as a future objective.

Finally, the variables Tm, Ts, ACW, helped to quantify and identify the risk of injury in gymnasts. Foster (1998) showed that workload, monotony of training, and stress during training are involved in 84% of athletes' injuries. In artistic gymnastics the percentage of injuries is high and is proportional to the gymnast's level (Meeusen & Borms, 1992); in the present investigation, a possible relationship between the risk of injury and the gymnast's level is intuited, since the HLG scored higher on the Tm, Ts and ACW variables than the MLG. All gymnasts in the HLG group showed an ACW value in the range of moderate risk consideration (1.00-1.49) while in the MLG group two of them showed values below 1.00, which defines a low risk injury. These variables (Tm and ACW) directly help to establish an injury risk quantification that can be very useful in artistic gymnastics.

Considering all these aspects that are the object of this analysis, we can conclude that the results found show us the possibilities if training load and other associated variables are controlled by registering gymnasts' perceptions during training. The RPE is an inexpensive, easy to administer method, and provides a unique value for interpreting training loads. This non-invasive measurement approach is particularly valuable for gymnasts, in addition to other internal load quantification instruments, such as FC, VO2max and CLS, which will all provide a more extensive and reliable information on the specific effort exerted and will assess and guide a training session according to the results obtained. In addition, limited scientific knowledge regarding the quantification of the load in artistic gymnastics reinforces the fact that it is a subject in which interesting possibilities for the future can be provided.

However, this study encountered certain limitations, such as the impossibility of having a larger sample size. Furthermore, it would be desirable to extend the duration of data collection and obtain data from a full training mesocycle.

CONCLUSION

As a general conclusion of the study, it can be observed that the sRPE has proved a useful tool to evaluate the internal training load in WAG. More studies should be carried out to confirm and properly guide the use of these variables, as they can be a very practical means that can be used on many levels of artistic gymnastics training.

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THE RELATIONSHIP BETWEEN SOCIAL MEDIA AND DISORDERED EATING IN COLLEGE-AGED FEMALE GYMNASTS

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Original article

Abstract

While the relationships between media and eating disorders and disordered eating patterns in college-aged women have been extensively studied (e.g., Bissel, 2004; Grabe & Hyde 2009; Harper & Tiggeman, 2008; Yamamiya, Cash, Melnyk, Posavac, & Posavac, 2005), fewer studies have been conducted with female athletes. More specifically, limited studies have focused on the relationship between social media and eating behaviors of athletes participating in aesthetic sporting events, even though the highest rates of disordered eating patterns occur in sports where female athletes are scored on judges' opinions (Hausenblas & Carron, 1999; Smolak, Murnen, & Ruble, 2000; Sundgot-Borgen, 1994), and where leanness, thinness, and aesthetic skills and aspects are emphasized (Byrne & McLean, 2002; DiBartolo & Shaffer, 2002). Thus, the current study sought to understand the links among college gymnasts' perceptions of body image, disordered eating behaviors, and perceptions of athletes' body images presented on social media. Furthermore, the study also explored how criticism presented on social media relates to disordered eating symptomatology. The study was conducted via an online survey system by 72 18-25-year-old females who were currently competing or recently competed in club or collegiate gymnastics. Results found significant correlations between the severity of critical comments about physical appearance, emotional reaction to criticism about physical appearance, and disordered eating behavior in instances where the comments were not made on social media, but no correlation was found between severity, emotional reaction, and disordered eating behaviors for comments made on social media.

Keywords: *twitter, facebook, snapchat, instagram, eating disorders, athletes, criticism.*

INTRODUCTION

In 2016, Mexican gymnast Alexa Moreno was berated with scalding, merciless comments criticizing her weight and aestheticism as she competed at the 2016 Rio De Janeiro Olympics. Moreno, a petite twenty-two-year-old was subjected to comments from social media users such as, "Alexa Moreno has the body of two gymnasts, a diet before going to Rio would have been good." While Moreno never publicly commented on the criticism she received on social media, she is not the only one who has experienced it. Numerous great gymnasts, such as Beth Tweedle, Gabby Douglas, Aly Raisman, and Simone Biles, have also been victims of intense criticism via social media outlets. Gabby Douglas was endlessly

criticized on social media during her second Olympic presence in 2016 for her physical appearance and facial expressions, with people saying she did not look happy enough (Boren, 2016). Simone Biles was criticized in 2017 for her hair style with some people saying that Biles needed a 'black friend' and that she did not look 'fresh' (Gray, 2017). While these athletes are at the professional level, they are not alone; athletes at all levels are receiving criticism about their physique from a variety of different venues. It has been reported that 14% of Division I and II NCAA athletes have been a victim of online criticism (Syme, 2014). It has also been found that gymnasts who heard comments about their body image from their coaches were significantly more likely to engage in disordered eating behavior and more likely to report a diagnosed eating disorder (Kerr, Berman, & De Souza, 2006).

Many different factors can play into an individual developing disordered eating pathology or a clinically diagnosable eating disorder. Recently, research has begun to identify how cultural, individual, and biological risk factors contribute to the development of eating disorders (Jacobi, Hayward, de Zwaan, Kraemer, & Agras, 2004; Stice, 2002). Evidence shows that women who present with a clinically diagnosed eating disorder negatively respond to remarks about their bodies (Lask & Bryant-Waugh, 2000; Palmer, 1998). Furthermore, these negative reactions to comments made by family and peers may predict the onset of binge-eating and purging in those living with bulimia nervosa (Palmer, 1998; Stice, 1998).

These reactions are consistent with the hypothesis of objectification theory, which states that the degree and kind of negative reactions, such as disordered eating, can be predicted through the extent to which societal contexts emphasize a woman's authentic opinions or possible observer's perceptions on her body (Fredrickson & Roberts, 1997). Furthermore, the objectification theory states that females commonly experience sexual objectification with their bodies being narrowed down to specific body parts such as breasts or thighs, instead of their whole body or person being represented (Bartky, 1990). When females experience this objectification from other individuals, it can lead to self-objectification which is exhibited by body monitoring, body shame, anxiety, and symptoms of depression which can all be possible precursors to disordered eating and eating disorders (Moradi, 2010). Cultural norms play a huge factor in the development of self-objectification, as women who are raised in a culture that objectifies the female body are more likely to self-objectify their own body and worth. This may lead to the belief that one's body is valued primarily on the opinions of other people, or that the body is an object for the consumption of others in and of itself. This segmenting of the body alone can lead to negative emotional outcomes such as shame, anxiety, and feelings of wanting to disappear which can all be common precursors to eating disorders. In support, research has found that anxiety stemming from one's appearance can develop from critical comments made about one's appearance (Dion, Dion, & Keelan, 1990). The shame involved in critical comments about one's physique can lead athletes to disruption of sport performance and activity due to focus on self and appearance rather than task-related cues (Lewis, 1992). Because of these negative comments, behaviors consistent with the formation of disordered eating may be undertaken. While many different factors play into an individual developing disordered eating patterns and/or eating disorders, important predisposing factors such as being female, low self-esteem, depression, perfectionism, dieting, pressure to be thin, and weight and shape criticism cannot be ignored.

Based on research, the social comparison theory may pose a possible

explanation for disordered eating patterns and eating disorders in some populations. Festinger (1954) suggested that people have a drive to measure how they are doing in a given circumstance. In order to accomplish that task, those measurements are often made to an individual who is viewed as having better physical appearance or attractiveness than those making the original comparisons (Pinksavage, Arigo, & Schumacher, 2014). Thompson and Sherman (1999) linked these social comparisons to "competitive thinness", which is a phenomenon seen not only in sport, but out of sport as well. This need to be thinner than the competitor may be especially relevant when discussing aesthetically-centered sports. If an athlete loses a competition or is not up to the level of the competition being seen on social media, the athlete may compare themselves with an athlete who won or is competing at that level and therefore link the other athlete's body image or thinness to imply a better performance. For example, a 2005 study found gymnasts stated that coaches gave preferential treatment to gymnasts who displayed certain physical characteristics (Cumming, Eisenmann, Smoll, Smith, & Malina, 2005).

Research has traditionally focused on established media forms such as print, television, and movies and their effects on body image in adolescents and/or females (e.g., Bissel, 2004; Grabe & Hyde, 2009; Harper & Tiggemann, 2008; Yamamiya, Cash, Melnyk, Posavac, & Posavac, 2005). Harper and Tiggemann (2008) found that traditional media such as magazine advertisements has an overwhelming impact on adolescent body image. Using fashion magazines, the researchers measured the effects of advertisements on female adolescents' self-objectification, social physique anxiety, mood, and body dissatisfaction and found that females who were shown photographs of models reported higher levels of self-objectification, social physique anxiety, mood, and body dissatisfaction immediately after being shown the images. An additional study by Grabe and Hyde (2009) found that adolescent females who watch music television channels have increasingly negative self-esteem. The researchers found that young women who watched music television channels at least once a week had higher levels of self-objectification than those who spent less time watching those channels. Furthermore, research has shown that even looking at a 'thin-and-beautiful' media image for just five minutes resulted in a more negative body image (Yamamiya, Cash, Melnyk, Posavac, & Posavac, 2005). The general consensus of research involving body image and media is that media sources that depict thinness correlate to a greater chance of body dissatisfaction, lower self-esteem, and self-objectification (Bissel, 2004). While traditional media and its effects on psychological health has been extensively studied in the past, it is unknown just how much social media usage impacts psychological health and the development of disordered eating in the regular population, let alone how it may impact athletes.

Although occurrence of clinically diagnosed eating disorders in elite and collegiate female athletes has been higher than those of non-athlete females (Johnson, Powers, & Dick, 1999), it is uncertain how media plays a role in an athlete developing disordered eating behaviors. For example, internet exposure has been found to correlate with drive for thinness in adolescent females (Tiggemann & Slater, 2013). Furthermore, for adolescent females, the more time spent on Facebook, the higher the levels of internalization of the thin ideal, body surveillance, and drive for thinness (Tiggemann & Slater, 2013). While this is certainly important to note, with athletes becoming ever-more accessible to the media, and available to fans via social media, research into how media is affecting disordered eating

behaviors in athletes has become more of a necessity.

While results indicate that criticism is related to the development of disordered eating pathology in gymnasts (Rosen & Hough, 1988) and social media correlates with the development of disordered eating patterns in adolescent and college-aged females (Tiggemann & Slater, 2013), these variables have not been studied together. Further, research indicates gymnasts have admitted that criticism about their body has led them to developing disordered eating behaviors (Rosen & Hough, 1988), but studies have not been conducted considering the relationships between social media and disordered eating pathology in female athletes, or more specifically, female gymnasts, an already vulnerable population of athletes (Martisen, Bratland-Sanda, Eriksson, & Sundgot-Borgen, 2013). Therefore, the purpose of this study was to explore criticism, social media usage, and disordered eating in college-age female gymnasts through five main research questions: 1) what are their social media patterns?; 2) is there a relationship between social media usage and disordered eating behaviors?; 3) are there relationships between criticism (i.e., emotional reaction and severity) about physical appearance and disordered eating behaviors?; 4) are there relationships between criticism (i.e., emotional reaction and severity) about physical appearance received on *social media* and disordered eating behaviors?; and 5) which factors predict disordered eating behaviors?

METHODS

Participants were recruited from club gyms and colleges throughout the United States via email, social media, and word of mouth to coaches, support staff, and directly to athletes. The final sample included 72 females between the ages of 18-25 years (M= 20.12, SD=1.89) who self-identify as competitive gymnasts (must have competed within the last three years). The overwhelming majority of the participants identified as Caucasian (79.31%), while 6.9% identified as Hispanic/Latina, 5.75% considered themselves Black/African-American, 3.45% considered themselves Asian, another 3.45% identified as Pacific Islander, and 1.15% of the participants identified as Native American. A large majority of the participants competed in college varsity level gymnastics (87.67%), while 6.85% stated that they participated in recreational gymnastics, and 5.48% only competed in club gymnastics; overall average years of participation across levels was 14.93 years (SD= 2.23).

To test the research questions, researchers employed the use of four questionnaires combined into one survey. The survey included a demographics questionnaire developed by the researchers to explore basic demographic information, including ethnicity, competitive level, gymnastics skill level, and perceptions of ideal body image for their sport. The second questionnaire included questions about social media engagement, such as do the participants allow strangers to follow them on social media, and have they ever been a victim of offensive and harsh comments on social media were asked. Two questions developed by Sidani, Shensa, Hoffman, Hanmer, and Primack (2015) were used to estimate how often participants used social media in a 24-hour period and how often participants visited nine common social media platforms (e.g., Twitter, Facebook, Snapchat, Instagram).

The Social Hassles Questionnaire (Muscat & Long, 2008) was also used to examine the "context, source, emotional response, and content of critical comments about weight and body shape" (p. 8). The scale has three subscales: the frequency of critical comments, emotional responses to those comments, and the severity of the comments. Overall, there are 12 questions, with 6 Likert-scale questions, ranging from 1 (not at all affected) to 4 (very affected)

and 6 questions examining the emotions felt around the comment or how well they remembered the comment. Examples of these questions include, "To what degree do you feel the comment made by this person about your body has had an impact on how conscious you are about your body shape, diet, or need to change your weight?" and "To what degree did you feel the comment made by this person about your body has resulted in you attempting to make changes to your body?" Participants were also asked to identify who they received the critical comment from, whether the person indicated told them they should lose weight or change their diet, how often they have received critical comments, and how long ago those comments occurred. The sum of all of the Likert scale answers indicate how much the critical comment impacted the participant, with lower scores indicating less impact and higher scores indicating most impact. Original inter-rater reliability was listed as 84% with a sample population of 223 female athletes between the ages of 18 and 25 (Muscat & Long, 2008).

For this study, the Social Hassles Questionnaire was included twice; once in original form as described above, and again with modifications made to identify how the participant reacted to critical comments made on social media about their aesthetic. Modifications consisted of re-phrasing the questions asked to include instances of social media usages, such as, "To what degree did the comment about your body made *on social media* impact your behavior/attitude towards your body?"

The fourth questionnaire was the Eating Attitudes Test (EAT-26; Garner et al., 1982), used to assess disordered eating behaviors. A three-part questionnaire, the EAT-26 includes questions and statements regarding the height, weight, and ideal weight of the participants and 26 items with a Likert-scale measuring from 1 (always) to 5 (never) measuring eating attitudes. For example, statements such as "I cut my food into small pieces," and "I feel extremely guilty after eating." Finally, five additional questions, with answer choices from 1 (never) to 5 (once a day or more), measure the behavioral components regarding disordered eating. Examples of such questions include "[have you] ever used laxatives, diet pills, or diuretics (water pills) to control your weight or shape?" and "[have you] ever made yourself sick (vomited) to control your weight or shape?" A score at or above 20 indicates that there may be a concern for disordered eating behavior.

Prior to data collection, approval was sought from the University Institutional Review Board. Upon approval, a request for participation was distributed by email, word-of-mouth, and flyers to athletes, coaches, and support staff at universities across the United States. The researchers also recruited participants via social media websites. With this participant request, researchers included the link to a Qualtrics-based survey. The link included informed consent obtained via electronic signature, as well as the components of the survey including the demographics questionnaire, the Social Hassles questionnaire, the modified Social Hassles Questionnaire, and the EAT-26. The participants were informed that the information is anonymous. The survey took approximately 16 minutes to complete.

This study was designed to explore the relationships among social media usage, disordered eating attitudes, and the experience of criticism about physical appearance for female college aged gymnasts.

Descriptive statistics were run to explore the demographics and the social media usage patterns. Pearson's correlations were conducted between participants' subscale scores (i.e., emotional reaction to criticism about physical appearance and severity of the critical comments about physical

appearance) from the Social Hassles Questionnaire and the modified Social Hassles Questionnaire related to social media with the EAT-26. Alpha levels were set at .05. Finally, a multiple regression analysis was run to predict disordered eating behaviors from critical comments from coaches, Instagram and Snapchat usage, emotional reaction to critical comments, severity of critical comments, years of participation in the sport, and body satisfaction. Assumptions of normality were met prior to data analysis.

RESULTS

All of the participants surveyed reported engaging in social media, while 56.2% of did not allow strangers to follow them on social media. As far as body satisfaction, the majority of participants were in the middle with 34.8% stating that they were somewhat satisfied with their body image, 22.5% stating that they were somewhat dissatisfied, and 12.4% stating they were neutral. Only 10% were on the continuum ends, with 9% of participants claiming that they were extremely satisfied with their body image, and 1.1% claiming that they were extremely dissatisfied. A large portion of the participants claimed that they had received criticism about their bodies from significant people in their lives (43.8%), who included coaches (32.6%), friends (15.7%), mothers (10.1%), fathers (5.6%), and boyfriends (3.4%).

Results for the first research question indicated that participants were using social media for an average of 3.27 hours a day, with Snapchat being the most utilized (see Table 1). In comparison to the college student population as a whole, a previous study found that college students spend a little more than 16 hours per week on social media (Huang & Capps, 2013).For this study, the usage for each individual social media outlet was scaled on a Likert scale because it was determined that participants would not be able to accurately report the hours/minutes spent on each source: *1 (I don't use this platform at all), 2 (Less than once a week), 3 (1-2 days a week), 4 (3-6 days a week), 5 (about once a day), 6 (2-4 times a day), 7 (5 or more times a day).*

Table 1
Means and standard deviations of social media outlet usage.

Outlet	M	SD
Snapchat	6.37	1.24
Instagram	5.80	1.67
Facebook	4.13	1.74
Twitter	4.09	2.21
YouTube	3.29	1.56
Google+	2.51	2.11
Pinterest	2.50	1.71
Tumblr	1.09	0.44
Reddit	1.03	0.17

Note: Likert Scale options: 1 (I don't use this platform at all), 2 (Less than once a week), 3 (1-2 days a week), 4 (3-6 days a week), 5 (about once a day), 6 (2-4 times a day), 7 (5 or more times a day).

Table 2
Descriptive Statistics for Social Hassles Results.

	Minimum	Maximum	Mean	SD
Severity	3	12	7.15	2.72
Emotional Reaction	0	8	4.40	2.28
Severity (Social Media)	3	9	3.60	1.46
Emotional Reaction (Social Media)	0	8	1.17	2.15

Table 3
Regression Analysis.

Variable	B	β	t	p
Coach	-.0201	-.217	-1.39	.175
Severity of comment	-0.053	-.325	-1.41	.168
Emotional reaction to comment	-0.013	-.068	-0.26	.799
Years of participation	-0.021	-.110	-0.74	.463
Body satisfaction	-0.086	-.213	-1.14	.262
Instagram usage	0.023	.094	0.549	.587
Snapchat usage	0.049	.382	2.337	.026

For research questions two, three, and four, descriptives were run (see Table 2) and Pearson's bivariate correlations were computed. For research question two, no significant correlations and a small effect size were found between average hours spent on social media and disordered eating behaviors (M = 1.74 ; SD= .44), r = .199, p >.01). According to Cohen (1992), effect sizes are considered small if r < .3, medium if r < .5, and large if r =.5 or greater. For research question three, a strong correlation in addition to a large effect size was found between severity of the critical comment about physical appearance and disordered eating behaviors, r = .722, p < .01, as well as emotional reaction to critical comments about physical appearance and disordered eating behaviors, r = .566 p <.01. This means that the more severe the emotional reaction to the comment and the more severe the comment itself, the more likely disordered eating behaviors were displayed. For the fourth research question, which explored comments made on social media, no relationships were found between the emotional reaction or the severity of the comment made on social media and disordered eating behavior, r = -.143, p > .01 and r = -.026 , p > .01, respectively.

For the fifth research question, a multiple regression analysis was conducted to examine potential predictors of disordered eating behavior. The potential predictors included criticism received by coaches, the emotional reaction and severity of comments not made on social media, years of participation in the sport, satisfaction with physical appearance, Instagram and Snapchat usage, and total hours spent on social media (see Table 3). The multiple regression analysis was significant with a large effect size (f^2=.43) predicting 43% of the variance in eating behaviors in college-aged female gymnasts (F (8, 31) = 2.90, R^2= .428, p < .05). A post-hoc power analysis with the 72 participants was run with the alpha of .05, which determined the power at .99 leading to confidence in the results.

DISCUSSION

The aim of this study was to explore the relationship between criticism, social media usage, and disordered eating in college-age female gymnasts. Significant associations were found between general criticism and disordered eating behavior. Combining variables related to social hassles, body satisfaction, usage of certain social media outlets, and years of participation could predict disordered eating. No relationships were found between social media variables and disordered eating behaviors.

Previous research has found significant association between social media usage and disordered eating in adolescent females (Becker et al., 2011). Furthermore, internet exposure has been linked to internalized body image concerns (Tiggemann & Slater, 2013), and Facebook usage correlates with disordered eating patterns in college-aged females (Tiggemann & Slater, 2013). Although a link was found between general criticism received and disordered eating behaviors, the results of this study did not find a link between critical comments received on social media and disordered eating behaviors in this sample of college-aged female gymnasts. This could be due to a variety of reasons, such as participation in the sport itself, which could serve as a protective factor, or the fact that over 72% of the participants had private social media accounts. This is significant because if a person only allows people that they know to follow them on social media, the chances of receiving a critical comment may be lower than if strangers can make comments. This may be different than professional elite gymnasts, who may be more apt to receive critical comments about their body on social media because of the high level of visibility. Additionally, 55% of the participants of this study reported being either extremely satisfied with their body or somewhat satisfied with their body, so this group in particular may not have been very vulnerable to criticism.

Another reason could be that these athletes may have developed mental skills that allow them to overcome criticism made on social media, such as coping with adversity. Additionally, while coaches could present as a risk factor in athletes' development of disordered eating patterns (Muscat & Long, 2008), athletes' peers could play a large role as a protective factor (Ulrick-French & Smith, 2006). Being accepted by peers and having strong friendships have been shown to predict perceived competence in athletes (Ulrick-French & Smith, 2006), which serves as a protective factor from disordered eating in itself. This could be explained by the social comparison theory that states people have the drive to measure how they are doing in any given circumstance by comparing themselves to their peers. If they are perceiving themselves as better or on equal level to their peers, the risk of developing disordered eating patterns may be less. Additionally, the objectification theory, which states that the degree and kind of negative reactions can be predicted through the extent to which women are objectified, could pose an explanation as well. If a gymnast is not objectified for her physical appearance, but rather her actual skill, then she may be less likely to be vulnerable to disordered eating behaviors. Finally, self-esteem may also play an important role as a protective factor against the development of disordered eating patterns. Sports participation has been linked to higher self-esteem levels in college-aged women (Cate & Sugwara, 1986), which is linked with lower instances of psychopathology (Larson & Kleiber, 1993). Previous research has found links between preexisting psychopathologies such as depression, anxiety, and disordered eating behaviors (Zucker, Womble, Williamson, & Perrin, 1999; Garner 2004).

Finally, criticism of one's weight has been shown to play a large factor in the

culmination of an athlete developing disordered eating behaviors (Muscat & Long, 2008). The results from this study are consistent with Kerr, Berman, and De Souza's (2006) findings that criticism from coaches could be a factor in a gymnast developing disordered eating patterns. This is because

"Comments from someone critically important in an athlete's life, someone whom the athlete always wishes to please, carry much weight. When these comments focus on a highly sensitive issue, they can devastate the athlete" (Rosen & Hough, 1988, p. 144). By criticizing or praising gymnasts for their weight without taking into effect why the gymnast has lost weight or investigating how the weight could be impacting her performance, significant people in the gymnast's life could enforce disordered eating behaviors (Rosen & Hough, 1988).

LIMITATIONS

It is important to note the limitations for the current study and provide suggestions for future research. The main limitation of this study was the sample size of the participants. Although measures were exhausted in the recruitment of participants; it may have been beneficial to have sent the recruitment materials out earlier in the off season as opposed to a month before the college gymnastics season started. Another limitation was the limited reliability data for the Social Hassles Questionnaire (Muscat & Long, 2008), as it is a relatively new instrument and has not been extensively tested. While the Social Hassles Questionnaire is relatively new, and not extensively tested, it is the only questionnaire that measures emotional response to criticism made specifically for athletes that is readily available. Furthermore, this study did not account for mental health status beyond possible disordered eating behaviors. Since depression and anxiety have been linked as a precursor to disordered eating patterns (Zucker et al., 1999; Garner, 2004), it may be beneficial to also account for those pathologies in any future study, along with self-esteem.

Future research should seek to further understand the relationship between criticism received on social media and disordered eating behaviors in athletic populations. This study was the first of its kind to study the relationship between social media usage and disordered eating in college-aged female gymnasts, but yet research is still extremely limited in studying these variables in the larger athletic population as a whole. Athletes from different sports may respond differently to criticism than gymnasts would. Because aesthetically centered sports are the most prone to disordered eating pathology (Byrne & McLean, 2002; DiBartolo & Shaffer, 2002), it could be beneficial to study these variables in other aesthetic sports such as figure skating, diving, cheerleading, or even sports that are not aesthetically-centered such as softball or basketball. Additionally, it may be useful to explore whether these variables are impactful in males in aesthetically-centered sports as well and social media usage's impact on mental health in athletes as a whole.

IMPLICATIONS

The results from this study could have implications for athletes from other sports, coaches, parents, mental health professionals, and other important support systems in an athlete's life. This study is consistent with previous findings that critical comments made by significant people in an athlete's life could impact their eating pathology and behaviors. This could be counteracted by immersing the athletes in environments where focus is put on physical and emotional components of an athlete's performance instead of an athlete's physical shape. Furthermore, it would be beneficial for athletes, parents, and other significant people in athletes'

lives to receive training in order to recognize the signs of disordered eating behaviors. Finally, while it has been shown that criticism received from significant people in a gymnast's life correlates with disordered eating, this study did not find links between criticism received on social media and disordered eating behaviors. The study did find that Snapchat usage, which is the most utilized social media outlet by the participants, may predict disordered eating behavior in gymnasts. This finding may be beneficial to significant people in athletes' lives as a way to help educate them of the potential dangers of social media outlets such as Snapchat and how to support an athlete if they develop disordered eating behaviors.

CONCLUSION

While this study did not find significant correlations between criticism received on social media and disordered eating behaviors in college gymnasts, findings were consistent with Kerr et al., (2006) findings that criticism from support systems in athletes' lives can play a significant role in the development of disordered eating behaviors. Comments made by coaches, parents, or other significant figures in athletes' lives can cause shame about one's body image which can lead to a decrease in athletic performance and achievement (Lewis, 1992). In order to combat the effects of criticism in athletes, including comments possibly made on social media, care should be taken to begin education initiatives for coaches, families, friends, and athletes themselves in order to prevent further and dangerous development of disordered eating behaviors and patterns now and in the future.

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THE PREDICTION OF ALL-AROUND EVENT FINAL SCORE BASED ON D AND E SCORE FACTORS IN WOMEN'S ARTISTIC GYMNASTICS

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Original article

Abstract

In the present study, we try to establish whether specific disciplines in women's artistic gymnastics are equal and should the applicable Code of Points (COP) be revised in terms of point standardization on apparatus. Our sample included all-around senior female gymnasts who participated in the qualification (C-I) competitions from 2009 to 2019. The aim of our research was to determine the impact of individual apparatus D and E score in women's artistic gymnastic in relation to the final result of all-around event. The age among seniors rise from 2009 to 2019 for 1.88 years. In our analysis, we have found that the results achieved on each apparatus were significantly different. The average final scores on vault were significantly higher than on all other apparatus. Significant predictors of all-around success seem to be uneven bars D and E scores and balance beam E score. It was interesting to observe that the vault, balance beam and floor D scores were not significant predictors. Coaches can use the results from this research in their planning of preparation tactics for gymnasts in all-around, team and apparatus competitions.

Keywords: *women's artistic gymnastics, judging, competitive performance, prediction.*

INTRODUCTION

In the program of the first Olympic Games (OG), artistic gymnastics was presented for the first time in Greece (Athens) in 1896, and in 1903 at the World Championship (WCh) in Belgium (Antwerp), while at the European Championship (ECh) it was presented for the first time in 1955, in Germany (Frankfurt). Women's artistic gymnastics (WAG) first appeared at the OG in the Netherlands (Amsterdam) in 1928; at the WCh in Hungary (Budapest) in 1934, and at the ECh in Greece (Athens) in 1957, (Grossfeld, 2014). Before 1996, competitions in gymnastics were different from what we have now. On the first day of a competition, gymnasts performed compulsory exercises in qualifications as prescribed by the Fédération Internationale de Gymnastique (FIG). On the second day, they performed free exercises. For the final result, points from both performances by each gymnast were taken into consideration. In 1996, compulsory exercises were eliminated as they were considered not interesting for television or general public viewing; the scoring became simplified, it was easier to follow the competition results, which made competitions more attractive to the general

public. Shortened competitions thus became less taxing on the gymnasts (Grossfeld, 2014).

Today, assessment in artistic gymnastics is based on the international *Code of Points* (COP), which are updated and published after every Olympic Games. The female competition COP is divided into D and E parts. There are independent members of D and E judging panels on all apparatus: panel D evaluates difficulty value, special requirements and bonus points and their evaluation starts from 0.00 points; panel E evaluates the performance of an exercise (technique of execution, body posture, and balance) and makes deductions from ten points downwards. The judging panel D determines the initial value of an exercise, and panel E registers performance errors related to technical performance, body posture and balance; the two grades are added up to make the final score (FS).

The basis of all competitions in WAG is all-around event which consist of competition on four apparatus. The term "*all-around*" simply means using different gymnastics apparatus. Artistic gymnastics is a typical multidisciplinary sport with four disciplines in women's competition: Vault (VT), Uneven Bars (UB), Balance Beam (BB) and Floor Exercise (FX). Women perform maximum 8 highest difficulty value elements (DV) including a dismount that are counted on UB, BB and FX. Currently, in the Olympics or WCh competitions, the event is divided into several sessions that are held on different days: qualification (C-I), all-around finals (C-II), team finals (C-III) and event finals (C-IV). The COP for the evaluation of artistic gymnastics includes seven levels of degree of difficulty. The lowest degree represents level A=0.10 points and the highest difficulty level is I=0.90 points (FIG, 2017). Two of the primary purposes of the WAG COP (FIG, 2017) is to "*provide an objective means of evaluating gymnastics exercises at all levels of regional, national and international competitions" and "assure the identification of the best gymnast in any competition"* (FIG, 2017).

In artistic gymnastics, the emphasis is on the aesthetic component, which must be performed in accordance with the prescribed movement structure. Although the methods of evaluation in individual sports differ, there are always criteria that determine how the final result is calculated. For individual sports, such as: figure skating, diving, synchronized swimming, gymnastics, including *acrobatics, aerobics, rhythmics, trampoline, artistic gymnastics;* ski jumping, freestyle snowboard: *snowboard-halfpipe and slopestyle*; dance, aerials, etc., it is typical that judges evaluate the quality of competitive effects on the basis of displayed compositions or jumps (Atiković, 2012).

The specificity of the gymnastics competition is that the result is not expressed in physical units (meter, kilogram or second); nevertheless, the technique of performing exercises is evaluated strictly and subjectively on the basis of pre-determined difficulty values of individual elements and compositions as a whole as prescribed by the relevant COP. Artistic gymnastics is a sport with a primary requirement of mastering techniques to perform most varied specific exercises. This means that learning new, more complex and demanding elements is the everyday principle of the training process (Ferkolj, 2010).

Whether technique is properly executed is largely decided on the efficiency of the visual performance. This means that it often happens that a harmless error in the technique of performing a complex element devalues or even prevents the entire element from being performed (Atiković and Smajlović, 2011).

Several critical aspects of performance judging were already identified in the past at various competitions and several propositions for further improvements in this field have

been made (Ste-Marie, 2000; Atiković and Smajlović, 2011; Plessner and Schallies, 2005; Boen, van Hoye, Vanden, Feys and Smits, 2008; Leskošek, Čuk, Karácsony, Pajek and Bučar 2010; Bučar, Forbes, Pajek, Leskošek and Čuk 2011; Bučar, Čuk, Pajek, Karácsony and Leskošek, 2012; Pajek, Čuk, Pajek, Kovač and Leskošek, 2013; Heiniger and Mercier, 2018; Atiković, Kamenjašević, Nožinović, Užičanin, Tabaković and Ćurić, 2020). The system works well for apparatus specialists; the more you show, the higher the score. However, for gymnasts in all-around individual (AAI) competitions there can be a problem due to the apparent equivalence among apparatus, even though there are special rules that apply only to vault. Gymnasts in AAI competitions only perform one jump on vault, while on the other three apparatus they present a series of elements that make their routines (Čuk and Forbes, 2010). The aim of our research was to determine the impact of D and E score on individual apparatus in relation to the final result in the all-around event in WAG.

METHODS

The number of competitors in the qualification round (C-I) varies from year to year. Our sample included all-around senior female gymnasts who participated in the qualification (C-I) competitions at WCh and/or OG held in: 2009 London (GBR), n = 79; 2010 Rotterdam (NED), n = 140; 2011 Tokyo (JPN), n = 154; 2012 London (GBR), n = 59; 2013 Antwerp (BEL), n = 80; 2014 Nanning (CHN), n = 154; 2015 Glasgow (GBR), n = 190; 2016 Rio de Janeiro (BRA), n = 59; 2017 Montreal (CAN), n = 74; 2018 Doha (QAT), n = 143 and 2019 Stuttgart (GER), n = 173.

We analysed the chronological age trend from the Longines official book results of the FIG of all-around female participants in WAG for the period of 2009 to 2019 (*see* Appendix). We used E score (or Execution score), D score (or Difficulty score) and FS from four apparatus: VT, UB, BB and FX as variables.

The data were analysed using the Statistical Package for Social Sciences – version 23.0 (SPSS Chicago, USA) and Microsoft Office Excel 2013. Descriptive statistics were calculated using the mean (M) values as a measure of central tendency, standard deviation (SD) as a measure of dispersion. Five percent level of significance $p < 0.05$ was considered for all statistic parameters except Pearson correlation was $p < 0.01$. We used regression analysis (method enter) as a form of predictive variables (predictors). For calculating the chronological age, the formulas from the Microsoft Office Excel 2013 package were used for the total *number of days* of one's age since the date of birth until the first day of the competition qualifications.

RESULTS

Despite all the results in Table 1, the results of VT in all competitions show significantly higher values in FS in comparison to other apparatus in all competitions. Value ratings range from VT FS 2018 13.080 points to VT FS 2016 14.244 points. In all competitions, this discipline has the highest average value. The lowest values are in UB FS 2009-2011, 2014-2015 and 2019, BB FS 2012-2013, 2016-2019 years. Analysing the results in arithmetical environments, the highest values were recorded for WCh 2019 (M = 20.18, SD = 3.67) years of age, and the lowest for WCh 2009 (M = 18.30, SD = 2.17) years. According to the results presented in Table 2, female participants were getting older from WCh 2009 to WCh 2019 by 1.88 years Fig 1.

We found statistical difference in age between 2009 and 2019 (t_{250} = 3.861, p < .000). It is evident that the trend of decreased scores happens gradually after the end of OG because new young

gymnasts are coming to competitions. At WCh, the correlation is small (15 or 16%) and almost negligible. There is a statistically significant positive correlation in Table 2 between the years of chronological age and the results in all-around competitions in years 2014 (*r*: 0.165, p < 0.041), 2015 (*r*: 0.155, p < 0.033), and a negative correlation of 29% at Olympic Games 2012 (*r*: -0.299, *p* < 0.022). These results at the OG show that the older the gymnasts get, the lower the number of points. It is evident that the trend of lowered scores happens gradually after the end of OG. Fig 2.

Table 1
Statistics of D, E and FS scores with mean results each apparatus.

Years	Vault (VT)				Uneven Bars (UB)			Balance Beam (BB)			Floor Exercise (FX)		
	N	D	E	FS	D	E	FS	D	E	FS	D	E	FS
2009	79	4.992	8.340	13.286	4.937	7.014	11.949	5.002	7.273	12.279	4.988	7.413	12.343
2010	140	4.935	8.580	13.505	4.861	7.069	11.930	5.076	7.368	12.441	4.891	7.961	12.808
2011	154	5.014	8.427	13.434	5.023	6.846	11.868	5.162	7.369	12.527	5.035	7.536	12.495
2012	59	5.394	8.617	13.994	5.611	7.810	13.388	5.545	7.503	13.041	5.355	8.046	13.332
2013	80	5.047	8.691	13.706	5.035	7.285	12.320	5.246	6.992	12.224	5.197	7.277	12.413
2014	154	4.979	8.798	13.755	4.829	7.165	11.995	5.099	7.277	12.365	5.079	7.412	12.430
2015	190	4.985	8.753	13.724	4.813	6.849	11.641	5.031	7.003	12.014	5.035	7.603	12.595
2016	59	5.428	8.835	14.244	5.700	8.086	13.786	5.608	7.738	13.338	5.462	7.970	13.395
2017	74	4.572	8.696	13.246	4.733	7.363	12.088	4.902	6.205	11.084	4.729	7.337	11.987
2018	143	4.531	8.569	13.080	4.490	7.113	11.602	4.803	6.597	11.392	4.617	7.486	12.050
2019	173	4.657	8.759	13.387	4.558	7.266	11.799	4.822	6.457	11.218	4.646	7.429	12.019

Abreviation: N; N is used to indicate the total number of subjects sampled, D; difficulty score, E; Execution score and FS; final score.

Table 2
Pearson correlation coefficients between average age and women's all-around qualifications (C-I) final score.

Years	N	M_AGE	SD	M_AAI_FS	SD	r	p
2009	79	18.30	2.171	49.858	4.708	-.136	.231
2010	140	18.33	2.377	50.686	4.025	.152	.073
2011	154	18.98	2.646	50.324	4.318	.006	.939
2012	59	19.92	3.228	53.756	3.587	-.299	.022*
2013	80	19.04	2.738	50.664	4.266	-.042	.710
2014	154	19.43	3.118	50.546	3.842	.165	.041*
2015	190	19.67	3.291	49.976	4.683	.155	.033*
2016	59	20.35	3.351	54.764	3.088	.018	.892
2017	74	19.40	3.056	48.406	4.398	.005	.964
2018	143	19.78	3.595	48.125	3.956	.088	.293
2019	173	20.18	3.674	48.470	4.111	.070	.359

*Abreviation: N; N is used to indicate the total number of subjects sampled, M; Mean – This is the mean of the variable, SD; This is the standard deviation of the variable, AGE; Chronological Age, AAI_FS; All-Around Final Score, r; The correlation coefficient can range from -1 to +1, p; p-value associated with the correlation is significant at the *p < .05 level (5% significance).*

Table 3
Pearson correlation matrix.

AAI_FS	N	VTD	VTE	UBD	UBE	BBD	BBE	FXD	FXE
2009	79	.747	.644	.820	.811	.702	.784	.825	.851
2010	140	.762	.571	.786	.747	.778	.764	.786	.706
2011	154	.690	.575	.784	.801	.803	.734	.786	.747
2012	59	.818	.605	.709	.715	.760	.688	.781	.636
2013	80	.626	.629	.774	.746	.813	.780	.783	.731
2014	154	.666	.586	.774	.719	.757	.716	.799	.660
2015	190	.662	.581	.821	.731	.814	.746	.871	.736
2016	59	.485	.532	.709	.691	.726	.735	.768	.650
2017	74	.735	.617	.743	.745	.701	.790	.772	.692
2018	143	.725	.521	.787	.660	.708	.735	.821	.650
2019	173	.695	.551	.806	.754	.699	.703	.783	.666

Abreviation: AAI_FS; All-around final score, All correlations are significant p < 0.01.

Table 4
Regression analysis (method Enter), predicted AAIFS variable (Beta Coefficients).

Years	VTD	VTE	UBD	UBE	BBD	BBE	FXD	FXE
2009	.109	.098	.202	.259	.133	.209	.106	.156
2010	.125	.078	.214	.285	.150	.242	.112	.125
2011	.117	.060	.221	.289	.139	.209	.120	.161
2012	.151	.120	.195	.244	.175	.277	.091	.141
2013	.132	.116	.207	.231	.141	.225	.121	.173
2014	.134	.079	.238	.269	.147	.212	.121	.189
2015	.114	.068	.244	.229	.113	.218	.177	.143
2016	.162	.155	.198	.228	.176	.221	.187	.162
2017	.128	.095	.192	.266	.120	.249	.104	.209
2018	.145	.099	.267	.210	.135	.275	.116	.155
2019	.135	.113	.285	.222	.110	.239	.136	.136

Abreviation: All correlations are significant p < 0.01; F-test of significance for all is p < 0.000.

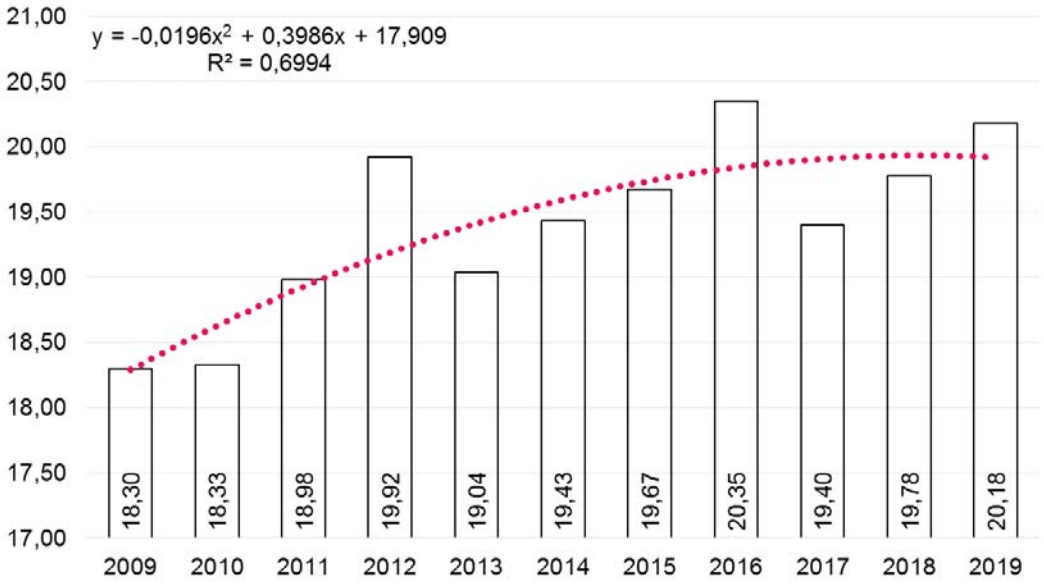

Figure 1. Average age women's all-around qualifications (C-I), second-order polynomial-regression equations, 2009–2019.

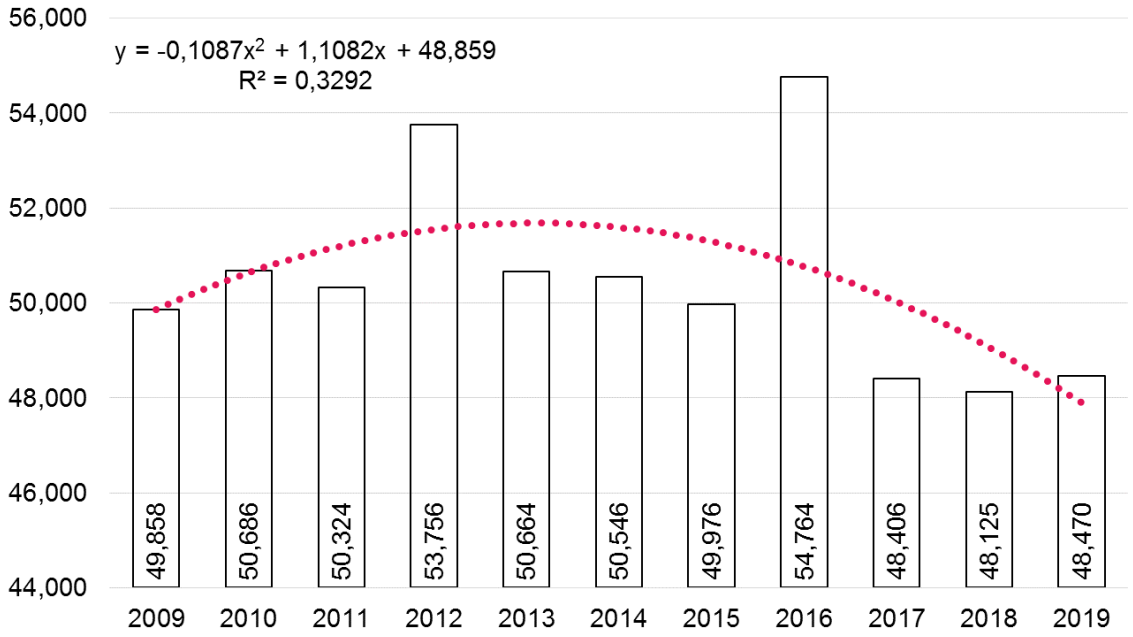

Figure 2. Results for women's all-around qualifications (C-I), second-order polynomial-regression equations, 2009–2019.

In the intercorrelation matrix in Table 3, the criterion variable AAI FS presented as the sum of all variables made statistically significant relationships with several variables: FX D from 2009 to 2021, BBD from 2010 to 2016, UB D from 2009 to 2010, UB D from 2014 by 2015 and UB D from 2018 to 2019. What we are noticing is that these are estimates that define the weight value of a composition on these apparatus.

All the regressions in Table 4 had such a prediction, which was not our aim. Should we analyse separately D and E results, the prediction would be much smaller (Čuk and Forbes, 2010). In gymnastics, we have no way of separating one D or E score from another because each score has its value. With the linear regression analysis between AAI FS and D and E scores for each apparatus (method enter) we have predictors of AAI success. Significant predictors of AAI success are UB D and E scores and BB E scores. It was interesting to observe that VT, BB and FX D scores were not significant predictors of AAI. It seems that it is more important to perform a slightly less difficult exercise well than a more difficult exercise with a fall.

DISCUSSION

If we compare the age of gymnasts in women's artistic gymnastic by years we can conclude that there is an increased complexity in the COP in terms of DV and an increased number of deductions which coincide with the need for a longer competitive career (Atiković, Delaš and Čuk, 2013[a]; Atiković, Delaš and Čuk, 2013[b]). This means that learning new, more complex and more demanding elements is the working principle of the training process. As such, it increases the length of training (Atiković, et al,, 2013[a]). For example, a gymnast like Simone Biles (USA) continues to develop and challenge the norms of WAG with her creative and technical abilities and skills. Biles at WCh 2019 in Stuttgart successfully performed a new element, a triple double, on FX, which was given a J value. It's worth one point. Previously, the highest element value was I (9/10th of a point). Many athletes achieved their best results in the final years before

the end of their sports career. Nowadays, professional athletes are expected to quit sport at a certain age, but sometimes such perceptions can be misleading. Namely, the average gymnast's age has changed in the last 15 years (Atiković et al., 2013[a]). Male gymnasts between 2003 and 2016 grew 2.3 years older and female gymnasts 3.3 years older. Atiković (2020) showed that top female gymnasts' chronological age increased by 4.02 years OG1996, (n = 105, M = 16.77, SD = 2.02); OG2000, (n = 97, M = 17.65, SD = 2.10); OG2004, (n = 98, M = 18.73, SD = 2.85); OG2008 (n = 97, M = 19.01, SD = 3.03); OG2012, (n = 96, M = 20.43, SD = 3.65); OG2016, (n = 98, M = 20.79, SD = 4.36).

In the near future, we expect (with further apparatus specialization in WAG) that age will increase further. Some gymnasts, such as Oksana Chusovitina (UZB), are successful at the age of 44 and ranked high in major competitions. Oksana Chusovitina will compete at her eighth Olympics in 2021, setting another age record at 46.14 years.

Unlike on other apparatus, in the all-around event a completely different philosophy of grading is applied to VT. On VT, gymnasts are allowed to perform only one element or one jump in contrast to other apparatus where the number of elements performed is significantly higher. On other apparatus gymnasts are expected to have 8 elements from different groups in their composition (FIG, 2017). The VT itself has to be pre-announced to the judging panel so that the panel and the audience know in advance what the gymnast will do in each of the vaulting phases. One harmless error during one of the vaulting phases can make the gymnast abort the announced jump and not be assessed. Unlike on VT, on other apparatus of gymnastics all-around event, the competitor can make a mistake in one of the elements and still get points for the whole composition. The difficulty value and bonus points are predetermined for each jump and presented in the form of rotation around the vertical and frontal axis. On other apparatus, gymnasts have the opportunity to achieve bonus points for connections between elements.

After our analysis of competitions, it is clear that some groups and types of jumps are more represented than others. The most represented are from Group 4, followed by Group 2 and Group 3. Most gymnasts had a start value of 4.60 p. The most frequent vault during the qualifying period is jump number 4.32, or as its description states: "*Round-off, flic-flac on – stretched salto bwd with 1/1 turn (360 °) off*" with 4.60 p. It can be noticed that very few jumps from other groups are performed. Jumps from *Group 1* type handspring, Yamashita, round-off with or without turn in 1st and/or 2nd flight phase, and jumps from *Group 5* type round-off with 1/2 turn (180°) in 1st flight phase – flip fwd/bwd with/without turn in 2nd flight phase are rarely performed at competitions.

During training, the time spent on VT is not the same as the time spent on other apparatus in men's artistic gymnastics (Hadjijev, 1989). In the past, normally the least amount of training time was dedicated to VT, and the most amount of time was spent on pommel horse (PH). Training times on on each of the other apparatus were similar (the gymnast's preferences, abilities, and individual characteristics are also important in determining training time spent on each apparatus (Hadjijev, 1989).

Interesting research on the use of information communication technology for sporting purposes and their implementation in practice was presented in 2011. Its authors (Bučar Pajek et al., 2011) created a program at the Australian Institute for Sport that worked as a "*real time judging system*". The program improved the objectivity of evaluation by the judging panel E as deductions were entered during gymnast's performance and could not be modified; judges had to deduct quickly and the moment they obseved a mistake. Similar research, conducted by Sands,

2010, under title "J*udging in Real Time*", mentioned the biggest problem of evaluation, and that is reliability and validity. In his paper, the author noted that judges could use modern technology and with that make their deductions immediately after a gymnast's performance.

Assessing the results of men's all-around qualifications at OG 2008, Čuk and Atiković (2009) found that VT was considered the most valuable apparatus, and the PH was less valued among all-around gymnasts. Using the COP, it is very hard to obtain a high D score on PH and easier to obtain a high D score on VT. Pairwise *t*-tests showed that D scores between VT and other apparatus, and between PH and other apparatus were significantly different. Equality of disciplines has been tested by other authors. On a sample of 49 all-around male gymnasts at the ECh 2009, the implications of the difficulty of scores were tested in relation to the success in all-around competition. Only one group had a chance to win an all-around medal; difficulty scores between all six apparatus were not equal; the highest prediction of the all-around score was the parallel bars difficulty score (Čuk and Forbes, 2010). One of the attempts to identify the most important routine apparatus for success in WAG at WCh was conducted in 2011 (Massidda and Calò, 2012). Performance scores on UB and BB for women, and on PH for men were least influenced by competitor's standing. Scores on UB, BB, and PH were consistently good predictors of final standing. The results suggest that high scores on these apparatus have a greater influence on overall performance than scores on the other apparatus, regardless of competitors' level.

It is possible to conclude that judging in artistic gymnastics is extremely complex. Studies that address it are mostly focused on metric characteristics of judging. In one (Bučar et al., 2012; Pajek et al., 2013), the authors investigated the reliability and validity of judging at the ECh in Berlin 2011. Thy concluded that the quality of judging was comparable to other examined gymnastics competitions at different levels and emphasized that inferior results on VT and FX require further analysis. Another study (Čuk, 2015) dealt with the predictors of success when spectators served as judges. It showed that the reliability of their judging was the same as when performed by official judges. Their rankings closely corresponded to the rankings set by official judges. With modern technology, such as smart mobile phones, FIG could organise some experimental judging by fans. Fujitsu Ltd has developed a judging system that can objectively score a routine based on the angles of gymnasts' joints. The system works by capturing the gymnasts' movements with a 3D laser sensor and analysing them as numerical data. After 2020, the program is expected to calculate the difficulty value and the execution score. This kind of technology will enable more objective judging in artistic gymnastic. Additional sports presentation information will also be made available for enhanced viewing by spectators in the arena as well as on television or social media (Fujiwara and Ito, 2018).

Technology has improved the accuracy, enjoyment, and experiences of both athletes and spectators at sporting events. Some of the key technological advancements for athletes and spectators include improved time-tracking systems, clothing, equipment, goal-line technology, video technology, GPS data tracking, virtual imaging, accuracy and decision systems (hawk-eye), coverage of events around the world via the internet and on multiple devices. In *athletics*: tracking race times and clothing; *football*: goal-line technology (GLT) and video technology (also known as VAR); *rugby*: data tracking (GPS tracking to collect data and stats on player performance) and video technology (hawk-eye video review technology is used

by television match officials (TMO) for better decision-making); *swimming*: virtual imaging, divecam and swimsuits, *tennis*: hawk-eye line-calling system, radar guns and tennis racquets; *gymnastics*: Instant Replay and Control System (IRCOS) and smart rings, etc. (Čuk and Atiković, 2009; Bučar Pajek et al., 2011; Aarts and Pluk, 2014, Čuk, 2015). IRCOS is a program that gives judges the ability to immediately visually review gymnasts' routines. Judges can analyse recorded video in the case of a scoring dispute among judges or a protest filed on behalf of a gymnast. In competitive men's artistic gymnastics, an exercise on still rings is composed of swing, strength and hold positions. All strength and hold positions must be held for a minimum of 2 seconds, otherwise a deduction of 0.3 points for each incomplete hold position is applied to the execution score by the execution jury (E-judging panel). An innovative measurement system called "*smart rings*" is based on the forces that a gymnast exerts on both rings and helps judges evaluate elements on this apparaus (Aarts and Pluk, 2014). Both systems provide important tools for the more accurate review of gymnasts' exercises. It is certain that FIG will have to facilitate more accurate evaluations in the future, either by using new modern technologies, or a better evaluation system, or both.

In the past, many different ways of calculating the FS were used in gymnastics. Author's Čuk, Fink and Leskošek (2012) compared 14 different models for calculating the final scores. Due to the lower complexity of VT routines (in comparison with other apparatus), those who perform well on VT can get a higher FS. An analysis of training loads shows that VT is also an apparatus where the least training time is spent (Atiković and Smajlović, 2011).

Author Fujihara contributed a significant review of previous research (Fujihara, 2016). One of the objective ways to determine the start value of vault is to use biomechanics characteristics of vault (Ferkolj, 2010; Atiković and Smajlović, 2011; Atiković, 2012; Farana and Vaverka, 2012; Farana, Uchytil, Zahradník and Jandačka, 2015; Fujihara, Yamamoto and Fuchimoto, 2017). Atiković and Smajlović (2011) tried to define which biomechanical parameters explain and define the DV. Their study showed that it explained 92.4% of the vault DV. For example, authors were able to prove that only 3 biomechanical variables were predictors: *degrees of turns around the transversal axis, degrees of turns around the longitudinal axis and body's moment of inertia around the transversal axis in the second flight phase*. With this research, its authors have confirmed that initial points on VT or other apparatus can be more objectively determined by the expert commission of the male and female technical committee of FIG. Unfortunately, the points for WAG so far have been dictated by experience rather than by scientific work and research.

Between two Olympic cycles, WAG COP 2013-2016 and 2017-2020 saw minor changes in Composition Requirements (CR) on apparatus - instead of 5 CR it is now 4 – as a few dismounts from UB, BB, and FX were dropped, due to the risk of injury when performing dismounts with high difficulty requirements (D, E and more). The new COP WAG 2017-2020 has a lower CR value, (2.00 points down from 2.5 points) but D evaluation is the same as it was in the last COP. Today's philosophy when developing gymnastics composition on an apparatus is based on safe performance, the fulfillment of all CR, and safe landing. Uncertainty or a fall may lead to a loss of placement in a competition and, thus, a change in the expected final score (FS). The change in the formation of D score did not lead to a change in the FS, because the DV has evolved and increased from 2009 (G=0.70 p.), 2013 (H=0,80 p.) to 2017 (I=0.90 p.). All gymnasts tend to perform their gymnastics composition with a maximum D score, but D score can be

differentiated differently. VT as a way to a higher FS in all-around is correct but no less demanding.

The results in WAG, especially on VT, should be equalised for all disciplines which is not the case at the moment. The results of this conducted research could be used as the basis for the launch of a change in the COP 2021-2024.

CONCLUSION

In the analysed results presented in this article, VT features significantly higher than other disciplines that make the all-around competition. The differences can be up to two points between two apparatus, e.g., VT and BB. This system works best for discipline specialists. However, in all-around the problem still exists and arises from the inequality between disciplines, that is, VT has special rules compared to UB, BB, and FX. A gymnast on VT shows one vault in all-around. In comparison to other disciplines, vault is similar to one element in a BB exercise. Significant predictors of AAI success are UB D and UB E scores and the BB E score. It was interesting to observe that VT, BB and FX D scores were not significant predictors of AAI. Coaches can use the results from this research for the planning of preparation tactics for gymnasts in all-around, team and apparatus competitions.

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APPENDIX

2019 https://www.gymnastics.sport/site/events/searchresults.php#filter
2018 https://www.gymnastics.sport/asset.php?id=fidb_7803
2017 https://www.gymnastics.sport/asset.php?id=fidb_7802
2016 https://gymnasticsresults.com/results/2016/olympics/index.html
2015 https://www.gymnastics.sport/asset.php?id=fidb_7801
2014 https://www.gymnastics.sport/asset.php?id=fidb_7798
2013 https://www.gymnastics.sport/asset.php?id=fidb_7797
2012 https://gymnasticsresults.com/results/2012/olympics/index.html
2011 https://www.gymnastics.sport/asset.php?id=fidb_7796
2010 https://www.gymnastics.sport/asset.php?id=fidb_7795
2009 https://gymnasticsresults.com/archive/worlds/2009/london2009.html

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EVALUATION AND DEVELOPMENT OF ARTISTIC ABILITIES OF 7-8-YEAR-OLD RHYTHMIC GYMNASTS

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Original article

Abstract

A competitive composition in rhythmic gymnastics is a small performance that has its own storyline. That is what judges E1 and E2 evaluate. Judges' penalties for unsatisfactory artistry can be up to 5 or 6 points. In the works of scientists, the issues of artistry education for 7-8-year-old gymnasts are hardly ever addressed. To develop a methodology for the development of artistic abilities of 7-8-year-old female gymnasts. Theoretical analysis and synthesis of scientific and methodological literature; questionnaire (survey of coaches); pedagogical observation, experiment, testing: expert assessments; mathematical statistics. The study involved 20 7-8-year-old female gymnasts who have engaged in rhythmic gymnastics for 2 to 3 year and have category 2 qualification. An analysis of scientific and methodological literature shows the need to intensify research into the development of the aesthetic component in the training of female athletes in rhythmic gymnastics. On the basis of our questionnaire, it has been determined that it is necessary to develop artistic abilities of young female gymnasts by using elements of facial gymnastics, performance and improvisation. Introduction of a methodology for shaping the artistic abilities of female gymnasts in the educational and training process of the experimental group subsequently led to an increase in the female gymnasts' marks for their competitive routine by 1.3 ± 0.12 points ($p < 0.05$). The improvement rate in artistry in the experimental group was 18.4%, and in the control group 8% ($p < 0.05$).

Keywords: *rhythmic gymnastics, artistic abilities, 7-8 years.*

INTRODUCTION

Rhythmic gymnastics is a complex young sport; it is a combination of arts and sports and includes gymnastic, acrobatic and dance exercises performed with apparatus to music (Borysova Yu., Yeromina O., 2015; Gantcheva G., 2018). In this sport, female athletes compete in the individual event or in the group event. One of the components that judges evaluate especially strictly is the artistry of their routine. A competitive gymnastics routine is a short performance with its own storyline. This is exactly what judges E1 and E2 evaluate (FIG, 2016). Penalties for unsatisfactory artistry can be up to 5-6 points (Borysova Yu., Mokhova I., 2017). The modern system of training female athletes in rhythmic gymnastics aims, first

of all, to teach a large volume of complex and extremely complex elements that must be mastered by very young female athletes. As a result, female gymnasts tend to display only technically correct performance of their competitive routine, ignoring the storyline and the imagery of the routine (Averkovich E.P., 1989; Viner-Usmanova I.A., Kryuchek E.S., Medvedeva E.M., Terekhina R.N., 2014). This is why the question of developing a methodology to teach young female gymnasts artistry is relevant and requires detailed studying.

The issue of performing skills and artistry in rhythmic gymnastics was investigated by Borisenko S.I., 2000; Goncharenko L.V., 1987; Gorbacheva ZH.S., 2000; Gorshkova E.V., 2003; Kabaeva A.M., Plekhanova M. E., 2009; Karavackaya N.A., 2002; Karpenko L.A., 1994; Viner-Usmanova IA, 2014. The authors identified the main components of artistry assessment, namely: plasticity, expressiveness, acting, etc. An analysis of literature shows that authors mainly pay attention to the study of how to correctly develop physical qualities, but not enough to the artistry of a composition.

In competitions, female gymnasts are required to perform their competitive routines perfectly: technically, artistically, musically and expressively. This task is very difficult for gymnasts in junior categories. Female gymnasts need to coordinate the simultaneous execution of balance, turns, jumps and work with an apparatus while connecting with the emotional component of their routine and the music. In scientific literature, the issues of artistic education for young female gymnasts are almost non-existent. Purpose of the study is to develop methods to develop artistic abilities in 7-8-year- old female gymnasts.

METHODS

We analysed 27 sources that addressed the distinctive features of educational and training process in preliminary basic training in rhythmic gymnastics as well as formation of expressiveness in 7-8-year-old girls with the help of various means of dramatic art. We also looked at scientific articles, dissertation abstracts and educational and methodical aids that focus on the development of expressiveness in sports and ballet.

In order to create methods to develop artistic abilities in 7-8-year-old female gymnasts we used information from coaches – practitioners and data from scientific and methodical literature.

We used a survey to learn more about the specificity of displaying artistic abilities and their control in gymnasts. Another aim of our survey was to learn about the distinctive features of the educational and training process in preliminary basic training.

10 coaches of artistic gymnastics who work in The Specialized Sports School of the Olympic Reserve for Children and Adolescents (SCASSOR), Dnipro City, and in the Sports School for Children and Adolescents (CASS), Kamenskoye City, took part in the questionnaire. The coaches were given a questionnaire with seven multiple choice questions. Their answers provided us with information on how coaches view the process of developing artistry in 7-8-year-old female gymnasts. This information was necessary to devise a methodology for the development of artistic abilities in young female gymnasts by highly qualified coaches.

The object of pedagogical observation were female gymnasts who attend rhythmic gymnastics training at the communal non-compulsory educational institution, The Specialised Sports School of the Olympic Reserve for Children and Adolescents (COSEI SCASSOR), Dnieper City Council (DCC), Dnipro City. 2 groups of 7-8-year-old female gymnasts (10 girls in each) were observed on multiple occasions. When evaluating the results of our observations, we took into account

both the positive and the negative aspects of the coachs' and athletes' activities. When selecting the groups for observation, the following requirements had to be met: 1) all gymnasts had to have about the same level of fitness; 2) the same choreographer worked with them; 3) their parents and trainers had to give their consent for the study.

During the observation, the following aspects were recorded: means and methods of developing artistic abilities that were used in classes; the ratio of the volume and intensity of the load in a class; quality and quantity of tasks that female gymnasts performed during a class. The results of observations during classes and within the period of competitive activity, after a mathematical analysis, showed the effectiveness of classes and disadvantages in their content, forms of organization and methodology.

In the course of the study, a pedagogical experiment was conducted on the basis of the COSEI SCASSOR in rhythmic gymnastics of DCC, Dnipro City, from September 2018 to November 2019. The experiment involved 7-8-year-old girls, engaged in rhythmic gymnastics at the stage of initial basic training at the Sports School for Children and Adolescents (CASS). All gymnasts had almost the same level of preparedness ($p > 0.05$). The girls ($n = 20$) were divided into two groups: control group ($n = 10$) and experimental group ($n = 10$). The exercises for the development of artistry were added to the training program of the gymnasts in the experimental group.

The main objective of the experiment was to test the effectiveness of the methodology by using a set of exercises and music games in order to develop artistic abilities in young female gymnasts.

By using pedagogical testing, we determined the level of artistic abilities in 7-8-year-old female gymnasts. For this, we used Viner-Usmanova's method, 2014, which comprises gymnastic compositions with musical accompaniment. In her training program for highly qualified athletes Viner-Usmanova highlights the main components of artistic abilities, namely: classical choreography, dancing, plasticity, elements of rhythmic gymnastics, musical rhythm, elements of circus skills and theatrical arts. Female gymnasts should master these components. Control over the artistic components is learned with the help of improvisation to music. Gymnasts need to express the music by their facial expressions, body movements as well as emotions. Pedagogical testing was carried out by marking the improvised performances to children music. The gymnasts in our study had to improvise for 1 minute. Assessment according to the criteria presented in Table 1, in points, was carried out by relevant experts. The members of the experts' group that assessed the level of artistic development were the same at the beginning and at the end of our experiment (Table 1).

In the practical part of our research, we used the method of expert assessments. Namely, processes or actions (phenomena) were evaluated by qualified experts and competent coaches (10 experts who are children or youth coaches at the Specialised Sports School of the Olympic Reserve), who evaluated gymnasts' performances. Then we calculated the degree of agreement among their opinions. The experts evaluated the quality of gymnasts' competitive program performances, giving marks to each gymnast from 0 to 10 points, with a step of 0.5 points for each composition. It was necessary to determine the degree of agreement of expert opinions on the criteria of artistry for each composition. In our study, the Kendall coefficient of concordance was used to process the experts' results and their consistency. It is a certain number from 0 to 1 that characterizes the degree of consistency of expert opinions (in the form of ranks) according to a set of criteria. The concordance coefficient range is $0 < W < 1$,

with 0 for complete inconsistency and 1 for complete unanimity.

Empirical data were processed with generally accepted methods of mathematical statistics: average value, average error, average quadratic deviation, Student's criterion, coefficient of concordance.

The study was conducted at the Higher Educational Institution of Specialized Children and Adolescents Sports School of the Olympic Reserve for Rhythmic Gymnastics, Children's Sports School of Dnipro in the period from September 2018 to November 2019. The study involved 20 gymnasts aged 7-8 years, who had been engaged in rhythmic gymnastics for 2-3 years and had category 2 qualification. The athletes were divided into a control group (n = 10) and an experimental group (n = 10). Classes were held 5 times a week for 90 minutes. The research methods were in accordance with the ethical standards of the Helsinki Declaration. Before and after the experiment, we conducted control tests with gymnasts to assess their progress in the development of artistic abilities.

Table 1
Criteria for scoring artistry (Viner-Usmanova I.A.).

№	Criteria	Score in points
1	Complete expression of the image corresponding to the nature of the given musical composition	9.5-10.0
2	Expression of the image for most of the dance	8.5-9.0
	Facial expressions partially do not correspond to the image set by the nature of the music	7,5-8,0
	Stiffness in some movements	6.5-7.0
3	Episodic expression of the image while performing the dance	5.5-6.0
	Unnatural facial expressions in several parts of the dance so that the artistic image is distorted	4.5-5.0
	Stiffness of movement in several parts of the dance	3.5-4.0
4	Stiffness of body movements when recreating an image in accordance with the nature of the musical composition	2.5-3.0
	Facial expressions do not correspond to the image of the given musical composition	1.5-2.0
	Movement partially or completely fails to corresponds to the given character of the music	0.5-1.0

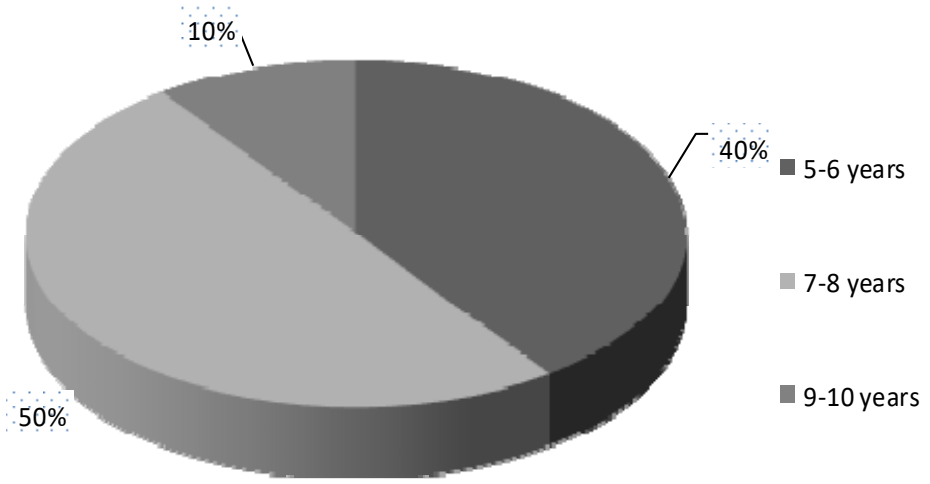

Figure 1. Answers to the question "From what age do you think it is necessary to train gymnasts to perform the composition expressively?"

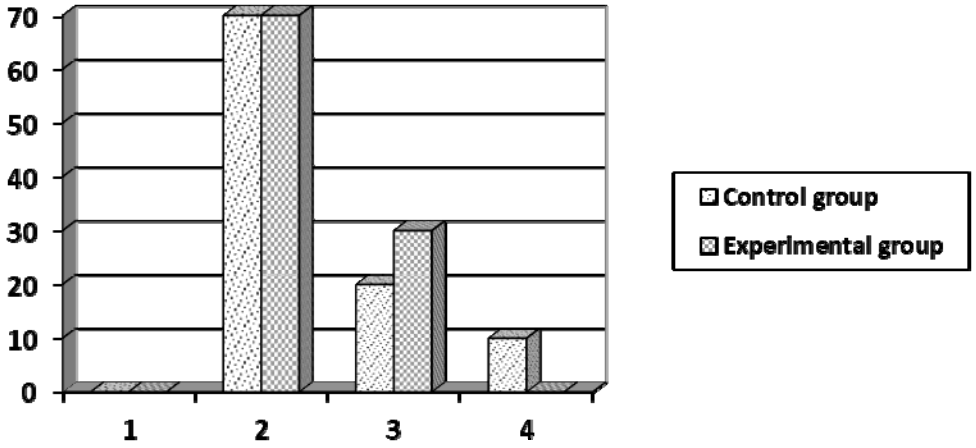

Figure 2. The distribution of gymnasts in the control and the experimental group according to the level of artistic abilities at the initial stage of the study. Notes: 1 - low level, 2 - medium level, 3 – upper medium level, 4 – high level.

Table 2
Methods to develop artistic abilities in young female gymnasts.

Training class	Control group	Experimental group
Before the class	-	facial gymnastics
Choreography	+	+
Main part	+	+
Exercises for general and special physical training	+	+ plus an outdoor action-oriented game according to the schedule
Final part	+	+ plus a music game according to the schedule

Note. + is the fulfillment of tasks in accordance with the schedule of sports training for preliminary basic training.

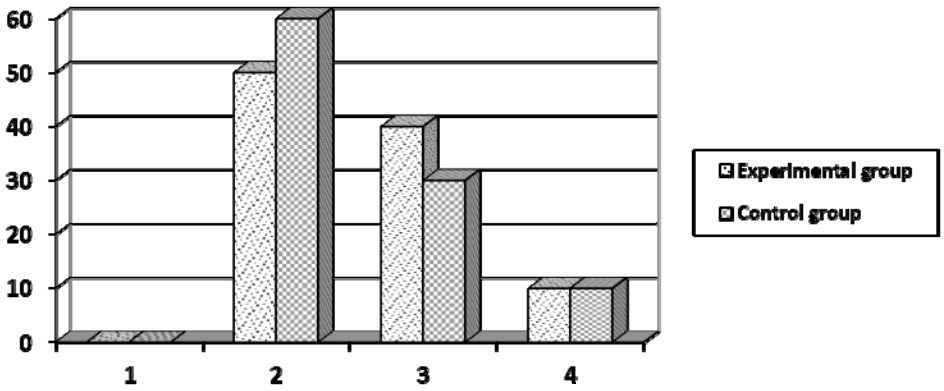

Figure 3. Distribution of female gymnasts in the control and the experimental group according to the level of development of artistic abilities after the pedagogical experiment. Notes: 1 - low level, 2 - medium level, 3 – upper medium level, 4 – high level.

RESULTS

In the first stage, interviews were conducted with specialists who had practical experience with basic training. The survey helped to determine the relevance of the research, potential problems and ways to solve them. 10 coaches, teachers of rhythmic gymnastics, were included in the survey. The questionnaire was used to obtain the following information: 1) to identify their level of education and work experience, and determining their main goals in each stage of the preparation; 2) to identify the optimal means and methods for the development of artistic abilities in gymnasts.

First of all, we identified the professional level of coaches: 6 coaches were first category coaches which means that they had experience with athletes participating in the national championships and above; and 4 coaches were second category, i.e., they had experience in training athletes participating in regional championships. Most of them (90%) had direct experience working with 7-8-year-old female gymnasts. Most of them (60%) had trained gymnasts for more than 20 years.

When determining the optimal means and methods for developing artistic abilities in female gymnasts, the opinions diverged on the question: “From what age do you think it is necessary to train gymnasts to perform the composition expressively?” 50% said that from the age of 5-6, 40% of coaches believed that these skills should be developed from the age of 7 - 8 and only 10% from the age of 9-10 (Figure 1). The information obtained will be helpful in devising a method for the development of artistry in both 5-6 year-old girls as well as those over the age of 10 in the future.

An article by Eliana de Toledo and Kizzy Antualpa clearly shows that there is a tendency toward a greater role of the aesthetic component. The aesthetic principle of rhythmic gymnastics in competition rules is considered not only an additional element, but also a basic element of the discipline’s structure that directly affects the sports results. Sport technique and its improvements contribute greatly to the realisation of the aesthetic program.

It brings rhythmic gymnastics back to the origins of this sport. Unfortunately, from the very beginning, the training system promoted mastering the technical elements with less emphasis on the aesthetic component. It is thus necessary to pay attention to this component when training gymnasts aged 7-8 in order to

further correct the imbalance between the technical and the aesthetic components.

Unambiguously, respondents believed that it was necessary to use improvisation to develop artistry, but their opinions differed on how much time should be spent on it. 60% believed that 5-7 minutes in each class is enough time to teach the expressiveness of the exercise, 30% thought that it was necessary to devote at least 10-20 minutes, and only 10% believed that the whole class should be dedicated to this.

The question of how to develop artistry was open-ended. The respondents listed their own means that they used to develop artistry in athletes: improvisation, outdoor games, listening and discussing musical compositions, visiting opera and a ballet theatre.

On the basis of our survey, we concluded that the development of artistic abilities needs to be paid a lot of attention and that special sets of exercises, games, improvisations and other means should be used.

In rhythmic gymnastics, artistry is characterized as a meaningfully expedient and emotionally rich performance of competitive compositions and the ability of female gymnasts to perform gymnastic exercises in this way. All indicators of artistic abilities, that is, expressing the image in a large part of the exercise; the correspondence of facial expressions and movements to the image and the given character of the music, were evaluated while female athletes performed an arbitrary competitive composition without an object. Compositions were evaluated by judges. The control and the experimental group were compared at the beginning and at the end of this experiment. The reliability of differences in the results was evaluated using Student's t-test. The control group followed the standard program for sports schools for rhythmic gymnastics and the experimental group followed the program for sports schools for rhythmic gymnastics with the addition of the newly developed methodology.

We found that gymnasts from both groups displayed their emotions in order to attract the attention of spectators and judges. The judges, however, saw such performances as primitively artistic and made large deductions from 3.0 to 6.0 points accordingly. A partial mismatch in the mimic, inability to maintain the given rhythm and the nature of music as well as insufficient number of correct body movements to express the music of the composition were also considered as deficiencies in their performances (Fig. 2).

In the initial stage of the study, not all gymnasts in the control and the experimental group were able to perform the prescribed composition at a fairly high level. The average score in both groups ranged from 6.6 ± 0.056 to 6.85 ± 0.06. Such a fitness level will not be sufficient to perform at a higher-level competitions in the future. Therefore, it is necessary to develop a methodology to develop artistic abilities in these young girls.

Thus, in order to improve the artistry in the experimental group, we developed our own methods for teaching artistic abilities. The methods were introduced in the training process according to the schedule below (Table 2).

The schedule was devised on the basis of the Rhythmic Gymnastics Program for Children and Adolescents Sports School.

Our methods for the development of artistic abilities dictated the use of facial gymnastics before choreography lessons and mobile and music games in the final part of each lesson. Thus, each training session (120 min.) began with mimic gymnastics that led to the activation of facial muscles. Coaches were given mimic gymnastics exercises to teach since they develop not only the facial muscles but also teach athletes how to appropriately express their emotions. All variations in the movements of arms, legs, head, eyes and even eyebrows characterize nine basic moods that a female gymnast should be

able to skilfully express by means of facial expressions. These nine moods include love, joy, sadness, heroism, anger, surprise, fear, disgust and calmness.

Our study used several sets of exercises, such as a set of exercises for the development of facial muscles (lower jaw movement from side to side; forward, back and slow down; inflate the cheeks, first one then the other; eyebrow movements up and down, and other exercises) and a set of exercises called "Masks". This exercise requires that athletes depict masks expressing joy, fear, delight and other emotions. During one musical phrase, they hold the mask, during the next they rest. Gradually the rate of occurrence and disappearance of masks increases. The ultimate goal is a quick transition from one mask to another.

Mimic gymnastics was performed before each training class and was followed by a lesson in choreography in accordance with the lesson plan.

Next, young athletes performed tasks that were part of their special technical training and solved problems set for each specific training session. In the final part, the young gymnasts engaged in outdoor games, music games and exercises for recovery and flexibility . They understood the reasons for most of the musical and motor exercises, that is, that they increased, refined and deepened their perceptions of music. Also, the gymnasts were asked to communicate with gestures, imagining that they were separated from each other by glass through which sounds could not penetrate. For example, they were offered a sentence: “You have forgotten to put on a hat, and it’s very cold outside,” or “Bring me a glass of water, I want to drink,” or the gymnast herself invented her own message for the others.

At the end of our experiment, we adjusted the indicators of female gymnasts’ artistic abilities. The results of show positive changes in these indicators (Fig. 3).

In the experimental group at the beginning of our study, artistic abilities of our gymnasts were rated 6.66 ± 0.05 points, and at the end of the study 7.88 ± 0.20. In the control group, however, there was no significant increase: in the first stage of the study, the indicator was 6.85 ± 0.06, and in the second stage 7.40 ± 0.07 points. The improvement rate in the artistry of the experimental group was 18.4%, and of the control group only 8%, which is significantly lower ($p < 0.01$). In the control group, there is some natural increase, though, due to the regular choreographic training.

Comparing the average indicators of artistry in the studied groups before and after our pedagogical experiment, we found that artistic abilities of female gymnasts in the experimental group, where the newly developed methodology for developing artistic abilities in young gymnasts was introduced, is effective and can be used in the educational process of 7-8-year-old female gymnasts.

We observed a competition before and after the experiment. We analysed the E1 and E2 team grades that reflect the artistry in competitive compositions. It was determined that before the experiment, the reductions for artistry in the control group were 3.2 ± 0.42 points, and in the experimental group 3.4 ± 0.37 points.

After the experiment, the reductions in the control and the experimental group decreased to the level of 3.0 ± 0.38 points and 2.1 ± 0.19 points respectively. This helped the female gymnasts in the experimental group to perform better at the Ukrainian competition in rhythmic gymnastics “Kroha” in Nikopol and become the champions and the prize winners.

Thus, the introduction of facial exercises, music games and special sets of exercises positively affected the development of artistic abilities and can be recommended for implementation in the educational process of training children and adolescents in rhythmic gymnastics.

DISCUSSION

In many aesthetic sports, the artistic component of athletes' performances is evaluated. Studies by Maja Bučar Pajek, Marjeta Kovač, Jernej Pajek and Bojan Leskošek, 2014, showed that in women's gymnastics, artistry is evaluated on the basis of such components as inappropriate gesture and facial expressions, insufficient artistry of performance, low confidence and insufficient variation in rhythm. Reductions range from 0.1 to 0.3 points, and the final artistic deduction is included in the final grade E. Thus, to create the required impression, coaches need to move away from their personal concept of beauty and follow the definition in the Code of Points or study the main components of beauty, which have a long tradition in the arts. For this purpose, our methodology provides choreographic exercises and musical games.

At the time of the birth of rhythmic gymnastics, French teacher Francois Delsarte developed a doctrine latter called Delsarte System of Expression. He devoted his life to discovering the laws that govern the human body movement when it expresses a particular feeling. He can be called the founder of the science of body expressiveness. F. Delsarte declared: “Art is the knowledge of those external methods by which life, soul and mind are revealed to a man — the ability to control them and freely guide them. Art is finding a sign corresponding to the essence.” (S. Volkonsky, 2012). Facial gymnastics used in our technique, aims precisely to do this, that is, help gymnasts learn how to control their face.

A spectator accurately reads the energy, the purity of the lines and the emotional performance of a female gymnast. This was proved in scientific research by I. Čuk, 2015, which found that despite the fact that each spectator had their own criteria, points increased or decreased in accordance with the quality of gymnasts' performances. The experiment with the audience as a judge showed sufficient reliability of such refereeing and its compliance with the results of official judges. It once again confirms that artistry, comprehensibility and conformity of actions are an important component of gymnast’s performance, and that this component must be developed from the initial stage of training female athletes. Exercises for facial expressions that are trained using mimic gymnastics and narrative outdoor games, help gymnasts form the appropriate expressive representations.

Music, and therefore its interpretation by a female gymnast, is a very important element in the gymnast’s performance (FIG, 2016). At the same time, strict harmony between the character and rhythm of the music, the nature of the exercise and its movements is necessary. By displaying this harmony with their body language, the athletes convey their thoughts and feelings to the audience (Eliana Toledo, Mateus Oliveira, Maria Letícia Scarabelim, Bianca Assumpção, 2018). Music is so important in the composition that changes associated with it in the rules of the competition occur every four years at the end of each Olympic cycle and make significant changes to the discipline. Therefore, during the training period, it is necessary to teach young athletes to hear and feel music. They need to know the basics of musical literacy (Viner-Usmanova, I.A., 2014). Our methodology uses musical and outdoor games to achieve this.

In her research, Rumba O., 2006, 2013, proved that certain aesthetic requirements are imposed on athletes in rhythmic gymnastics, namely, the culture of movement, musicality, expressiveness and artistry of performance. The author proved the effectiveness of choreographic training to improve performing skills and increasing the “aesthetic” component. That is why our methods included a full lesson in choreography, and each lesson corresponded to the tasks that were set.

Thus, the developed methodology includes the most effective mechanisms to date for the development of artistic abilities of 7-8-year-old female gymnasts and can be used in any training program for female gymnasts.

CONCLUSIONS

Our analysis of the scientific and methodological literature shows that there is a need to intensify research on how to further develop the aesthetic component in the training of female athletes in rhythmic gymnastics.

On the basis of our questionnaire, it was determined that it is necessary to pay a lot of attention to the artistic abilities of female gymnasts starting from age 7-8, and using specific clusters of exercises, games and improvisation.

The introduction of these methods in the educational and training process of the experimental group helped gymnasts gain additional 1.3 ± 0.12 ($p < 0.05$) points for their competitive composition. Moreover, the improvement rate in the artistry in the experimental group was 18.4%, and in the control group only 8% ($p < 0.05$).

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SOMATOTYPE ANALYSIS BY AGE CATEGORIES IN SPANISH FEMALE ACROBATIC GYMNASTS

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Original article

Abstract

Somatotype is one of the variables seen as the key to success in sports and talent detection at different ages. This is confirmed by evidence in some gymnastic disciplines in different age categories, but no study has been conducted for Acrobatic Gymnastics. The objective is to establish the characteristic somatotype profile in Acrobatic Gymnastics for each age group, determining whether there are differences among them and between the roles in each one. The sample was made up of 54 female tops (X= 11.23 years; 29.62 Kg) and 75 female bases (X= 14.46 years; 50.48 Kg). The somatotype was calculated using the Heath-Carter method to determine the mesomorphy, endomorphy, and ectomorphy of each group. The statistical analysis carried out consisted of a descriptive and comparative analysis based on the component in particular and the mean somatotype dispersion in general. The results showed that mesomorphy was the most important component in all categories and roles. They indicated different somatotype classifications in each group, but the importance of ectomorphy in tops and endomorphy in bases should also be pointed out. Significant differences were obtained in mesomorphy (tops: p = .012; bases p = .026) and ectomorphy in both roles (tops p = .036; bases p = .001). Despite finding significant differences among certain categories, this did not follow a linear, chronological development. Therefore, one cannot conclude that the somatotype evolved with age, since this may be due to sports specialization. However, it was confirmed that mesomorphy, as in other gymnastics disciplines, is the predominant component in all categories and roles.

Keywords: *anthropometry; somatotypes; growth and development; age groups.*

INTRODUCTION

The somatotype has been recognized as one of the determining morphological variables in sport performance (Carter & Heath, 1990; Kutseryb, Vovkanych, Hrynkiv, Majevska, & Muzyka, 2017). It is not exceptional in different gymnastics disciplines, since athletes in each may have different body shapes. It could provide

assistance in talent detection throughout the growth stage due to the stability of the somatotype in gymnasts during this period (Corbella & Barany, 1991; Irurtia et al., 2009b).

The International Gymnastics Federation (FIG) currently encompasses eight different gymnastics disciplines, ranging from the latest entry of Parkour to Gymnastics for All, Aerobic Gymnastics (AER), Acrobatic Gymnastics (AG), Trampoline, and to the more traditional Men's Artistic Gymnastics (MAG), Women's Artistic Gymnastics (WAG) and Rhythmic Gymnastics (RG). Anthropometric studies have been conducted on them all and many focused specifically on the somatotype. However, MAG, WAG and RG have been the preferred disciplines of study.

The studies carried out on MAG athletes noted a somatotype with a predominant mesomorphic component. The classification most commonly obtained in top-level gymnasts is the balanced mesomorph (Bies & De la Rosa, 2006; Claessens et al., 1991; João & Filho 2015). However, other studies pointed towards an ecto-mesomorphic classification (Irurtia, Busquets, Marina, & Galilea, 2009a), in which the ectomorphic component, related to longilinearity, was stronger than the endomorphic one.

It has also been noted that female artistic gymnasts have a predominantly mesomorphic somatotype. They have been mostly classified as ecto-mesomorph, with the ectomorphic component being the second most important (Claessens et al., 1991; Irurtia, Busquets, Marina, Pons, & Carrasco, 2008; João & Filho, 2015; Massidda, Toselli, Brasili, & Caló, 2013).

The somatotype is different in RG. There is evidence that allows for the classification of national- or higher-level gymnasts as balanced ectomorphs as the predominant somatotype (Menezes & Filho, 2006; Purenović-Ivanović & Popović, 2014). Other studies, despite providing different classifications for the distribution of the mesomorphic and endomorphic component, also agreed that the ectomorphic component was the most important in RG (Irurtia et al., 2009b; Purenović-Ivanović & Popović, 2014).

Research in trampoline gymnastics is more limited. Gómez-Landero, Vernetta and López Bedoya (2009) established the profile of top-level Spanish gymnasts. The authors defined the somatotype of the absolute category gymnasts (15+ years) as endomorphic mesomorph, while the U-15s were characterized as a central somatotype. On the other hand, in male trampoline the endomorphic component is much more important, defined as balanced mesomorph (Gómez-Landero, Vernetta, & López Bedoya, 2010).

Finally, there is not much evidence about AG either. The few studies carried out showed a predominance of mesomorphy in different competitive events (Taboada-Iglesias, Vernetta, & Gutiérrez-Sánchez, 2017) as well as in different performance roles, with greater predominance of the ectomorphic component in tops and of the mesomorphic component in bases (Taboada-Iglesias, Gutiérrez-Sánchez, & Vernetta, 2016).

In addition to the differentiated and characteristic profile of each sport that requires specific features for the execution of its motor patterns and conditions, the research focuses on the fact that different somatotype distributions can be conditioned by the development typical for specific age, as it happens with the non-sporting population (Corbella & Barany, 1991). The somatotype can be influenced by maturation development or diet; however, sports specialization may be of greater importance, hence these characteristics will not be analysed.

Research on the gymnastic disciplines provided answers by showing the profiles of each age category in MAG (Fontana, Soares, Santos, Molina, & Riehl, 2014), WAG (Bacciotti, Baxter-Jones, Gaya, & Maia, 2018; Massidda et al., 2013) and RG (Corbella & Barany, 1991; Oliveira et al.,

2017; Purenović-Ivanović & Popović, 2014; Quintero, Martín, & Henríquez, 2011). However, there are no references to somatotype distribution in the different age categories of AG competitions.

In this gymnastic discipline, the Code of Points established different age range categories. The existence of age ranges derives from the fact that it is a motor and social sport, in which one competes in a group or in a pair, performing technical elements such as figures and throws (Vernetta, López Bedoya, & Gutiérrez-Sánchez, 2008), i.e., in which one gymnast plays the role of the top and the other the role of the base (FIG 2017).

In view of the lack of evidence in AG, the goal of this study is to establish the characteristic somatotype profile for each age group, determining whether there are differences among them and between the roles played in each one.

METHODS

All the procedures followed in this study were approved by the Autonomous Ethics Committee of Research of Xunta de Galicia (Spain) (Reference Number 2015/672). Participants volunteered their cooperation, and their participation was in the case of minors authorised by their parents or legal guardians.

The precepts of the Helsinki Declaration were followed. The procedures were explained, indicating that they were harmless, painless, and that the subjects could leave the study at any time.

There was a total of 129 female gymnasts in this study, 54 of them playing the role of the top and 75 the role of the base. Table 1 shows the classification by age categories according to the rules of participation in the Spanish championships.

Table 1
Distribution of the sample and ages of the different age categories of national Tops and Bases competition.

Group	Tops			Bases		
	N	Age		N	Age	
		X	SD		X	SD
Age Group 1 (6-13 years old)	5	7.28	0.83	4	11.08	1.37
Age Group 2 (7-14 years old)	7	9.94	1.70	9	13.53	0.93
Age Group 3 (8-15 years old)	12	10.79	3.04	14	13.26	1.78
Age Group 4 (9-16 years old)	18	11.39	1.95	29	14.83	1.46
Junior (10-19 years old)	9	14.14	3.99	17	15.94	2.32
Senior (+ de 12 years old)	3	12.93	0.38	2	15.98	1.90
Total	54	11.23	3.04	75	14.46	2.08

In order to calculate the components of the somatotype, certain variables were previously measured. These measurements were taken by a researcher who is an accredited expert level 2 in the field, following the recommendations of the International Society for the Advancement of Kinanthropometry (ISAK) (Marfell-Jones, Olds, Stewart, & Carter, 2006).

The kineantropometry variables were: height, weight, 4 skin folds (triceps, subscapular, supraspinal and medial calf), 2 diameters (humerus condylar-trochlear and femur bicondylar) and 2 circumferences (contracted arm and maximum leg). The height was taken with a portable stadiometer Seca 213 (GmbH & Co. KG, Germany) to 1 mm precision, the weight with a Tanita digital scale UM-040 (Tanita corporation, Japan) with precision of 100 g, the folds with a Holtain skinfold calliper (British Indicators, England) with 0.2 cm precision, and the circumferences with a Cercorf antropometric (Equipamentos Cercorf, Brasil) with 1 mm precision.

The calculation of the three components of the somatotype was performed using the Heath-Carter method (Carter & Heath, 1990) and the following formulas:

1. *ENDOMORPHY = -0.7182 + 0.1451Sc- 0.00068Sc^2 + 0.0000014Sc^3*

S=Σ Triceps, subscapular, supraspinal folds (mm)

Sc= S x (170.18 / height (cm))

2. *MESOMORPHY = [0.858HumD + 0.601FemD + 0.188CAc + 0.161MLc]* - [height (cm) x 0.131] + 4.5

Humerus condylar-trochlear diameter (HumD) in cm; femur bicondylar diameter (FemD) in cm; contracted arm circumference (CAc) in cm; maximum leg circumference (MLc) in cm.

CAc= Contracted Arm circumference (cm) – Triceps fold (cm)

MLc= Maximum leg circumference (cm) – medial calf fold (cm)

3. *ECTOMORPHY*

a. If the weight index (WI)< 40.75: Ectomorphy = (0.732WI) – 28.58.
b. If WI< 40.75 and > 38.25: Ectomorphy = (0.463WI) – 17.63.
c. If WI≤ 38.25: Ectomorphy = 0.1

Weight index (WI)

(WI= height(cm)/$\sqrt[3]{}$weight (kg))

The somatotype was represented using a somatocard, and its dispersion and homogeneity were analysed by different specific indices. The somatotype dispersion index (SDI) was calculated to assess the homogeneity of each group, establishing heterogeneity with SDI>2. Likewise, for the comparison of the somatotype among groups, the mean somatotype dispersion distance (SDD_{SM}) was used, reflecting significant differences with SDD_{SM}>2. Differences among age categories and between roles were compared in each of them.

The statistical treatment of the data was performed using SPSS 22.0 0 (Statistical Package for the Social Sciences), and a significance level of $p < 0.05$ was applied in all performed tests. First, a descriptive analysis of each somatotype variable expressed by the mean (X) and the standard deviation (SD) was performed. The normality of each group was analysed using the Shapiro-Wilk test, and Levene's test was employed to check the variance homogeneity. Second, since not all variables behaved normally and homogeneously, different parametric and non-parametric tests were necessary for the comparative study. For normally distributed variables, we applied the one-way ANOVA test (F tests on homogeneous variables and Brown-Forsythe [B-F] on non-homogeneous variables), using Tukey's test for the multiple analysis of homogeneous variables, and the Games-Howell test for those that did not present homogeneity. Moreover, for the variables that did not follow a normal distribution, the Kruskal-Wallis H nonparametric test (K-W) was applied, along with the Mann-Whitney U test for multiple analysis. A comparative analysis between roles in the same category was also carried out with the Mann-Whitney U test.

RESULTS

Tops. Mesomorphy and ectomorphy followed a normal distribution ($p > 0.05$) and presented homogeneity of variance ($p < 0.05$). However, endomorphy did not follow a normal distribution, thus non-parametric tests were applied.

Table 2 shows the values of the different somatotype components. Analysing the means of each component, the highest endomorphic values were obtained by the tops in age group 2 and the lowest values corresponded to the junior category. However, no significant differences were found among groups (K-W = 8.14; $p = 0.148$). Since no differences were obtained, the multiple analysis was not relevant.

Ectomorphy was higher in juniors and lower in age group 1, finding significant

differences in the overall analysis (F = 2.62; p = 0.036). Significant differences were established only between junior and age group 1 categories (p = 0.023) in the multiple analysis.

Significant differences among groups were also found in mesomorphy (F = 3.33; p = 0.012). The mesomorphic component had the highest mean value in age group 1 and the lowest in the junior category. The differences established in the multiple analysis were between junior and age group 1 (p = 0.037), and junior and age group 3 (p = 0.016).

If we analyse the classification of the tops' somatotype as a whole, mesomorphy is the predominant component in all categories, except in the junior category, where the ectomorphic component predominates. The most common somatotype was the balanced mesomorph, characteristic of age group 2, age group 3 and senior girls. Although in age group 1 mesomorphy is still the highest component, endomorphy is more important than ectomorphy and is therefore defined as endo-mesomorphy. However, when it comes to age group 4, the contrary is the case and can be classified as ecto-mesomorphic. In the junior category, ectomorphy comes first, followed by mesomorphy differing by more than one unit from endomorphy, thus these gymnasts are defined as ectomorphic mesomorph.

Figure 1 shows the somatocharts of each group of tops, including all the particular cases, as well as the mean. The SDI of the different age groups established that all of them presented a heterogeneous somatotype. On the other hand, SDD_{SM} only established significant differences between the somatotype of the age group 1 and age group 4 categories (SDD_{SM} = 3.54), the junior (SDD_{SM} = 2.77) and senior categories (SDD_{SM} = 2.06), and the age group 4 and junior categories (SDD_{SM} = 2.45).

Bases. Mesomorphy and ectomorphy followed a normal distribution (p > 0.05), which was not the case for endomorphy. Mesomorphy presented homogeneity of variance (p < 0.05), unlike ectomorphy.

Table 3 shows the values of the different somatotype components of the bases. When analysing the means of the components, ectomorphy obtained the highest values in age group 3 and the lowest in the senior category, finding significant differences between groups (B-F = 5.26; p = 0.001). The analysis of multiple comparisons found differences only between age group 2 and senior categories (p = 0.006), age group 3 and junior categories (p = 0.023), age group 3 and senior categories (p = 0.000), age group 4 and senior categories (p = 0.000), and the junior and senior categories (p = 0.001).

Regarding mesomorphy, the highest values were posted by seniors and the lowest by age group 4. This difference proved to be significant in the overall analysis (F = 2.744; p = 0.026). The only differences found in the multiple analysis were between age group 4 and senior categories (p = 0.048).

Despite the differences in the two components above, no significant difference was found in endomorphy (K-W = 10.66; p = 0.059). However, the highest results were recorded by the senior girls and the lowest by age group 1 and age group 4.

In the joint analysis of the somatotype of the bases, mesomorphy remains the predominant component in all categories. The balanced mesomorphic somatotype was characteristic of age group 1. The endomorphic component was the second most important in the age group 2, junior and senior categories, classified as endo-mesomorphic in the first two, and endomorphic mesomorphic in the seniors. Finally, age group 3 and age group 4 categories obtained a central somatotype, in which none of the components differed in more than one unit.

Table 2
Tops somatotype of the different categories (mean, SD).

	Age Group 1 (n=5)		Age Group 2 (n=7)		Age Group 3 (n=12)		Age Group 4 (n=18)		Junior (n=9)		Senior (n=3)		Sig.
	X	(SD)	X	(SD)	X	(SD)	X	(SD)	X	(SD)	X	(SD)	p
Heigth	120.70	5.55	128.73	6.87	129.30	5.22	135.96	5.73	143.74	7.79	147.03	3.80	-
Weigh	23.80	1.73	26.74	1.86	27.01	3.64	30.08	3.69	34.27	6.73	39.73	1.47	-
Trochlear condyle of the humerus breath D Femur	4.74	.25	5.24	.26	5.23	.26	5.33	.26	5.48	.20	5.87	.15	-
Bicondyle of the femur breadth	4.16	.17	4.47	.14	4.42	.21	4.56	.23	4.56	.25	5.07	.31	-
Corrected arm girth	19.09	0.89	19.54	1.07	19.96	1.44	20.54	1.50	21.40	2.22	24.15	0.98	-
Corrected calf girth	24.82	1.11	25.80	1.03	25.57	1.63	26.45	1.56	27.24	2.19	28.54	0.70	-
Σ triceps, subescapular, supraspinal skinfolds	19.90	3.26	21.76	5.92	18.19	2.57	17.93	3.23	21.08	9.20	25.53	9.44	-
Endomorphy	2.86	.58	2.91	.92	2.38	.37	2.21	.48	2.44	1.12	2.9	1.25	.148
Mesomorphy	4.67	.18	4.48	.91	4.52	.53	4.06	.72	3.50	.71	4.3	.70	.012*
Ectomorphy	2.14	.84	2.99	1.46	3.03	.66	3.48	1.00	3.97	1.07	2.97	.84	.036*

*p<0.05

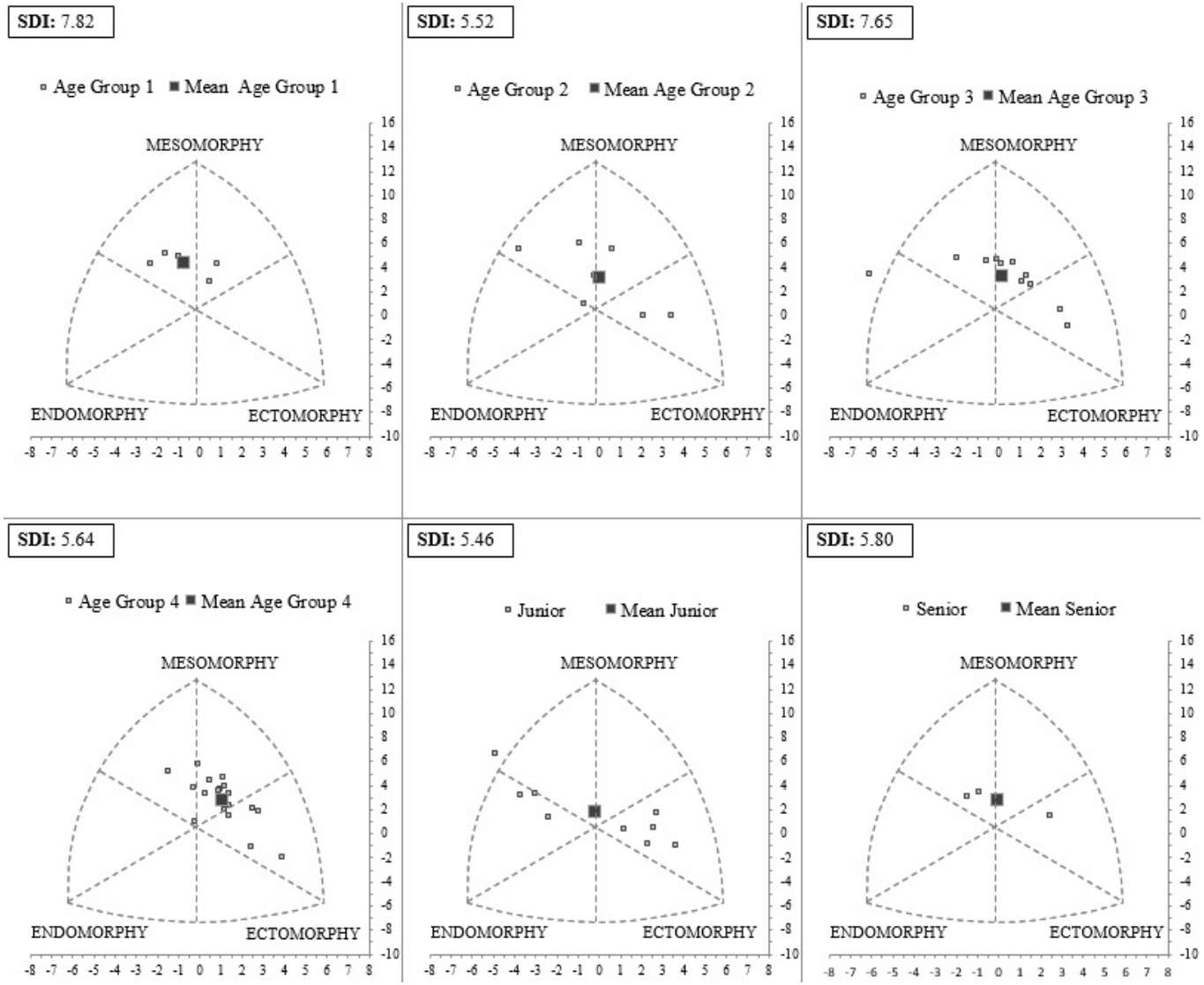

Figure 1. Somatocharts of different categories of tops and homogeneity (SDI).

Table 3
Bases somatotype of the different categories (mean, SD).

	Age Group 1 (n=4)		Age Group 2 (n=9)		Age Group 3 (n=14)		Age Group 4 (n=29)		Junior (n=17)		Senior (n=2)		Sig.
	X	(SD)	X	(SD)	X	(SD)	X	(SD)	X	(SD)	X	(SD)	p
Heigth	145.88	7.71	156.06	7.79	154.51	4.91	160.09	5.44	162.29	4.91	152.85	4.31	-
Weigh	39.33	8.41	48.90	6.20	44.34	4.57	50.73	6.96	57.98	7.62	55.55	4.17	-
Trochlear condyle of the humerus breath D_Femur	5.65	.26	5.90	.25	5.72	.24	5.88	.32	6.06	.37	5.85	.49	-
Bicondyle of the femur breadth	8.25	.25	8.51	.40	8.38	.32	8.34	.39	8.88	.57	8.95	.21	-
Corrected arm girth	23.11	1.76	24.83	1.81	24.08	1.56	25.82	2.10	26.99	2.03	27.90	1.79	-
Corrected calf girth	29.09	2.46	31.17	1.49	30.16	1.76	31.74	2.42	33.13	1.92	33.75	1.06	-
Σ triceps, subscapular, supraspinal skinfolds	26.25	12.93	31.19	7.78	27.59	6.26	28.17	8.65	34.81	11.68	47.45	7.28	-
Endomorphy	3.02	1.42	3.46	.90	3.08	.78	3.02	.93	3.66	1.09	5.25	.82	.059
Mesomorphy	4.22	.38	3.92	1.00	3.58	.81	3.55	.98	4.18	.90	5.55	1.62	.026*
Ectomorphy	2.97	.87	2.72	1.01	3.43	.99	3.18	1.30	2.22	.97	.92	.06	.001**

*p<0.05, **p<0.001.
(X: mean; SD: Standard Deviation)

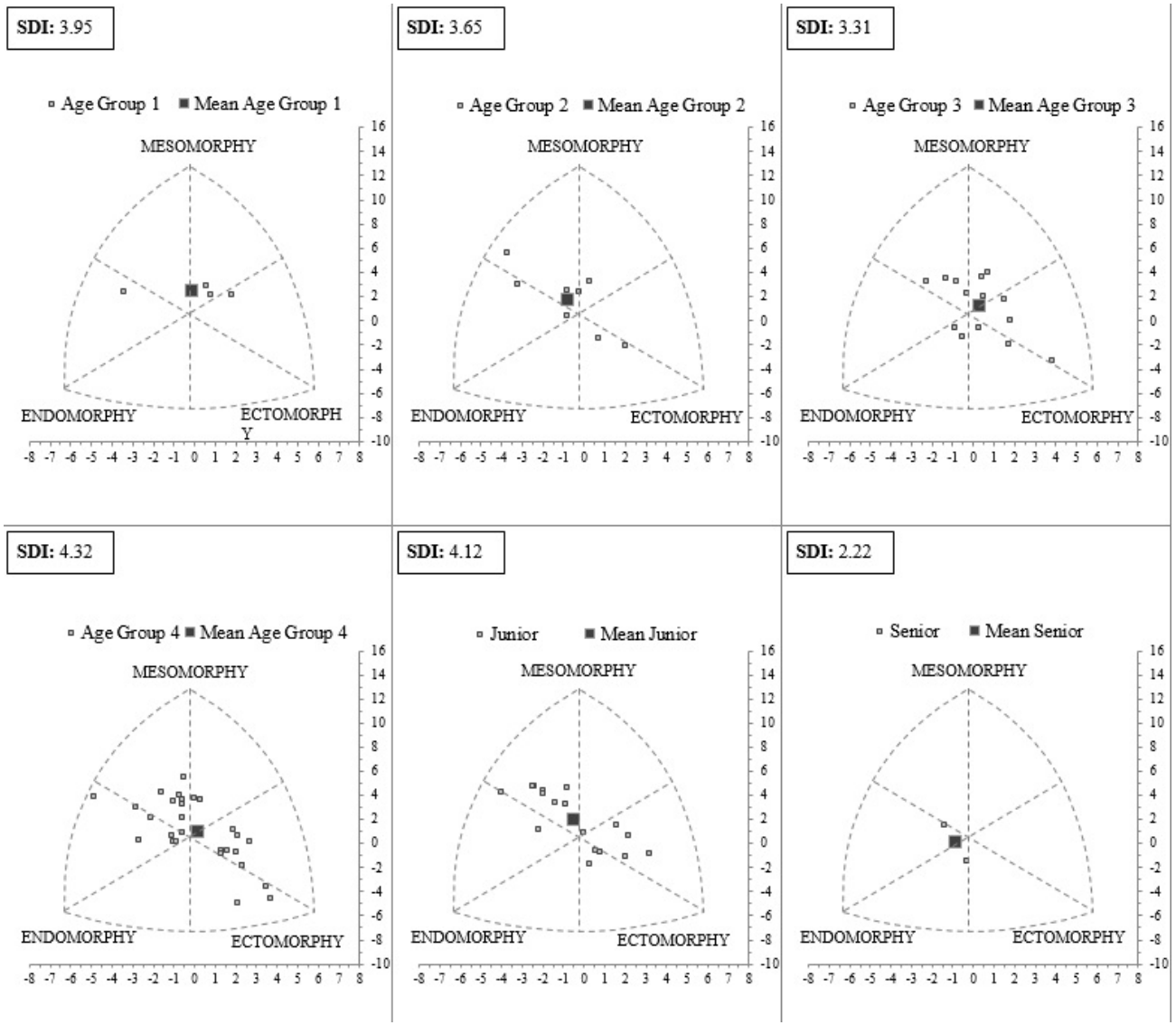

Figure 2. Somatocharts of different categories of bases and homogeneity (SDI).

Table 4
Comparison between roles in each of the age categories.

	Endomorphy		Mesomorphy		Ectomorphy	
	U	Sig. Exact (bilateral)	U	Sig. Exact (bilateral)	U	Sig. Exact (bilateral)
Age Group 1	7.50	0.556	2.00	0.063	17.00	0.111
Age Group2	44.50	0.174	24.00	0.470	27.00	0.681
Age Group 3	130.50	0.015*	26.00	0.002*	100.00	0.432
Age Group 4	406.50	0.001*	182.00	0.084	219.00	0.358
Junior	123.00	0.011*	110.00	0.075	21.00	0.002*
Senior	6.00	0.200	4.00	1.000	0.00	0.200

(U= U value of Mann-Whitney) *p<0.05

Figure 2 shows somatocharts for each group of bases, describing the individual cases and the group mean. The SDI of the bases also proved that all age groups had a heterogeneous somatotype. On the other hand, the SDD_{SM} showed significant differences between senior bases and the following age categories: age group 1 (SDD_{SM} = 2.79), age group 3 (SDD_{SM} = 2.34), age group 4 (SDD_{SM} = 2.03) and junior (SDD_{SM} = 2.05).

Role differences. The SDD_{SM} between roles for each category established significant differences in age group 1 (SDD_{SM} = 2.24), age group 3 (SDD_{SM} = 2.04), age group 4 (SDD_{SM} = 2.41) and seniors (SDD_{SM} = 3.07). However, no significant differences were found in either the age group 2 category (SDD_{SM} = 1.98) or the junior category (SDD_{SM} = 0.49). On the other hand, the differences of each component individually only indicated a significant superiority of endomorphy of the bases in the age group 3, age group 4 and junior categories. This means a significantly superior mesomorphy of tops in the age group 3 category, and a clear superiority of ectomorphy among junior tops (Table 4).

DISCUSSION

Sports like gymnastic disciplines where early specialisation is required need an approach to these anthropometric variables in each age group in order to understand what the physical evolution of gymnasts is like in terms of talent detection. This research provides data regarding one of the least studied disciplines, acrobatic gymnastics, and innovates in the determination of these values in each age category. The need to carry out a proper evaluation in AG arises from the fact that each gymnastic discipline presents a different physique. However, many of them stand out for their high levels of mesomorphy, reflecting common aspects. Previous evidence in AG research (Taboada-Iglesias et al., 2017) have shown that mesomorphy was the predominant component of both tops and bases in all categories of competition or female modality (women's pair, women's group or tops in a mixed pair).

This clear superiority of mesomorphy is even more important in MAG, where it is the predominant component (Bies & De la Rosa, 2006; Fontana et al., 2014; Irurtia et al., 2009a). The same trend is observed in WAG, with mesomorphy being the most important somatotype component, defined as ecto-mesomorph (Bacciotti, Baxter-Jones, Gaya, & Maia, 2017; Irurtia et al., 2008; Massida et al., 2013) as well as tops in the age group 4 category, pointing out the possible relationship between mesomorphy and sport performance. In

general, all categories of AG tops and bases in the present study obtained the highest values in mesomorphy, confirming previous studies and providing evidence of their similarities with MAG and WAG disciplines.

However, in RG, mesomorphy is surpassed by ectomorphy, the latter being the predominant component throughout the history of this gymnastic specialty (Canda, Rabadán, Sainz, & Agorreta, 2019). This specialty shows a somatotype that differs from the rest. Similar results were found for the Portuguese national team; it has been defined as a balanced ectomorph. However, in Brazil, even though the ectomorphic component is predominant, endomorphy is the second most important (Batista, Garganta, & Ávila-Carvalho, 2019). Although mesomorphy is predominant in AG, Taboada-Iglesias et al. (2016) indicated that there was a clear difference between the acting roles except in mesomorphy. Endomorphy and ectomorphy presented significant differences between the roles, with ectomorphy being the second most important component in tops and endomorphy in bases. Thus, the somatotype of the tops is closer to that of the RG gymnasts than to that of the bases. This study follows this trend, given that ectomorphy in female tops is the second most important component in all categories, except for age group 1 and seniors, with significant differences in the junior category. In bases, however, the second most important component is endomorphy except for age group 3 and age group 4, where ectomorphy ranks second. In spite of high ectomorphy values obtained by bases in age group 3 and age group 4, in both categories along with juniors endomorphy is significantly higher in bases than in tops. The significant differences between the roles are confirmed through the SDD_{SM} in all categories except for age group 2 and juniors.

Studies suggest that across age categories gymnasts obtain different results that affect the distribution of components. In MAG it was observed that despite the higher mesomorphic component at younger ages, ectomorphy was the second most important component, above endomorphy, but that in older groups both components tended to be equal (Fontana et al., 2014).

Studies on WAG gymnasts show that the mesomorphic component is the most important in all age categories (Bacciotti et al., 2018; Massidda et al., 2013). Despite this, the authors observed a greater importance of ectomorphy in younger gymnasts, and an increase in endomorphy, even surpassing ectomorphy, in gymnasts over 16 (Bacciotti et al., 2018). This increase in the endomorphic component cannot be confirmed for AG, as no significant differences were found between categories in either tops or bases.

The results indicated that tops in age group 1 had a SDD_{SM} with significant differences from the older categories, and there may be a certain tendency associated with age. However, the endomorphic component did not present any significant differences between any categories. Hence, this increase in endomorphy with age was not observed as noted by Bacciotti et al. (2018) in gymnasts in WAG. It can only be stated that the junior category presented significantly greater differences in ectomorphy with respect to age group 1, and in mesomorphy with respect to age group 1 and age group 3.

This evolution towards an increase in bases' endomorphy is not observed, since no significant differences can be found among any categories. It should be noted that, except for age group 3, the endomorphic component is higher than the ectomorphic one. In contrast to the tops, the SDD_{SM} in bases indicated only significant differences between seniors and age group 1, age group 3, age group 4 and juniors, thus one cannot conclude that the

somatotype has a linear relationship with age.

The absence of a linear relationship of the somatotype in AG gymnasts was also observed in the fact that, although there were no age differences between junior and senior bases, there were somatotypical differences. We should note that in senior bases, endomorphy and mesomorphy are practically equal, whereas the ectomorphic component is very low. However, in the junior category, the ectomorphic component is the most important. In fact, significant differences were obtained in the ectomorphy of both categories in the multiple comparison, which may be due to sports performance factors rather than age development. However, the results of this study are similar to those found by Irurtia et al. (2008), Irurtia et al. (2009a) and Corbella and Barany (1991) in WAG, MAG and RG respectively, in which authors found no significant differences in somatotype over age.

However, unlike the AG results in this study, for RG, WAG and MAG, there are also studies that point to a somatotype variation in relation to age. Research showed that ectomorphy is the most important component in the younger age categories, but mesomorphy and, to a greater extent, endomorphy increase over the years, possibly due to biological maturation, with endomorphy becoming the most important component in the senior category (Oliveira et al., 2017; Purenović-Ivanović & Popović, 2014). On this research line, Poliszczuk, Broda and Poliszczuk (2012) observed in a sample of RG gymnasts with an initial mean age of 9.79 years that over a two-year period they increased the proportion of the endomorphic and mesomorphic component. However, Quintero et al. (2011) indicated that ectomorphy was only dominant in the age group 1 and age group 2 categories, but with very similar endomorphy values, this being the highest component even in the junior and age group 4 categories. The difference from other studies may be due to the fact that it is an autonomous sample, as opposed to the high dependency level of the previous ones. Similarly, to interpret the results, we must note that in our sample we had to add up all the modalities (trios and pairs) and that the age categories of competition have such wide ranges that the average age is not always higher in higher categories. Likewise, another limitation derives from the characteristics of the modality that mixes athletes of very different ages with very varied numbers of years of sport experience. This trend of evolutionarily increasing endomorphy across age categories was not seen in either the tops or the bases in this research. In fact, the ectomorphic component that characterizes RG gymnasts, and which is more specific to the role of the tops, is more present in the age group 4 and junior categories, pointing out that the tops in age group 4 are older than seniors. This situation may be due to the creation of competition groups for a greater projection of the sport, as the Code of Points allows for age ranges, and it is not clear whether senior groups or pairs have the highest performance level.

CONCLUSIONS

Given the results obtained, despite finding certain differences, one cannot conclude that there is a clear evolution of the somatotype associated with maturation. This lack of differences may be due to the highly specialized roles of gymnasts from a very early age, as some studies in MAG, WAG and RG pointed out. Similarly, the heterogeneity of the sample level may have been the factor that established these small variations found in the study. However, we can state that mesomorphy, as in other gymnastics disciplines, is the predominant component in all categories and roles.

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DEVELOPMENT OF BALANCE IN CHILDREN PARTICIPATING IN DIFFERENT RECREATIONAL PHYSICAL ACTIVITIES

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Original article

Abstract

Balance, an important motor coordination ability, underlies the performance of various motor skills and allows for participation in common childhood activities. Research indicates that sport participation could support balance development in children. To confirm the above effect, this study investigated whether participation in different recreational physical activities could induce differences in children's balance ability. Specifically, 138 children, 5-11 years old (M_{age}=8.4±1.3), classified into four groups according to the activity they took part in (basketball, track and field, rhythmic gymnastics, contemporary dance), were assessed by the balance subset of the KörperKoordinationstest für Kinder. Pearson correlations were applied to detect associations of balance scores with age, height, body mass index (BMI) and showed significant correlations for BMI ($p < .001$). The analyses of covariance (covariate: BMI) that were computed on children's balance scores showed statistically significant effects of group ($p < .001$). Sidak post hoc tests indicated that children participating in rhythmic gymnastics surpassed all three other groups; whereas those taking part in basketball had the lowest scores in almost every balance item. It seems that the type of physical activity a child participates in could be a significant contributor to the development of his/her balance. Physical activities encompassing the execution of various balance tasks, such as rhythmic gymnastics, seem to offer children greater opportunities to make improvements in this area compared to children engaging in activities of low balancing requirements. This finding highlights the potential that is available to coaches: they can contribute to children's balance development by implementing sport-specific programs that target this human ability.

Keywords: *motor coordination, balance, sport participation, rhythmic gymnastics.*

INTRODUCTION

Motor Coordination (MC), a general construct addressing multiple abilities, underlies the development of fundamental motor skills and specialized motor skills (Vandorpe et al., 2012a); it is thus of vital importance for human motor development (Savelsbergh, Davids, Van Der Kamp, & Bennett, 2003). During childhood, the gradual maturation of the nervous system along with the provision of appropriate training stimuli is thought to influence MC (Lima, Bugge, Pfeiffer, & Andersen, 2017) and consequently result in successful motor learning (Hirtz, & Starosta, 2002). Importantly, as indicated by longitudinal research, supporting the development of MC contributes to the prevention of subsequent motor delays and favours

participation in physical activity (PA) (de Souza et al., 2014; Henrique et al., 2018; Lopes, Rodrigues, Maia, & Malina, 2011). Additionally, there is consistent evidence showing that a high MC level predicts athletic success both in childhood (Vandorpe et al., 2012a) and adolescence (Pion et al., 2015a).

A distinct ability within the MC construct is balance (Hirtz, 1985). Balance is responsible for the maintenance or recovery of the body's center of mass within the body's base of support to prevent falling and complete the required movements (Shumway-Cook, & McCollum, 1991). The importance of its development is profound, considering that it is thought to be an integral part of the performance of all movements (Westcott, Lowes, & Richardson, 1997). The development of both static and dynamic balance in children facilitates the performance of a wide range of locomotor and object control skills (Shumway Cook, & McCollum, 1991; Ulrich, & Ulrich, 1985); therefore, it is fundamental for common childhood activities, such as play, schooling (Franjoine, Darr, Held, Kott, & Young, 2010; Kolic, O'Brien, Bowles, Iles, & Williams, 2020) and also for participation in any sport (Ricotti, 2011).

The development of general MC and balance in childhood is affected by both individual and environmental parameters. To start with gender, conflicting findings have been published, with boys and girls found to either present equal MC levels (Henrique et al., 2018; Söğüt, 2016) or demonstrate differences in relation to the different abilities/tasks examined by the MC tests (Freitas et al., 2015; Vandorpe et al., 2011). Specifically for balance, existing evidence shows, on one hand, the absence of differences between genders (Freitas et al., 2015; Söğüt, 2016) and on the other the superiority of girls compared to boys (D'Hondt et al., 2011; Lima et al., 2017; Vandorpe et al., 2011). Nevertheless, several researchers attribute the above differences between boys and girls to the discrete gender roles imposed by society (Al-Haroun, 1988; Du Toit, & Pienaar, 2002), since it has been suggested that compliance with these roles could influence the motor performance of children (Malina, 2004). In reference to weight status, findings are largely consistent across studies, revealing the negative association of BMI with MC (Antunes et al., 2015; Bardid, Rudd, Lenoir, Polman, & Barnett, 2015; D'Hondt et al., 2011, 2013; Henrique et al., 2018; Lima et al., 2017; Lopes, Stodden, Bianchi, Maia, & Rodrigues, 2012) and particularly balance (Antunes et al., 2015; Bardid et al., 2015; D'Hondt et al., 2011, 2013; Franjoine et al., 2010; Kolic et al., 2020), underlining the fact that weight management can influence, to some extent, children's MC and balance development. As far as the age effect is concerned, it seems that MC and balance improve during the preschool years (Venetsanou, & Kambas, 2011), but during childhood remain either relatively stable (D'Hondt et al., 2013; Lopes et al., 2011; Vandorpe et al., 2012b) or, according to other researchers, improve (Antunes et al., 2015; Bardid et al., 2015; Henrique et al., 2018; Kolic et al., 2020; Söğüt, 2016). Regarding the latter, it has been advocated that children who undergo regular sports training develop a higher general MC level than children who do not participate (Vandorpe et al., 2012b) or partially participate (spending fewer hours) in PA and sport (Fransen et al., 2012; Graf et al., 2004; Opstoel et al., 2015; Vandorpe et al., 2012b).

To further confirm the positive effect of sport participation and therefore highlight the contribution of this environmental parameter to MC development, some researchers have attempted to investigate the potential effect the different types of sport could have on the development of MC in youth (Jaakkola, Watt, & Kalaja, 2017; Opstoel et al., 2015; Pion, Fransen, Lenoir, & Segers, 2014; Pion et al., 2015b). From

their findings, it can be assumed that regular engagement in a specific sport may be responsible for differences in MC, indicating that some types of sport are more effective in improving MC than others. Specifically for balance, the above studies show that engagement in certain sports, such as gymnastics, offers children the opportunity to better develop their balance in comparison to other sports, such as basketball, badminton, martial arts (Jaakkola, Watt, & Kalaja, 2017; Opstoel et al., 2015), handball, soccer, volleyball, table tennis (Pion et al., 2015b), swimming or ice hockey (Jaakkola, Watt, & Kalaja, 2017). However, most of these studies focus on highly trained adolescent athletes, leaving it unclear whether participation at a recreational level could be a sufficient stimulus to induce improvements in the balance ability of children. Therefore, the purpose of this study was to examine whether children who regularly participate in one of four different types of recreational PAs (basketball, track and field, rhythmic gymnastics, contemporary dance) present differences in the development of balance. It was hypothesized that (a) children participating in the above PAs would not develop balance at an equal level, mainly as a result of the different training stimuli they have received, and (b) children engaging in rhythmic gymnastics, a PA of high balancing demands, might be more capable in motor tasks that require balance comparing to children engaging in the other PAs.

METHODS

For this study, 138 children, aged 5-11 years (M_{age}=8.4±1.3, 44.2% boys, M_{weight}= 31.7kg±7.7, M_{height}=1.30m±.09, M_{BMI}=18.5±3.4), participating in four different types of recreational PAs, i.e. basketball (n=36), track and field (n= 32), rhythmic gymnastics (n= 34) and contemporary dance (n=36), were recruited from local sport clubs in Athens, Greece, and were classified into four respective groups. Participants' engagement in their PA was regular, ranging from two to four 60-minute sessions per week. During the period of data collection, none of the participants was enrolled in any other PA program. Prior to data collection participants' parents and legal guardians were informed about the purpose and the procedures of the research and were asked to submit their written consent. Each participant's verbal approval was also required.

Balance. The KörperKoordinationstest für Kinder (KTK; Kiphard, & Schilling, 1974, 2007) is a reliable test battery (Kiphard, & Schilling, 2007; Vandorpe et al., 2011), developed to measure, in four relative subsets, the gross MC of children and adolescents (5-15-year-old). In this study, participants' balance was assessed by the respective subset within KTK, which includes three similar tasks addressing the dynamic balance. For their assessment, the examinees were asked to walk backwards on three balance beams of decreasing width, i.e. 6cm, 4.5cm and 3cm. The length of each beam was 3m and its height 5cm. Each task was performed three times. Examinees' assessment was based on the number of successful steps they managed to take to complete each task. The highest score for each is eight successful steps. Scores on each balance beam were recorded (maximum of 24) and then added up to generate the balance subset score (maximum of 72).

Anthropometry. Measurements of anthropometry included: (a) participants' stature at the nearest 0.5m obtained by a portable stadiometer (Seca 217), (b) participants body mass at the nearest 0.1kg measured by a digital scale (Seca 899) and (c) BMI calculations using the body mass(kg)/height(m^2) formula. According to the International Obesity Task Force (IOTF) gender- and age-specific cut-off criteria (Cole, Bellizzi, Flegal, & Dietz, 2000), participants of this study were

classified into three BMI categories (normal weight, overweight and obese).

Data were collected from May to July 2019 at the facilities provided by each sport club. Before the examination of the balance tasks, the anthropometric characteristics were recorded. During the measurements of stature and body mass, the examinees were barefoot and lightly dressed. The familiarization and examination procedures for the balance tasks were conducted in reference to the KTK manual guidelines (Kiphard & Schilling, 2007). According to these, each child was assessed individually by experienced examiners.

Initially, data were screened for normality and outliers, and descriptive statistics (M, SD) were calculated. The percentages (%) of normal weight, overweight and obese participants were also computed. Pearson correlation coefficients were then applied to detect the potential associations of balance scores with age, height and BMI. Given the observed correlation of BMI with balance scores, BMI was defined as a covariate, and a univariate analysis of covariance (ANCOVA) was then performed on the participants' total balance subset score to examine potential differences among the four groups. To obtain a more detailed picture of the collected data, a multivariate analysis of covariance (MANCOVA) was also conducted on the three balance items scores. The application of Sidak post hoc tests followed both analyses. Significance level was set at $p<.05$. For the interpretation of the results, effect sizes (eta-squared, η^2) were calculated and reported for all analyses. In this study, effect sizes above $\eta^2 > .14$ were considered important (Cohen, 1988). Data were analysed by the IBM SPSS 25.0 software package.

RESULTS

Descriptive statistics of participants' age and anthropometric characteristics stratified by group are summarized in Table 1.

Table 1
Descriptive statistics for age, anthropometric characteristics and percentages (%) of BMI categories stratified by group.

	Basketball (36)	Track and field (32)	Rhythmic Gymnastics (34)	Contemporary dance (36)
Age	8.6±1.3	8.5±1.3	8.3±1.2	8.2±1.3
Weight	34.3±9.3	31.2±7.9	29.6±7.2	31.6±6.3
Height	1.30±0.1	1.24±0.1	1.32±0.1	1.35±0.1
BMI	20.2±4.8	20.0±3.0	16.6±2.2	17.2±2.2
Normal weight[a]	44.4%	37.5%	88.2%	83.3%
Overweight	22.2%	50.0%	11.8%	16.7%
Obese	33.3%	12.5%	-	-

[a] Classification of BMI categories according to IOTF gender- and age-specific cut-off criteria (Cole et al., 2000)

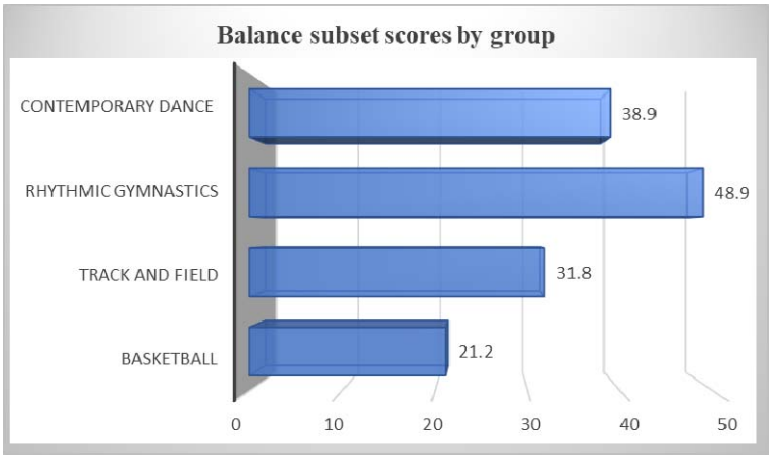

Figure 1. Balance subset scores of participants by group.

Table 2
Estimated Marginal Means, Std. Errors, F ratios, p and η^2 values for balance subset score and each balance task score stratified by group.

	Basketball	Track and field	Rhythmic Gymnastics	Contemporary dance	Type of Activity		
					F	p	η^2
Balance Subset Score (step counts)	21.2± 1.9	31.8± 2.0	48.9± 1.9	38.9± 1.8	34.173	.0001	.082
6cm balance score (step counts)	11.5± 0.8	16.0± 0.9	20.8± 0.9	19.1± 0.8	20.595	.0001	.317
4.5cm balance score (step counts)	6.2± 0.8	11.0± 0.8	19.0± 0.8	13.5± 0.8	38.307	.0001	.464
3cm balance score (steps counts)	3.6± 0.6	4.8± 0.6	9.1± 0.6	6.3± 0.6	13.061	.0001	.228

As it can be seen in Table 1, in respect of BMI, a high percentage of participants in this study were overweight (24.6%) and obese (11.6%). Both basketball and track and field groups presented the highest percentages of overweight and obese children (55.5% and 62.5%, respectively); whereas rhythmic gymnastics and contemporary dance group had the highest percentages of normal weight children (88.2% and 83.3%, respectively). No obese children were found among the participants in the latter activities.

Correlations of both the balance subset score and the score of each balance task with age, height and BMI indicated that only BMI was significantly associated with balance scores, presenting negative values ranging from *r*= -.34 to -.51 (*p*=.0001) *(balance subset score: r=-.48, 6cm balance beam: r= -.51, 4.5cm balance bean: r= -.42, 3cm balance beam: r= -.34).*

ANCOVA's results showed that, after adjusting for BMI (*F*=11.916, *p*=.001, η^2=.082), significant differences were detected among the four groups

(F=34.173, p<.0001, η^2= .435) (Figure 1). As it was indicated by Sidak post hoc tests, on one hand, participants of rhythmic gymnastics were significantly different from participants in all other groups as they obtained the highest total balance subset scores; on the other, participants of the basketball group also significantly differed from all others as they received the lowest respective score. No other statistically significant differences were observed (p<.05) (Table 2).

According to MANCOVA's results, BMI proved to be a significant covariate (Pillai's trace= .120, F=5.954, p= .001, η^2=.120). After adjusting for BMI, group was found to be both statistically significant and practically important (Pillai's trace=.540, F=9.736, p<.0001, η^2=.180). The univariate analyses that followed showed that the covariate was significant both for the 6cm and 4.5cm balance score. Also, the effect of group was significant and practically important for all three balance task scores (p<.05) (Table 2).

Sidak post hoc tests uncovered the following differences: (a) on the 6cm balance beam, participants of rhythmic gymnastics scored higher than all other groups, but differed statistically significantly only from those in the basketball and track and field groups, not from those engaged in contemporary dance; at the other end, participants in the basketball group received the lowest scores and differed statistically significantly from all the others; (b) on the 4.5cm balance beam, participants of rhythmic gymnastics and basketball, who obtained the highest and the lowest scores respectively, were statistically significantly different from participants in the other two groups, whereas participants in the contemporary dance and the track and field groups, which posted similar results, scored significantly better than those engaged in basketball, and (c) on the 3cm balance beam, participants of rhythmic gymnastics statistically significantly surpassed all other groups, while participants in the basketball group had the lowest score and differed from those engaged in both rhythmic gymnastics and contemporary dance (p<.05) (Table 2).

DISCUSSION

The positive consequences of developing MC in childhood are well documented (de Souza et al., 2014; Henrique et al., 2018; Lopes et al., 2011; Vandorpe et al., 2012a). Substantial evidence indicates that participation in sport could lead to relative improvements and support MC development (Fransen et al., 2012; Graf et al., 2004; Opstoel et al., 2015; Vandorpe et al., 2012b). However, it is likely that each sport impacts MC, balance included (Jaakkola et al., 2017; Opstoel et al., 2015; Pion et al., 2014; Pion et al., 2015b), differently. Potential differences in balance associated with the sport type further support the role of environment and therefore the role of coaches in designing, in line with their sport's objectives, effective programs to enhance the development of this ability in children.

Exploring this perspective, the present study examined if children participating in four different types of recreational PAs, i.e. basketball, track and field, rhythmic gymnastics and contemporary dance, present differences in their balance ability. As it was initially hypothesized, the main finding of the present study is that children of different training backgrounds differ in their balance ability, indicating that the type of PA could be more or less effective in improving children's balance. The major implication of this finding is that, contrary to the claim that MC is stable during childhood (D'Hondt et al., 2013; Lopes et al., 2011; Vandorpe et al., 2012b), we are led to assume that MC could be subject to changes imposed by environmental parameters, such as participation in PAs. This is in agreement with a bulk of studies reporting that MC is not a stable condition

but, on the contrary, increases as children grow (Antunes et al., 2015; Bardid et al., 2015; Henrique et al., 2018; Kolic et al., 2020; Söğüt, 2016).

The review of literature shows that relevant studies are very few; however, they report similar results. Among them, the only study that refers particularly to children is that of Opstoel et al. (2015), which attempted to examine, among other personal characteristics, the MC abilities, as addressed in KTK, among children aged 9 to 11 years participating in 25 different sports. Participants' engagement in their sport was regular, however, its frequency per week varied from 1 to 5 hours (or more). The results showed that there were differences in the scores of children both in general MC and balance. Similarly, in the study of Jaakkola et al. (2017), which investigated the potential differences in MC in adolescent athletes participating at a competitive level in artistic gymnastics, swimming and ice hockey, it was found that the athletes in each sport obtained different scores in KTK tests, including balance. Likewise, according to Pion et al. (2015b), adolescent elite athletes participating in nine sports, including ball sports, racquet sports, martial arts, triathlon and gymnastics, demonstrated differences in their balance ability. Interestingly, as it was revealed in the study of Pion et al. (2014), relative differences were also reported among highly trained adolescents participating in sports with similar characteristics, i.e. taekwondo, judo, and karate.

However, in most of the above studies (Jaakkola et al., 2017; Pion et al., 2014; Pion et al., 2015b), participants were mainly adolescents or older children, who competed at an elite level or had an intensive training background. Inversely, the present study included participants of a different age range, including younger children (5-11-year-old) who do not participate in sport at a competitive level. Therefore, this study extends the existing knowledge on the specific topic, confirming that regular participation in sports, even at a recreational level, can play a role in improving balance in young children, provided that balance is prioritized in their training programs.

In line with the second hypothesis of this study, rhythmic gymnastics' training, which prioritizes the execution of many balancing tasks, was far more effective in improving children's balance in comparison to the other PAs. Additionally, participation in contemporary dance, a PA which also requires balance, led to some improvements - greater improvements than those achieved by participants in basketball, but not significantly different from the improvements associated with track and field. Among the four recreational PAs which were examined in the study, basketball was the least effective in developing the ability of balance in its participants, probably due to the fact that in basketball balancing requirements are lower than in the other three activities and, therefore, respective training usually does not target balance. Concerning the three balance tasks, respective results were not very different from the overall results for balance. The general finding from the analysis of each task is that children engaging in rhythmic gymnastics demonstrate a higher balance level than children engaging in all other PAs, further highlighting the contribution of rhythmic gymnastics to the development of balance in children.

Similarly, the relevant study of Opstoel et al. (2015) showed that children who regularly participated in gymnastics (e.g., artistic gymnastics, acrobatics) received higher scores in the KTK's balance test, compared to children participating in many other sports, such as basketball, soccer, volleyball, martial arts, tennis, swimming or dance. However, in contrast to the present findings, Opstoel et al. (2015) reported that participants of rhythmic gymnastics and track and field received similar scores in balance. The reason for this discrepancy is probably the

different level of children's engagement with track and field. Gymnasts' superiority in balance was also noted in the report by Jaakkola et al. (2017) - it revealed that gymnasts scored better in the KTK test in comparison to swimmers and ice hockey players; and in the report by Pion et al. (2015b) which found gymnasts to be better in balance than athletes engaging in badminton, basketball, handball, judo, soccer, table tennis, triathlon or volleyball. It should be noted that in the above studies athletes in artistic, not rhythmic, gymnastics were compared to athletes in other sports. However, since children's improvement in balance is equally important for all types of gymnastics, it can be assumed that, similarly to artistic, rhythmic gymnastics could also be more effective in enhancing children's balance than the sports mentioned above. Moreover, in agreement with the results of the present study, both in the reports by Opstoel et al. (2015) and Pion et al. (2015b), basketball was associated with the lowest balance score comparing to the variety of other sports that were examined. At this point, it is prudent to acknowledge that in the aforementioned reference studies which assessed gymnasts of artistic gymnastics the utilization of the KTK's balance beam test may have favoured better performances in these participants, since this test simulates part of their practice. Therefore, their results should be interpreted with caution. However, for the present study this should not be considered a limitation, since participants in rhythmic rather than artistic gymnastics were assessed.

As many researchers suggest, BMI is another parameter that affects balance (Antunes et al., 2015; Bardid et al., 2015; D'Hondt et al., 2011, 2013; Henrique et al., 2018; Lopes et al., 2012; Lima et al., 2017). BMI in this study was found to be negatively correlated with children's balance; thus, group differences on balance were examined after the removal of the effect of BMI, since it was not among the purposes of this study to investigate potential differences in children' balance across the three BMI categories. However, the correlation among BMI and balance scores are in line with literature findings, which suggest that overweight and obese children receive lower scores in balance tests than normal-weight children (Antunes et al., 2015; Bardid et al., 2015; D'Hondt et al., 2011; 2013; Franjoine et al., 2010; Kolic et al., 2020). Therefore, apart from the opportunities for childen to develop their balance through sport participation, the maintenance of a healthy weight is also important for MC and balance development.

Although this study confirms the role the participation in recreational PA could play on the development of balance in children, it has certain limitations. In particular, children's previous experience with the activity (years of training) was not taken into consideration, and the cross-sectional design of the study did not capture the potential longitudinal nature of this effect. A more detailed picture of how balance is influenced by participation in different PAs would be obtained if additional and more diverse activities were examined. Furthermore, it would be useful for future research to investigate the effect of additional parameters, such as gender. Lastly, it needs to be clarified that by using KTK' balance beam test in this study, the dynamic not static balance was assessed.

CONCLUSION

The type of PA a child regularly participates in, even at a recreational level, could be a significant contributor to the development of his/her balance ability. PA that encompasses the execution of a variety of balance tasks, such as rhythmic gymnastics, seems to offer children a greater opportunity to make improvements in this area in comparison to children who engage in PA of low balancing requirements, such as basketball. The confirmation of the positive effect of this

environmental parameter has implications for coaches of young children as it highlights their potential to contribute to the development of children's balance through the implementation of sport-specific programs that target, among other things, this essential human ability. This further means that during childhood, participation in PAs should not only be about learning sports techniques but also about providing children with multiple opportunities to develop a wide base of movement skills as well as the entire spectrum of MC abilities. In this way, children would be equipped to confidently and safely engage in different PAs and sports and thus demonstrate a high level of physical literacy.

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GYMNASTICS, GREEK TRADITIONAL DANCE AND TENNIS AS LEISURE-TIME PHYSICAL ACTIVITIES: WHICH ONE TRIGGERS THE MOST POSITIVE PSYCHOLOGICAL RESPONSES?

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Original article

Abstract

Participating in leisure-time physical activity (PA) is thought to positively associate with mental health. The aim of the present study was to investigate the acute psychological responses of adults who take part in different types of leisure-time PA (gymnastics; Greek traditional dance; tennis). A total of 277 adults, aged 18-65 years (M= 35.9, SD= 12.76 years), taking part in Greek traditional dance (n=89), gymnastics (n=88), or tennis (n=100) volunteered to participate. In order for potential changes in participants' positive well-being, psychological distress and perceived fatigue to be examined, the Subjective Exercise Experiences Scale (SEES) was administered before and after a session of the aforementioned programmes. The 3 (group [gymnastics vs Greek traditional dance vs tennis]) X 2 (time [pre-test vs post-test) analyses of variance that were performed on the SEES subscales (positive well-being; psychological distress; fatigue) revealed practically significant improvements in the positive well-being for all participants ($p<.001$, $\eta^2=.25$) and statistically significant interactions (though not of practical importance) between group and time in positive well-being ($p<.001$, $\eta^2=.068$), psychological distress ($p<.05$, $\eta^2=.02$) and fatigue ($p<.05$, $\eta^2=.033$), with participants in gymnastics presenting the most optimal results, followed by those of Greek traditional dance. Although further research is needed to fully understand the features of a PA/exercise that lead to the greatest boost in people's well-being, taking into account the growing prevalence of mental health disorders in our society, encouraging adults to join in a leisure-time PA/exercise programme seems imperative for their (psychological) health benefit.

Keywords: *positive well-being, psychological distress, perceived fatigue.*

INTRODUCTION

Mental health is defined as "a state of (psychological) well-being in which an individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and is able to make a contribution to his or her community." (World Health Organization; WHO, 2005). Based on the above definition, mental health should be considered very important for public health, societal well-being, and economic development (WHO, 2013). Nevertheless, nowadays, many people suffer from mental disorders, with depression being among the main factors of disability worldwide (WHO, 2005). In the WHO European

Union alone, 44.3 million people present depression and 37.3 million present anxiety (Vos et al., 2016).

Among the factors that are thought to positively associate with mental health is physical activity (PA) (Bize, Johnson, & Plotnikoff, 2007; Ohrnberger, Fichera, & Sutton, 2017), with the domain in which PA takes place playing an important role (White et al., 2017). Specifically, leisure-time PA that provides people with positive feelings, is related with self-efficacy (DeBoer, Powers, Utschig, Otto, & Smits, 2012; Delahanty, Conroy, Nathan, & Diabetes Prevention Program Research Group, 2006; Middelkamp, van Rooijen, Wolfhagen, & Steenbergen, 2017), provides opportunities to interact with other people (Bailey & McLaren, 2005) as well as escape from stressful lives (Leith, 2010), is more strongly associated with psychological benefits than other domains, such as transport PA, work PA or household PA (Asztalos et al., 2009; Kull Ainsaar, Kiive, & Raudsepp, 2012; Ohta, Mizoue, Nishima, & Ikeda, 2007; White et al., 2017).

In a recent large-scale study (Chekroud et al., 2018), it was found that people who physically exercise, have approximately 43% fewer days/per month of poor mental health than those who do not exercise. Moreover, sufficient research evidence supports the value of several types of leisure-time PA and physical exercise, such as popular team sports (Chekroud et al., 2018), tennis (Groppel & DiNubile, 2009; Yazici, Gul, Yazici, & Gul, 2016), dance (e.g., ballroom dance [Haboush, Floyd, Caron, LaSota, & Alvarez, 2006], Greek traditional dance [Mavrovouniotis, Argyriadou, & Papaioannou, 2010]), aerobic exercise (Broman-Fulks, Berman, Rabian, & Webster, 2004; McAuley et al., 2000), and mindful exercise (Hofmann, Sawyer, Witt, & Oh, 2010) for positive psychological outcomes. It is interesting to note that several researchers report that even one single session of leisure-time PA/ physical exercise, such as aerobic gymnastics (Genti, Goulimaris, & Yfantidou, 2009; Lox & Rudolph, 1994; Netz & Lidor, 2003; Panagopoulou, Charalampopoulos, Piperidou, & Rokka, 2016; Rokka, Mavridis, & Kouli, 2010), Greek traditional dance (GTD) (Genti et al., 2009), or mindful exercise (Netz & Lidor, 2003) can trigger positive psychological responses.

In Greece, 4.7% of population report that they suffer from depression (80.8% increase compared to 2009), 7.5% present stress disorders, and 1.7% have various mental disorders. Taking into account both the above worrying levels of mental disorders and the benefits of leisure-time PA, it would be useful to gather evidence regarding the type(s) of leisure-time PA with the most positive effects on the mental health of participants. For this purpose, evidence from experimental research comparing the acute effects of different programmes would be valuable, helping people choose the PA that best suits them and offers the most benefits. However, relevant published studies are limited to just a handful, with most of them examining programmes with several similarities, such as Zumba and Salsa dance (Domene, Moir, Pummell & Easton, 2016); dance aerobics, step aerobics, and aqua aerobics (Panagopoulou et al., 2016), or Pilates and yoga (Fotiadi, Petsa, Rokka, Mavridis, & Bebetsos, 2017). Only two studies examine different types of PA/physical exercise, such as aerobics, GTD, and muscle strengthening with additional weights (Genti et al., 2009), or Zumba, hip-hop, body conditioning, and ice skating (Kim & Kim, 2007).

From the above, it is obvious that although aerobics has attracted researchers' interest, other popular types of PA/physical exercise have been investigated to a lesser extent (or even not at all). For example, the positive effects of GTD, compared to other programmes, were examined only in one study (Genti et al., 2009), although GTD is a type of PA

much-loved among Greeks. Another very popular type of exercise thought to offer plenty of health benefits for participants of all ages (Groppel & DiNubile, 2009; Kovacs et al., 2016; Pluim, Staal, Marks, Miller, & Miley, 2007) is tennis. Nevertheless, there is only one study examining the acute effects of tennis, focusing only on participants' physiological, not psychological responses (Murphy, Duffield, & Reid, 2014). Based on the above, the aim of the present study was to investigate the acute psychological responses of adults who participate in gymnastics, GTD, and tennis, in an attempt to shed light on the psychological benefits that can be gained from PA/physical exercise programmes with different characteristics.

METHODS

A total of 277 adults (87 men; 190 women), aged 18-65 years (M = 35.9, SD = 12.76 years), who took part in GTD (n=89), gymnastics (Zumba [n=42] and Pilates [n=46]), and tennis (n=100) in Athens, 2-3 times per week, volunteered to participate. The age of participants by group as well as the years of their participation in the above programmes is presented in Table 1.

Table 1
Descriptive statistics of participants' age and years of participation in GTD, gymnastics and tennis.

	Greek traditional dance	Tennis	Gymnastics
Age	37.10 ± 10.70	31.18 ± 9.89	40.82 ± 13.23
Years of participation	2.21 ± 2.04	1.28 ± 1.07	1.59 ± 1.19

The Subjective Exercise Experiences Scale (SEES; MeAuley & Courneya, 1994) that aims to assess subjective responses to exercise participation, adapted for the Greek population (Papaioannou et al., 2010), was used for data collection. The SEES consists of 12 items, answered on a seven-point Likert scale (1= "not at all", 4= "so and so" and 7= "very much"). Those items are classified by three factors: Positive Well-Being (PWB; 4 items), Psychological Distress (PD; 4 items) and Fatigue (4 items). The first two factors (PWB; PD) respond to the positive and negative sides of psychological health-wellness, whereas the third factor represents the perceived fatigue. SEES' construct validity (Mavrovouniotis et al., 2010; MeAuley & Courneya, 1994) and internal consistency (Bartholomew, Morisson & Ciccolo, 2005; Mavrovouniotis et al., 2010) are well established.

First, informative meetings took place at sport/dance clubs (November 2016 - March 2017), in which potential participants were informed about the aim and the procedures of the study. Those who agreed to take part were provided with written consent forms for participation and asked to fill them in and sign. Within the next two weeks, the researchers re-visited the clubs and administered the SEES to participants 10 minutes before (pre-test) and 10 minutes immediately after (post-test) a randomly selected 60 minute-session.

Regarding data analysis, at a preliminary level, Cronbach's α index was computed to examine the internal consistency of the three SEES subscales in both pre- and post- tests. A value of α = .70 was considered as the cut-off for accepted internal consistency (Cicchetti, 1994). Moreover, potential differences between the two types of gymnastics

(Zumba vs Pilates) on the three SEES subscales (PWB; PD; Fatigue) were examined, using analyses of variance with repeated measures. Their results revealed no significant interaction of time and gymnastics type (p >.05) nor significant main effect of gymnastics type (p >.05); thus, data of the participants in Zumba and Pilates were merged.

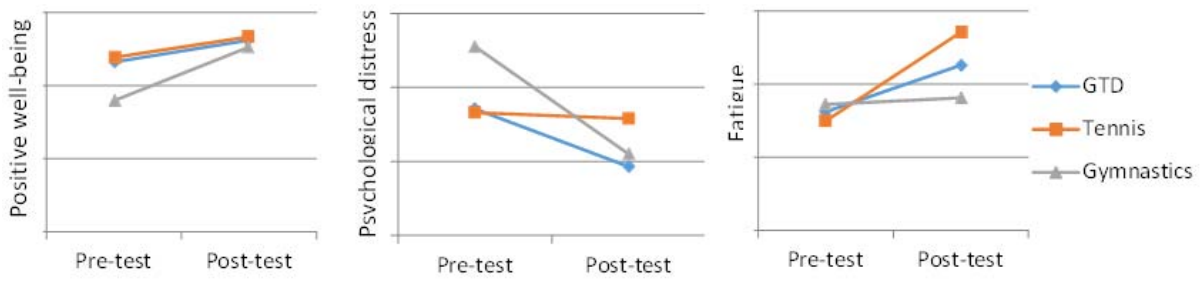
Then, 3 (group) X 2 (time) analyses of variance were performed on the SEES subscales scores to examine potential differences in participants' psychological responses due to the type of leisure-PA (gymnastics vs GTD vs tennis) they took part in. In cases of significant interactions, Bonferroni post hoc tests were utilized. The IBM SPSS 25.0 software package was used to perform data analysis and the level of statistical significance was set at .05. Furthermore, effect sizes, with η^2, were also utilized for data interpretation, following Cohen's (1988) cut-offs (values ≥ 0.14 are considered to show a practically significant effect).

RESULTS

The values of Cronbach's α for the three SEES subscales were above .70 in both measurements (PWB= .83 and .85; PD= .71 and .76; Fatigue= .84 and .85 for pre-and post-test, respectively), revealing sufficient internal consistency. In Table 2, means and standard deviations of participants in GTD, gymnastics and tennis on the SEES subscales are presented.

Table 2
Descriptive statistics on SEES subscales, by group.

	Greek traditional dance		Tennis		Gymnastics	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Positive Well-Being	21.62 ± 4.01	23.12 ± 3.95	21.93 ± 3.85	23.35 ± 3.92	18.97 ± 4.6	22.64 ± 4.35
Psychological Distress	6.71 ± 3.64	5.93 ± 3.40	6.66 ± 3.00	6.58 ± 3.45	7.55 ± 3.58	6.10 ± 3.40
Fatigue	9.25 ± 4.09	10.52 ± 5.19	9.00 ± 4.61	11.43 ± 5.18	9.45 ± 4.77	9.63 ± 4.57



(a) (b) (c)

Figure 1. Alterations to PWB (a), PD (b) and Fatigue (c) per group.

Regarding PWB, the results showed a statistically significant interaction between group and time ($F_{2,274}$=10.009, p<.001, η^2=.068), and a statistically significant effect for both time ($F_{1,274}$=90.71, p<.001, η^2=.25) and group ($F_{2,274}$=6.72, p<.005, η^2=.047). According to Bonferroni tests, although in the pre-test the gymnastics group had lower PWB scores than the other two groups, in the post-test all groups had similar scores. Moreover, all groups

presented statistically significant improvements ($p<.001$) (Figure 1a).

As far as PD is concerned, there was a statistically significant interaction between group and time ($F_{2,274}=3.72$, $p<.05$, $\eta^2=.02$) as well as significant main effect for time ($F_{1,274}=13.76$, $p<.001$, $\eta^2=.05$) but no for group ($p= .52$). Specifically, there was a statistically significant reduction in the PD of the participants in both gymnastics and GTD but not of those participating in tennis (Figure 1b).

As regards Fatigue, there was a statistically significant interaction between group and time ($F_{2,274}=4.61$, $p<.05$, $\eta^2=.033$), and a significant main effect for time ($F_{1,274}=18.04$, $p<.001$, $\eta^2=.06$) but not for group ($p= .52$). Bonferroni tests revealed that, although in the pre-test the three groups had similar levels of fatigue, in the post-test there was a statistically significant difference between the gymnastics and the tennis group. Furthermore, both the TGD and the tennis group had higher fatigue scores in the post-test compared to their pre-test scores; whereas the gymnastics group presented similar levels (Figure 1c).

DISCUSSION

The aim of the present study was to examine potential differences in the acute psychological responses of adults after different types of leisure-time PA (gymnastics, GTD, tennis). Provided the worrying levels of mental disorders nowadays and the potentiality of leisure-time PA and physical exercise to positively contribute to the psychological well-being of people, research evidence about the type(s) of PA/exercise that could lead to optimal improvements seems beneficial for public health, helping people choose a useful PA/exercise that suits them.

To begin with, our results revealed that, after a single session of gymnastics, GTD or tennis, the participants presented practically significant improvements in their positive well-being, thus supporting the claim that leisure-time PA and exercise offer psychological benefits for people (suggestively: Asztalos et al., 2009; Kull Ainsaar et al., 2012; Ohta et al., 2007; White et al., 2017). Nevertheless, in PD and Fatigue, changes did not reach practical significance (Cohen, 1988). Moreover, statistically significant differences were noticed among the three programmes in the SEES subscales, with gymnastics presenting the most optimal results. Specifically, the participants in gymnastics had the greatest improvement in positive well-being compared to those participating in the other two programmes. Furthermore, a reduction in psychological stress was noticed only in the data of those taking part in gymnastics and GTD but not in the participants in tennis. Finally, those who danced or played tennis felt significantly more tired in the post-test than the gymnastics trainees. Similarly, Genti et al. (2009), who investigated potential differences in the acute impact of three different programmes (aerobics; GTD; muscle strengthening with additional weights) on the mood of adult participants, found that aerobic gymnastics and GTD caused more positive mood changes than the muscular strengthening programme.

Gymnastics, a popular, broad field of exercise, including various types, has been examined for its psychological benefits in several studies. In the present study, data of participants in Pilates and Zumba were gathered. Starting with Pilates, in a study by Fotiadi et al. (2017) it was revealed that one session of Pilates and yoga had equally significant impacts on reducing psychological stress and tension of trainees. Similarly, Domene et al. (2016) found that a lesson of either in Zumba or salsa dance conferred significant psychological benefits to physically inactive women. A higher acute psychological impact of Zumba and hip-hop compared to body conditioning and ice skating in young adults was also revealed in a study by Kim and Kim (2007). Positive outcomes of other types of aerobic

gymnastics are also reported in literature. For example, both Charalampopoulos, Panagopoulou, Loukou, & Rokka, (2016), who focused on aqua aerobics, and Panagopoulou et al. (2016), who compared the effects of dance aerobics, step aerobics, and aqua aerobics, concluded that this kind of exercise improves the psychological health and well-being of the participants and reduces their psychological stress and fatigue. In their large-scale study with approximately 1.2 million participants, Chekroud et al. (2018) concluded that, although every type of physical exercise is better than no exercise, certain types are more strongly related to psychological benefits than others, with aerobic gymnastics, popular team sports, and cycling being among the most beneficial for both those with typical mental health and those diagnosed with depression. Additionally, Bartholomew et al. (2005) found that a single moderate-intensity aerobics lesson led to reductions in anxiety, confusion, fatigue, tension and anger and a significant increase in the well-being and self-confidence of participants receiving treatment for depressive disorder. Thus, our results confirm previous studies and reveal that gymnastics can serve as an effective means for the improvement of people's psychological health.

Regarding GTD, our findings are in agreement with previous studies that have showed significant improvements in both young adults' mood state (Argiriadou & Mavrovouniotis, 2001, 2002) and old adults' quality of life (Mavrovouniotis et al., 2010) after a single GTD session. It is furthermore known that dance triggers several positive feelings that reduce psychological burden (Adilogullari, 2014; Domene, Moir, Pummell, & Easton, 2014; Quiroga Murcia, Kreutz, Clift & Bongarg, 2010; Payne, 2003; Steiner, 2003).

Concerning tennis, to our knowledge there are no published studies that investigate the acute psychological effects of a single session; and the relevant literature regarding this type of exercise is quite limited. There is actually only one published study in which the impact of a 13-week tennis programme on mental health was investigated; it revealed positive results regarding stress and depression, especially in young athletes (Yazici et al., 2016). Nevertheless, in the present study, tennis presented the poorest results compared to gymnastics and GTD. Although Groppel and DiNubile (2009) claim that the emotional stress that characterizes tennis forces the player to develop an effective stress-copying capacity, it seems that this perspective does not optimally work in recreational adult participants.

A potential factor that contributed to the better scores achieved by the participants in gymnastics and GTD compared to tennis may be the use of music in these programmes. According to Boutcher and Trenske (1990), although the co-existence of both intrinsic and extrinsic information sources may impede the deep understanding of complex sport/dance skills, music seems to significantly reduce exercisers' psychological distress. That is why Rejeski and Kenney (1988) advocate the use of music during any kind of physical exercise. Perhaps a pleasant music could help participants in tennis avoid focusing on their fatigue and feel better. GTD provides the participants with the opportunity for socializing (Mavrovouniotis et al., 2008); thus, one would expect that GTD participants would present more positive psychological responses than the other two groups, but this did not happen. As Chekroud et al. (2018) underline, all types of physical exercise, including social and non-social ones, associate with lower mental health burden.

This study has some limitations that should be taken into account when interpreting its results. To begin with, the psychological responses of participants were recorded immediately upon completion of gymnastics, GTD and tennis

sessions. Follow-up tests that would have provided valuable information about the duration of the aforementioned positive impacts of the three progammes on the well-being of participants were not conducted. Moreover, although it is known that the duration of a session can influence the efficacy of a programme (Chekroud et al., 2018), in this study only 60-minute programmes were compared. Nevertheless, this study took place in naturalistic settings providing real-life data; it is the first study examining the acute effect of a recreational tennis programme and among the first comparing GTD with other programmes. Last but not least, in this study, three popular types of recreational PA/exercise that have different characteristics (gymnastics; dance; sport) were examined; thus, its findings can be helpful to people seeking different kinds of PA.

In summary, a single session of gymnastics, GTD or tennis seems to trigger positive acute psychological responses in terms of participants well-being. Gymnastics programmes appear to associate with the most optimal improvements, followed by GTD; whereas tennis presents the poorest results among the three leisure-time physical activities. Although further research is needed to fully understand the features of a PA/exercise that lead to the greatest boost in people's well-being, taking into account the growing prevalence of mental health disorders in our society, encouraging adults to join a leisure-time PA/exercise programme seems imperative for their (psychological) health benefit.

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THE INFLUENCE OF HAND GUARDS ON EXPLOSIVE FORCE AND PAIN AND EXERTION PERCEPTION IN A HANG HOLDING TASK

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Original article

Abstract

We investigated whether hand guards (HG) influence the perception of pain and exertion during the execution of a standardized task on high bar to induce forearm muscle fatigue as well as a decline in grip strength after the task. Design: A cross-over study design was employed 15 healthy and physically active volunteers completed static bodyweight holds (8 cycles of 20 second load in hang and 10 second rest), on a high bar. The exercise protocol was performed with and without HG. Perception of pain and exertion during the task were recorded. Peak handgrip force and explosive force parameters (i.e., rate of force development [RFD] and contractile impulse [CI] at 30 to 200 ms) were obtained from force-time curves. Peak force and explosive force parameters were normalized (i.e., POS/PRE) for statistical analysis. The use of a HG significantly attenuates pain perception ($p < 0.05$), with a moderate to large effect size ($d = 0.52$), but did not alter the perception of exertion during the task, nor did it alter peak force, RFD, or CI. The use of HG reduces the perception of local pain during static holds. However, HG do not alter the perception of exertion during the task nor do they alter the gripping force ability immediately afterwards. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Keywords: *mixed modality training, hand guards, rate of force development, safety, gymnastics.*

INTRODUCTION

High-intensity functional training (HIFT) programs, which comprise the basis of world-renowned programs such as Crossfit™, among others (Neto & Kennedy, 2019), have been growing in popularity and recruiting adherents from diverse age ranges (children, youth and the elderly). These training programs use

weightlifting (e.g., clean, jerk, snatch) and gymnastic movements (e.g., pull up, ring muscle up, bar muscle up, handstand push up, handstand walking) and as such justify the recent use of the term "mixed modality training" (MMT) (Figueiredo, Pereira, & Neto, 2018; Marchini, Pereira, Pedroso, Christou, & Neto, 2017) to designate this training methodology.

Generally, this training method aims to develop a set of muscle strength and endurance, cardiorespiratory conditioning and motor skills (Brisebois, Rigby, & Nichols, 2018; Maté-Muñoz, Lougedo, Barba, García-Fernández, Garnacho-Castaño & Domínguez, 2017), obtained with workouts that involve one or more of the previously mentioned movements and seeking to perform as many repetitions as possible in a given time interval (i.e., As Many Rounds-Reps As Possible (AMRAP)), or every minute (i.e., Every Minute One Minute (EMOM)), or even performing a certain number of repetitions as quickly as possible (also called "for time workouts" or "time-limited physical workouts"). Thus, MMT training involves a constant quest for performance improvement.

The culture of challenging oneself to improve partly explains the popularity of this training method, since it arouses great motivation. However, as with any high-intensity physical activity, excessive workloads can endanger the practitioners' physical safety. In this context, as in any other sport, protective equipment is widely recommended and used (Church, Allen, & Allen, 2016; Colado & Garcia-Massó, 2009; Kulund, Dewey, Brubaker, & Roberts, 1978), including lifting belts (Renfro & Ebben, 2006), knee-pads or knee wraps (Baltaci, Aktas, Camci, Oksuz, Yildiz & Kalaycioglu, 2011), weightlifting shoes (Sato, Fortenbaugh, & Hydock, 2012), and hand guards for gymnastic bar exercises (Wettstone, 1941).

Though proposed as a safety measure, a possible positive effect of wearing "protective equipment" on physical performance cannot be neglected. For instance, wearing knee wraps has been found to directly increase squatting strength through the spring effect (Lake, Carden, & Shorter, 2012). This raises debates about the legality of their use for competitive purposes. In the gymnastics field, hand protection could be ensured by magnesium (Pušnik & Čuk, 2014) and/or equipment commonly referred to as hand guards (HG) as safety equipment for bar exercises (Neal, Kippers, Plooy, & Forwood, 1995; Wettstone, 1941; Eckers, Fischer & Tscholl, 2020).

Wettstone describes the great importance of HG during periods of practice as it protects against the development of blisters, allowing the gymnast to have a longer period of practice (Wettstone, 1941). This description makes clear the protective purpose of this equipment. Additionally, Neal et al. (1995) studied the influence of the use of different types of HG on hand and wrist tension forces and the electromyographic (EMG) activity of the wrist and fingers flexor and extensor muscles during 3 giant swings on the high bar. The authors demonstrated that the use of this equipment increases wrist tension and bar forces, but did not observe any difference in EMG activity, indicating that the use of this equipment does not change the demand of the muscles involved in the body support during the studied gymnastic exercise. It is important to note that the movement studied (i.e., giant swings) is applied to artistic gymnastics, but is not typically practiced in HIFT programs.

In the context of HIFT, the use of HG, in addition to the safety aspect, may involve an aspect of "advantage" by allowing athletes to perform a greater volume of gymnastic movements, such as pull ups, kipping pull up, chest-to-bar, toes-to-bar and bar muscle ups, which may be related to two aspects: 1) minimize skin friction with the bar, thereby reducing local pain and blistering, and/or 2) mechanically favour the performance of

the movements, reducing the demand of the forearm muscles. It is important to note that in many typical HIFT workouts, gymnastic exercises are succeeded by exercises that require strength and endurance of forearm flexors and extensors, such as deadlift, clean and snatch exercises, so that the performance in subsequent tasks can be optimized if the use of hand guards minimizes the effort of the aforementioned muscles, allowing a smaller decline in the capacity to produce force after gymnastic exercises.

Thus, the present study aimed to investigate whether the use of HG influences the perception of pain and exertion during the execution of a standardized task on high bar to induce forearm muscle fatigue as well as the decline in force after the task. Our hypothesis is that HG can minimize the perception of pain in hands, while not reducing the exertion from the forearm muscles.

METHODS

In this cross-over study design, 15 healthy and physically active volunteers (9 men / 6 women; 26.0 ± 3.9 years, 70.0 ± 10.0 kg, 170.1 ± 6.4 cm) were submitted to the same protocol to support their own body weight in hang on two non-consecutive days (1 week apart). All volunteers were regular HIFT practitioners and had prior experience with gymnastic exercises, such as pull ups (at least 6 months of training experience).

Before starting the study, the volunteers were informed about the study procedures and signed an informed consent form, which was evaluated and approved by the local (Universidade Estadual do Sudoeste da Bahia) Research Ethics Committee. Additionally, volunteers were instructed to avoid the practice of exercises in the 24 hours preceding each experimental session.

In order to induce fatigue of the forearm flexor and extensor muscles, all volunteers underwent a protocol to support their own body weight from a high bar (diameter = 2,8 cm). The protocol consisted of 8 cycles of 20 seconds load in hang and 10 seconds rest, totaling 160 seconds sustaining their own body weight. This choice of testing with a static hold was used to ensure reproducibility of the session volume, as performing pull ups could lead to great variability in the degree of exercise-induced fatigue due to the technical level of each volunteer. Figure 1 presents the experimental design.

The same procedure was performed twice, one week apart, so that on each day volunteers performed the protocol in one of the two conditions: 1) with “hand guard”, or 2) without “hand guard”, and the order of these conditions was randomized. For this study we used a Skyhill® hand guard (Florianópolis, SC, Brazil) developed to practice gymnastic exercises applied to HIFT (Figure 2). During the task execution, the use of magnesium was allowed, since its protective effect on the hands has been demonstrated by Pušnik & Čuk (2014).

Prior to and immediately after the exercise protocol used to induce fatigue of the forearm flexor and extensor muscles, maximal voluntary handgrip isometric contractions (MVIC) and the perception of pain and exertion were recorded.

Prior to the exercise protocol, volunteers were familiarized with the pain perception scale, which consists of a 100 mm line representing "no pain" at the left limit (0 mm) and "very, very painful" at the right limit (100 mm), as used by Borges, Cerqueira, Rocha, Conrado, Machado, Pereira & Neto (2014). In the present study, the volunteers were instructed to consider the perception of hand and wrist pain to indicate the level of pain on the line. Volunteers were also asked if pain perception was located in the hand (palm), wrist or both regions. Similarly, volunteers were previously instructed regarding the assessment of perception of exertion from the forearm

muscles during the task. The Borg CR10 effort perception scale was used to assess the perception of exertion during the task, as used by McGorry, Lin, Dempsey, & Casey (2010).

The volunteers underwent 4 maximal voluntary handgrip isometric contractions (MVIC) (two with each hand) with a strain gauge-based force transducer (EMG System, São José dos Campos, SP, Brazil). To perform the MVIC, the volunteers stood in an orthostatic position, and were instructed to position the arm at 90° of elbow flexion with their forearm in the neutral position. The device's handle was fit into their palm with the fingers at 90° flexion at the proximal and distal interphalangeal joints with the thumb in 90° abduction. Two handgrip maximal isometric force attempts with an inter-attempt rest interval of 30 seconds were performed for each arm (right and left), and the maximum handgrip force of each trial was identified. The order of tested hand (i.e., right and left) was random. Subjects were carefully instructed to contract "as fast and forcefully as possible" after the command "go," sustaining the contraction for 3 seconds when the command "stop" was given. Verbal encouragement was given by the evaluator during the maintenance of the MVIC and the best attempt at each moment (i.e., before and immediately after the fatigue protocol) was used for analysis purposes. The sampling rate from force transducer was set at 2 kHz, as performed by Schettino, Luz, Oliveira, Assunção, Coqueiro, Fernandes, Brown, Machado & Pereira (2014) and Borges, Fernandes, Schettino, Coqueiro & Pereira (2015).

The force-time curves were analyzed to obtain the rate force development (RFD) in the first 200 milliseconds of MVIC. Briefly, the force-time curves were smoothed by a digital fourth-order, zero-lag Butterworth filter, with a cutoff frequency of 15 Hz, as proposed by Aagaard, Simonsen, Andersen, Magnusson & Dyhre-Poulsen (2002). The Δ force / Δ time ratio was measured at time intervals of 30, 50, 100, 150 and 200 ms after the onset of MVIC. Likewise, the area under the force-time curve was calculated at the same time intervals as mentioned above, obtaining the contractile impulse (CI) parameter (Aagaard et al., 2002). Both CI and RFD measure explosive force, however, they use distinct but complementary methods. The CI measures accumulated area under the force–time curve which reflects the entire time period of contraction, including the overall influence of the various time-related RFD parameters (Aagaard et al., 2002; Schettino et al., 2014).

The onset of muscle contraction was defined as the time point at which the force curve exceeded the baseline by 2.5% of the difference between baseline force and the maximum voluntary contraction (i.e., maximum handgrip force), as proposed by Aagaard et al. (2002) and Schettino et al. (2014). All analyses were conducted using specific algorithms developed in MATLAB®.

For descriptive purposes, the explosive force data (i.e., RFD and CI) obtained immediately after the fatigue protocol were normalized by the measurements obtained before the fatigue protocol (Δ (%) = [POS / PRE] * 100) for each arm (i.e., right and left). For statistical analysis, Δ POS / PRE from the right and left arm were grouped, so that comparisons between the experimental conditions with and without hand guard were made considering the mean ΔPOS / PRE (%) from the right and left arms. Figure 3 illustrates the data analysis and grouping procedure for statistical analysis.

Student's t-test was used to compare pain and effort perception in the task performed with and without hand guard. Similarly, ΔRFD and ΔCI from each experimental condition (i.e., with and without HG) were compared with Student's t-test. For all comparisons, the significance level of $p \leq 0.05$ was used, and all statistical analyses were performed using

SPSS 21.0 software (IBM Corp., Chicago, IL, USA). The effect size was calculated to obtain Cohen's *d*-index as proposed by Cohen (1988). The following interpretation was considered: small (d = 0.2), medium (d = 0.5), and large effect size (d = 0.8). Data are presented as mean ± standard deviation.

Figure 1. Experimental design.

Figure 2. "Hand guard" used, and its proper use mode.

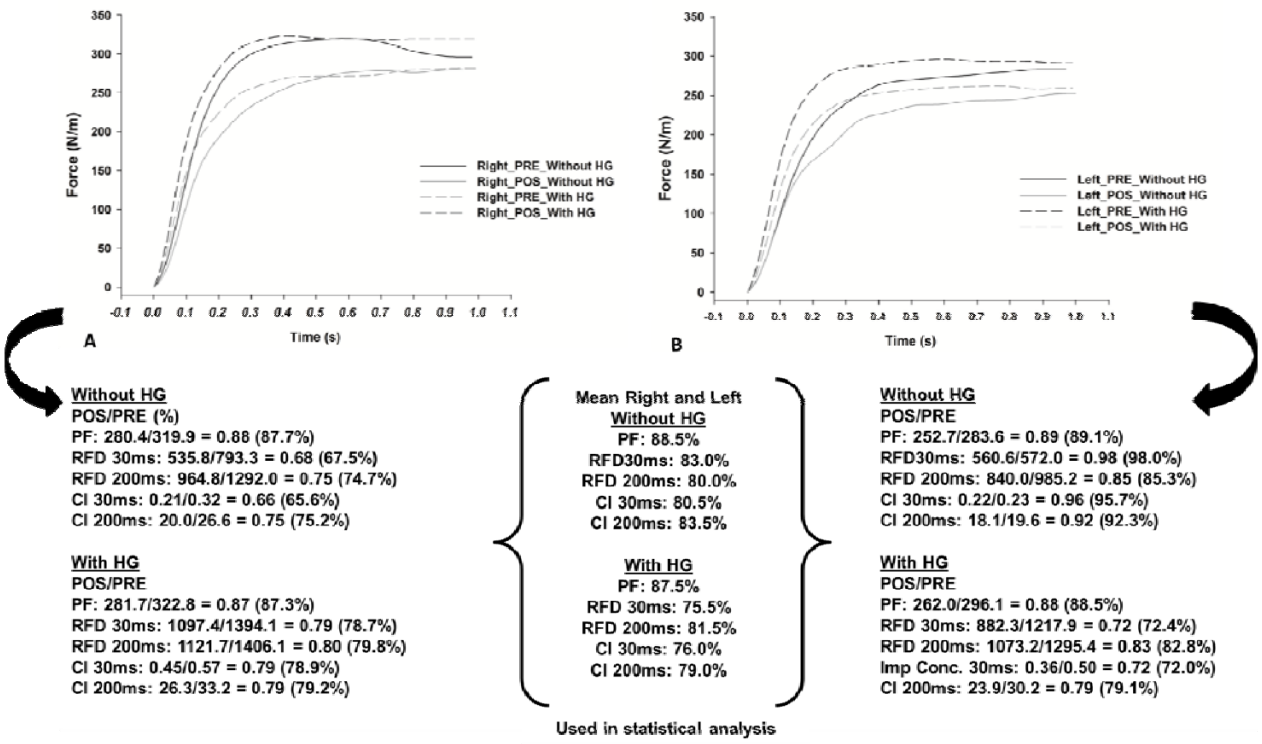

*Figure 3***.** Force / time curves of the right (A) and left (B) arms, before (PRE) and after (POS) the task for fatigue induction without and with hand guard (HG). Peak Force (PF), rate of force development at 30 (RFD 30ms) and 200 ms (RFD 200ms), Contractile Impulse at 30 (CI 30ms) and 200 ms (CI 200ms) values are presented in absolute and normalized values (POS / PRE). The central column shows the mean of the right and left arms in studied conditions (i.e., without and with HG).

Table 1
Perception of pain and exertion during the proposed task without and with hand guard.

	Without HG	With HG	P value	Mean difference [95% Conf. Int.]	Effect size
Perception of Pain (mm)	5.5±0.5	4.1±0.6	0.038*	1.40 [0.09 to 2.71]	0.52
Perception of exertion (A.U.)	7.5±0.5	7.1±0.5	0.290	0.46 [-0.44 to 1.38]	0.28

Table 2
Mean ± standard deviation from the difference (Δ POS / PRE (%)) of the peak force and the right and left arms explosive force parameters under experimental conditions with and without hand guard (HG). P values, mean difference and effect size of comparisons between experimental conditions are also presented.

	Without HG			With HG			P value	Mean difference	Effect
	Right	Left	Mean	D	E	Mean		[95% Conf. Int.]	size
Peak Force	88.8±16.6	86.6±16.5	87.7±14.8	86.9±22.0	80.3±19.1	83.6±18.8	0.520	4.1 [-9.2 to 17.4]	0.17
RFD 200ms	75.5±19.5	71.6±17.8	73.5±17.0	68.2±22.0	62.1±18.1	65.2±19.2	0.163	8.4 [-3.8 to 20.5]	0.37
RFD 150ms	74.8±20.1	70.2±19.4	72.5±18.0	67.9±26.6	59.1±19.9	63.5±22.0	0.197	9.0 [-5. 3 to 23.3]	0.34
RFD 100ms	76.1±23.0	70.0±21.7	73.0±20.4	69.2±33.2	58.3±22.5	63.8±26.0	0.270	9.3 [-8.0 to 26.6]	0.29
RFD 50ms	79.0±27.6	73.6±26.1	76.3±24.5	71.0±35.5	60.9±26.3	66.0±28.6	0.281	10.3 [-9.4 to 30.1]	0.29
RFD 30ms	80.7±29.1	75.5±28.1	78.1±26.1	71.9±34.7	63.8±29.1	67.8±29.5	0.299	10.3 [-10.2 to 30.7]	0.28
CI 200ms	75.7±21.2	70.4±19.6	73.0±18.7	68.1±27.1	59.6±20.3	63.9±22.3	0.194	9.2 [-5.2 to 23.6]	0.34
CI 150ms	76.3±22.7	70.4±21.3	73.3±20.1	68.9±31.2	58.9±22.0	63.9±24.9	0.238	9.4 [-7.0 to 25.8]	0.31
CI 100ms	77.8±25.4	71.7±23.9	74.8±22.6	70.2±34.4	59.8±24.3	65.0±27.3	0.275	9.8 [-8.7 to 28.2]	0.29
CI 50ms	80.2±28.6	74.9±27.4	77.5±25.5	71.5±34.6	63.2±28.1	67.4±29.0	0.295	10.2 [-9.9 to 30.2]	0.28
CI 30ms	81.3±29.6	76.6±28.5	79.0±26.5	72.5±34.1	65.5±30.8	69.0±30.0	0.314	10.0 [-10.5 to 30.5]	0.27

RFD = Rate of Force Development; CI = Contractile Impulse

RESULTS

All volunteers completed the proposed exercise protocol in both experimental sessions. Pain perception reported immediately after the experimental session was significantly lower in the experimental session with the use of hand guard ($p < 0.05$), and the observed effect size was classified as medium to large ($d = 0.52$). All volunteers reported pain at the end of the task performed without a hand guard. From 15 volunteers, 14 (93.3%) reported hand (palm) pain and only 1 (6.7%) reported wrist pain at the experimental session without HG. When the HG was used 6 volunteers (40%) did not report pain, 8 (53.3%) reported hand (palm) pain and only 1 (6.7%) reported wrist pain.

The perception of exertion during the task was not different between experimental sessions ($p > 0.05$). The results from perception of pain and exertion during the task are presented in table 1.

The peak force and explosive force parameters decreased by about 13 to 37% after the induced fatigue by the used hang holding task (see table 2). The peak force and the explosive force parameters decline did not differ significantly between experimental conditions with and without hand guard ($p > 0.05$), as shown in table 2.

DISCUSSION

The present study aimed to investigate whether the use of HG influences the perception of pain and exertion during a standardized task to induce forearm muscles fatigue as well as a decline in peak force and explosive force after the applied task. Our results showed that the use of HG significantly attenuates pain perception, with a moderate to large effect size, but did not attenuate the perception of exertion during the task, as well as the ability to produce maximum force and explosive force immediately after the task.

HG are proposed as protective equipment to perform gymnastic exercises on the bar (Neal et al., 1995; Wettstone, 1941) and our results corroborate this proposal, since HG attenuated pain perception during a standardized task sustaining the body weight on high bar. The compression and friction generated on the palm during this task generates pain and may therefore be a limiting factor for the practice of higher volumes of exercises

on high bar. Our results indicate that the use of HG may effectively enable a greater volume of training in the same session, even though factors other than pain may limit the session volume.

Despite the lower pain perception in the palm and wrist, HG did not attenuate the perception of exertion during the task. This may be due to the fact that this model of HG does not attach to the bar (see figure 1), requiring maintenance of the contraction of forearm and fingers flexor muscles to sustain the hold. McGorry et al. (2010) demonstrated that the measure of perceived exertion involving forearm muscles, as used in our study, has a direct relationship with the handgrip strength demand.

Many HG models are used by gymnasts, with differing models suited to various gymnastic movements. In the present study we examined the model where the HG is fixed to the wrist but not fixed to the bar. Our results indicate that the used HG model does reduce the demands of the forearm muscles. Previous research by Neal et al. (1995), compared the forces applied to the bar and the electromyographic activity (EMG) of the forearm muscles of gymnasts during the execution of 3 giant swings on the high bar with and without the use of HG (2 typical models – webbing loops and dowelled hand guards, used for gymnastics). EMG activity was equal during the performance of the movements under conditions with and without both HG models.

Neal et al. (1995) submitted 10 gymnasts to a movement typically used in artistic gymnastic competitions, which is not directly applicable to HIFT-based workouts. Despite the differences in movement analyzed (giant swing vs. static support) and HG style, our results are in line with the cited study, leading us to infer that the used HG model in our study meets the criteria of hand protection, but does not alter muscular demand when sustaining the body on high bar, which was confirmed by the force measurements before and immediately after the proposed task. In fact, the ability to generate maximum force and explosive force were not different in studied experimental conditions (i.e., with and without HG).

It is important to note that the explosive force analysis applied in our study permits the differentiation of influence of neural factors (i.e., the ability to recruit motor units and its recruitment pattern) and muscular factors (i.e., the contractile apparatus characteristic and availability of energy substrates), since the ability to increase force within the first 100 ms of a MVIC is directly related to neural factors, while the ability to increase strength from 100 to 200 ms is directly related to muscle factors (Cerqueira, Pereira, de Mesquita, Rocha, & de Moura Filho, 2019; Maffiuletti, Aagaard, Blazevich, Folland, Tillin, & Duchateau, 2016; Oliveira, Corvino, Caputo, Aagaard, & Denadai, 2016).

Perception of palm pain has been found to directly influence the descending command pattern of the central nervous system to the muscles involved in the handgrip task (Tokimura, Di Lazzaro, Tokimura, Oliviero, Profice, Insola, Mazzone, Tonali, & Rothwell, 2000) and consequently in the ability to produce muscle force. Despite this, the present results did not show any advantage in the use of HG in regards to force production, as there were no observed differences between conditions in the force measurements in the first 100 ms of the MVIC after the applied task. However, it is important to emphasize that we used a time-limited task, where all subjects were able to complete the task, regardless of the use of HG. Thus, we cannot infer whether the use of HG would enable one to sustain the task for a longer time period before the onset of fatigue. The effect of HG on time to exhaustion during static holds could be investigated in future studies, since the current experimental design was directed to investigate the neural and mechanical

factors involving the use of HG during a time-limited task.

The results of this study shed light on aspects related to the mechanisms involved in the use of HG in a time-limited task, while future studies should investigate how the use of HG influences the performance-limited tasks (i.e., the maximum time sustaining the body weight or recording the maximum pull-ups, toes-to-bar or bar muscle ups repetitions), which would require good control of technical variables during the movement execution.

The practical implications of these results may affect athletes and coaches in the area of HIFT or related modalities where gymnastic exercises, such as pull ups, toes-to-bar and bar muscle ups are applied. In this context, our results indicate that athletes and coaches should choose whether or not to use HG on the basis of pain perception rather than the possible mechanical advantage of using this accessory. Additionally, it is possible to hypothesize that in typical HIFT workouts, where weightlifting exercises (e.g., clean, snatch) can be performed immediately after gymnastic exercises on high bar, the use of HG would not favour a higher grip strength and would lend no advantages.

CONCLUSION

In conclusion, the results of this study suggest that the use of HG reduces the perception of local pain (palm). However, it does not provide any mechanical advantage for the applied task, since it does not reduce the perception of exertion during the task nor the ability to develop force based on neural and/or muscular aspects immediately after the proposed task. When deciding whether to use HG for HIFT-based workouts, athletes and coaches should be aware that this is protective equipment and there is no evidence that it offers any mechanical advantage.

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THE ROLE OF MENTAL PRACTICE IN DECREASING FORGETTING AFTER PRACTICING A GYMNASTICS MOTOR SKILL

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Original article

Abstract
Parallel to processes of memory consolidation, forgetting is a functional mechanism that allows the maintenance of relevant information or learning in memory. Practice condition can affect the forgetting rate, favouring or not memory consolidation. Physical practice has been shown to be effective in decreasing forgetting, but the role of mental practice is not known yet. Thus, in this study, we aimed to investigate the role of mental practice in the forgetting rate of a motor skill. Twenty-four participants with the mean age of 26.13 years (± 3.04) of both genders were divided into three groups: (a) mental practice group (MG); physical practice group (PG) which practised the handstand skill either mentally or physically, respectively, and (c) control group (CG) that did not practice the skill. Results showed no difference between the forgetting rate of MG and PG. Also, they had forgetting rates lower than CG. Thus, it is suggested that mental practice is as effective as physical practice to decrease the forgetting rate of motor skills, favouring the maintenance of the movement representation in memory. Possibly, physical and mental practice conditions share mechanisms that slow down forgetting processes.

Keywords: *handstand skill, mental practice, forgetfulness, memory consolidation, cognitive processes.*

INTRODUCTION

Memory is one of the key elements involved in motor performance, learning, and control (Robertson, 2012). Working-memory (WM) is involved in the process of storing and manipulating information during a given task (Diamond, 2013), playing a decisive role in mechanisms of error detection and correction (Seidler, Bo, & Anguera, 2012). The greater rate of improvement in motor performance at the beginning of practice typically observed in motor learning, as opposed to the rate of improvement at the end of the practice period, is entailed by trial-to-trial adjustments in motor command that aim to reduce the discrepancy between the performed and the desired behaviour (Smith, Ghazizadeh, & Shadmehr, 2006). WM participates in the updating of motor plans through mechanisms of error

detection (Seidler et al., 2012). Throughout practice both the errors and the WM influence decrease, and the participation of cognitive processes associated with learning consolidation increases (Smith et al., 2006). Although the encoding and adaptation of long-term memory (LTM) influence learning since the beginning of practice, this process is paramount for motor learning consolidation not only at the final stages of practice, but especially after acquisition (Robertson, Pascual-Leone, & Miall, 2004). Through more stable memories, the learner is capable of maintaining her performance similar to the performance reached at the end of the last practice session, even after a period without practice (Mosha & Robertson, 2016; Robertson, 2012).

The long-term reverberation of the information acquired during practice is crucial for the LTM consolidation, since forgetting processes act in an adaptive fashion in which only relevant information is retained long-term (Schacter, 1999). The first empiric evidence on forgetting processes was shown at the end of the 19th century with studies by Ebbinghaus (Murre & Dros, 2015). One of his best scientific contributions pertains to the forgetting curve, wherein it was shown that the largest forgetting rate occurs only moments after learning (Murre & Dros, 2015). Considering the pieces of evidence provided by Ebbinghaus` groundbreaking experiments, the Decay Theory suggests that forgetting is entailed by decayed activation of memory traits (Ricker, Vergauwe, & Cowan, 2016). According to this theory, the weakening of memory traits is faster after its encoding and, if this trait was not strengthened enough, it gets lost over time (Brown, 1958).

Other than time, practice is one of the factors that can contribute to increasing or diminishing forgetting (Robertson et al., 2004). Different practice conditions may increase or diminish the rate of forgetting. For instance, the suppression of sensory receptors that participates in the coding of mental representation may increase the rate of forgetting (Ventura de Oliveira et al., 2019). Conversely, increasing the quantity of practice slows the rate of forgetting, entailing distinct levels of motor consolidation (Lage et al., 2017).

Practice conditions with explicit movement are usually known as physical practice, while those that do not include movement are called mental practice (Gomes et al., 2014; Millard, Mahoney, & Wardrop, 2001; Wulf, Horstmann, & Choi, 1995). Studies often see physical practice as superior to mental practice, while the latter, to a lesser extent, leads to better performance and learning than conditions with no practice (Toth, Neill, Hayes, Moran, & Campbell, 2020). One of the explanations for the benefits of mental practice is related to the cognitive processes underlying it, which are similar to those of physical practice (Munzert & Zentgraf, 2009). Considering this similarity, it is reasonable to expect a similar rate of forgetting between these two practice conditions during motor memory consolidation. Nevertheless, to the best of our knowledge, the forgetting rate of these two practice conditions has never been investigated in the literature. In line with the idea that mental practice may be an important factor to aid the consolidation of motor learning, we investigated the rate of forgetting in mental and physical practice of a sports skill. We hypothesized that mental and physical practice would show a similar rate of forgetting, and a lower rate than the no-practice condition.

METHODS

Twenty-four undergraduates in physical education (12 female and 12 male), with the mean (M) age of 26.13 years (standard deviation [SD] = 3.04) participated in this study. As a prerequisite for participation in the experiment, the individuals had to be able to raise their legs at a 90º angle while both hands were touching the ground (Rohleder & Vogt,

2018). Volunteers could not have previous systematic experience with the handstand movement or with mental practice. They also did not report any pathology that could restrict their movements. The selected volunteers were informed of the purpose of the study and asked for their written informed consent to participate in this study. The experiment was reviewed and approved by the local Ethics Committee (Universidade Estadual de Minas Gerais - CAAE 97208818.3.0000.5093).

Data collection was conducted in a university laboratory, with standard luminosity and windows properly covered by curtains. To perform the kinematic analysis of handstand, we used a video camera (Nikon, D-750 Sigma - lens 17-50 mm) with a 60 Hz frame rate and the Kinovea software (v.0.8.15) to process the data.

Volunteers were marked on the right side of their bodies with red adhesive tape in a plus (+) shape in the following locations: lateral condyle (knee), greater trochanter (hip), humeral head (shoulder), ulna's styloid process (hand), and temporal bone (head). After the placement of landmarks, the volunteers received the following instructions: “To perform the handstand skill, you must remove your feet from the ground, while maintaining support with your hands, and straighten your arms, legs, and spine as much as possible. You must touch the ground with fingers extended, and place the hands apart, at the shoulder width. The legs must remain upright and side-to-side with one another, while the head must remain aligned with the body”. Further, an image of the ideal execution of the task was shown to each participant, and a video of an ideal execution pattern (performed by a professional) was reproduced twice. After these initial procedures, participants performed three pre-test trials, which were filmed for posterior analysis. Participants were allowed to start each trial after the “prepare and go” command was given by the experimenter.

After the pre-test, participants were randomly assigned and counterbalanced by sex in three groups: mental practice group (MG), physical practice group (PG), and control group (CG). The practice phase of MG consisted of imagining the task. Before starting mental practice, participants comfortably sat down on a chair facing a desk and holding a pen with their left-hand. Fifteen trials were performed mentally, and participants were required to signalize the end of each trial by touching the far end of the pen on the desk. The PG physically performed 15 trials of the handstand skill after the pre-test. 30 seconds of rest were provided to participants in-between trials, and each trial started after the “prepare and go” command given by the experimenter. Participants in the CG played T-Rex Game on the offline Google Chrome browser for 10 minutes after the pre-test (a time similar to the time spent by participants in the MG and PG groups). This procedure was adopted to avoid any unwanted mental practice by participants of the CG.

Ten minutes after the end of the practice session, a post-test was performed. Similarly to the pre-test, all participants performed three trials of the motor task, which started after the command “prepare and go” was given by the experimenter. The trials were recorded for posterior analysis.

For video analysis, three angles were defined on Kinovea (Figure 1): (i) Angle between the lateral condyle and greater trochanter (angle 1); (ii) Angle between the greater trochanter and ulna's styloid process (angle 2); (iii) Angle between the greater trochanter and temporal bone (angle 3). The reference values were: angle 1 = 200º, angle 2 = 164º, and angle 3 = 159º. The reference values were extracted from the analysis of a gymnastics athlete with more than 10 years of experience and participation in international artistic gymnastics competitions.

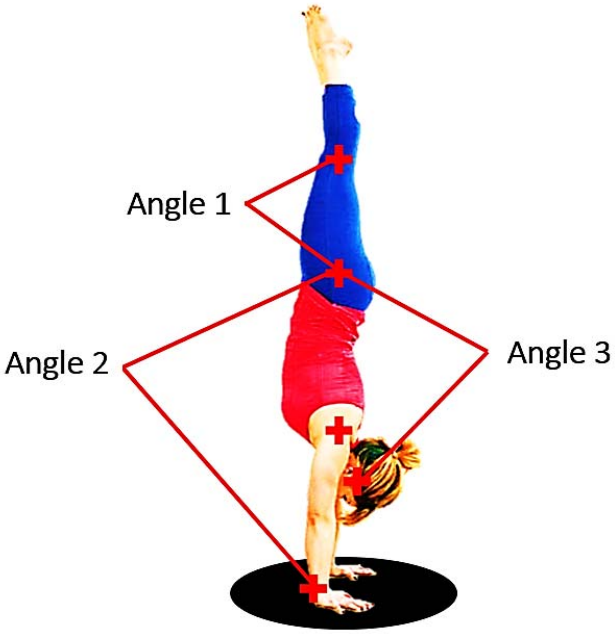

Figure 1. Angles analysed.

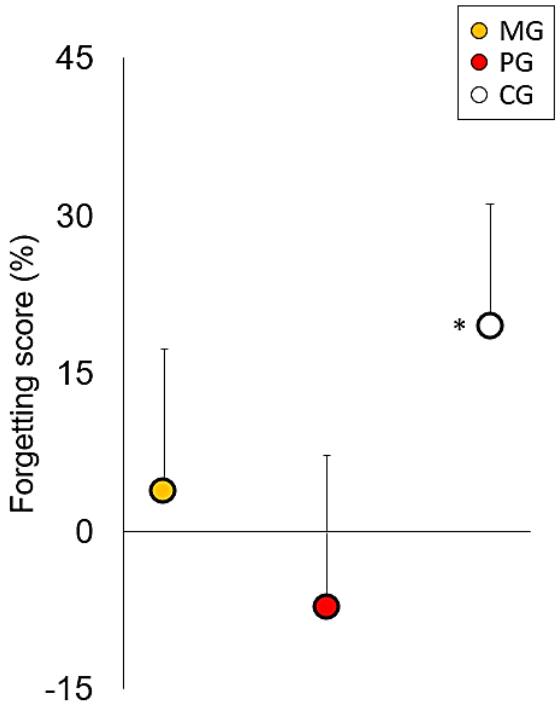

Figure 2. Mean and standard deviation of the groups' forgetting score. MG = mental practice group; PG = physical practice group; CG = control group; * = indicates a significant difference from the other groups

Performance error was computed as the difference between the actual angles and the angle criteria:

$$Performance\ error = [|(Angle\ criterion^{i} - Actual\ angle^{i})| + |(Angle\ criterion^{ii} - Actual\ angle^{ii})| + |(Angle\ criterion^{iii} - Actual\ angle^{iii})|].$$

A forgetting score was calculated as follows:

$$Forgetting\ score = [(post\text{-}test - pre\text{-}test)*100]/pre\text{-}test.$$

Smaller numbers indicate less forgetting from pre- to post-test (Lee & Fisher, 2019).

One-way ANOVAs and post hoc Fisher LSD tests were used to compare groups. Effect sizes were calculated using eta-squared (η^2). An alpha level of .05 was set for all inferential statistics.

RESULTS

Descriptive statistics are presented in Figure 2. The inferential analysis detected a significant effect of groups [$F(2, 21) = 7.16$, $p < .01$, $\eta^2 = .40$]. Post hoc analysis indicated that the forgetting rate was greater in CG than in MG ($p = .02$) and PG ($p < .01$). No difference was found between MG and PG ($p = .33$).

DISCUSSION

In this study, we investigated the effects of mental practice in the forgetting rate of a motor skill. Our results support our hypothesis that a similar forgetting rate between mental and physical practice would be found, with both practice conditions showing a smaller forgetting rate than the no-practice condition. The lower rate of forgetting of the MG compared to the CG suggests that mental practice is capable of slowing down the forgetting process after the implicit practice of a movement. Also, the similar forgetting rate of the MG and PG groups support the idea of shared underlying cognitive processes between mental and physical practice (Munzert & Zentgraf, 2009).

Studies showing the existence of unconscious implicit muscle movements during mental practice provided the first pieces of evidence of similarity between physical and mental practice (Hale, 1982; Jacobson, 1930). By using electromyography, Jacodson (1930) and Hale (1982) showed that thinking about a movement of elbow extension led to increased neuromuscular activity of the biceps brachii. This muscle activity of the same muscles involved in physical practice, although in smaller magnitudes, suggested that the benefits of mental practice are related to neuromuscular changes that favour future physical movement.

Other possible links between mental and physical practice were suggested in the literature, such as the hypothesis of functional equivalence that proposes that mental and physical practice share memory representations, neural structures, and perception, planning and execution mechanisms (Moran, Guillot, Macintyre, & Collet, 2012). Among the shared brain areas are the premotor cortex, the supplementary motor cortex, the primary somatosensory area, cerebellum, and basal ganglia (Hardwick, Caspers, Eickhoff, & Swinnen, 2018). Studies presenting these neural correlations between physical and mental practice do not show a clear relation to memory formation or forgetting. However, the similarity between the brain areas involved in both practice conditions and the similar forgetting rate between the MP and PP groups suggests that motor memory strengthening and forgetting are also processes shared by these two practice conditions.

The superiority of mental practice over a no-practice condition is recurrently demonstrated in the literature (Toth et al., 2020), and our study also supports this premise. The smaller forgetting rate of the MG compared to the CG may be associated with a greater ability to protect

a previous performance level from factors that interfere with forgetting processes. In this study, for instance, the time between the end of the practice session and the post-test is one of these factors. Considering that the greatest weakening of memory traits occurs immediately after its encoding, resting time is paramount for memory survival (Brown, 1958). A recent memory goes through a phase of instability of its neuronal representation, thus vulnerable to perturbations and interferences (Robertson et al., 2004). The early consolidation processes are responsible for the stability and robustness of the memory after a period of sleep (Diekelmann & Born, 2007, 2010). Mental practice likely acts as a protecting agent against the short-term effects of time on forgetting, as shown in the present study. Another study also investigated the effects of mental practice on the learning of a gymnastics skill (Šešum & Kajtna, 2018). It is important to highlight that during the mental practice condition in their study, a relaxation technique was applied, which is not usual in study designs investigating mental practice. Given the use of such relaxation technique, it is difficult to support the hypothesis that there are no benefits of mental practice in the learning of gymnastic skills, since relaxation may have interfered with the results by Šešum and Kajtna's (2018). It is also worth noticing that they did not investigate the rate of forgetting. If relaxation in conjunction with mental practice results in better memory consolidation, this additional effect could be observed in the rate of forgetting.

Even though our results suggest a relation between mental practice and decrease in forgetting, more evidence is needed to further our comprehension of the role of mental practice in motor memory consolidation. For instance, our single session design allows inferences about the early stages of memory consolidation, but not about the whole process of LTM formation. Future studies should investigate how the forgetting rate under a mental practice condition behaves with distinct intervals between the practice session and the post-test. We could expect that the forgetting curve, as a function of time, would follow the same features of the one under physical practice conditions, wherein the faster forgetting rate occurs immediately after acquisition (Murre & Dros, 2015). Additionally, future studies could investigate the interaction between mental practice and factors such as the quantity of practice and sleep duration. Since fewer practice trials and shorter sleep times maximize forgetting processes (Krause et al., 2017; Lage et al., 2017), the benefits of mental practice could be better observed under conditions with more trials or after a period of sleep. More than behavioral research, given the neural correlations found between mental and physical practice (Hardwick et al., 2018), studies investigating brain areas and cognitive processes related to LTM consolidation could help to explain the mechanisms underlying the decreased forgetting under mental practice. In addition to studying the effects of mental practice in LTM and forgetfulness, investigating the role of combined practice (physical + mental practice) in forgetting processes should be the next step, since this type of practice seems to produce increased benefits compared to physical or mental practice alone.

CONCLUSION

The results of this study suggest that mental practice of a gymnastics skill lessens forgetting rate compared to a no-practice condition. Also, the forgetting rates of mental practice and physical practice do not seem to differ from each other, suggesting that these two practice conditions share mechanisms that diminish forgetting, favouring LTM consolidation. Although incipient, our results broaden the possibilities of future studies, since the relation between mental practice and

forgetting processes were not strongly investigated in the literature yet. In terms of practical implications, this study supports the use of mental practice to improve motor performance of gymnastics skills. Especially in cases in which physical practice is not an option, such as in injury conditions, mental practice can be a viable alternative to practice in order to acquire new motor skills.

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WORLD AGE GROUP COMPETITIONS (WAGC) AS A DEVELOPMENT PILLAR FOR TRAMPOLINE GYMNASTICS: ANALYSING NATIONAL FEDERATIONS' RESULTS BETWEEN 1999 AND 2019

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Original article

Abstract

Trampoline Gymnastics is a consolidated sport within the gymnastics family. Since the International Trampoline Federation (FIT) and the International Gymnastics Federation (FIG) merged in 1999, the growth and expansion of Trampoline Gymnastics have remained constant. In this process, the role played by the World Age Group Competitions (WAGC) is worth to be mentioned, as this event has been established as the main entrance pathway to any gymnast or national federation willing to reach the international elite level. The first edition of these competitions dates back to 1973 in London, and the 27th took place in Tokyo in November 2019. This article aims to explain the key role played by WAGC in the evolution and consolidation of this Olympic sport, by conducting an in-depth analysis of the participation data and medal distribution during the last fourteen editions, all the ones taking place under the FIG umbrella. In order to complete a broader picture of these competitions, a detailed analysis in terms of editions, gender and disciplines is presented. Results return a clear dominance of the Russian Federation national team and a group of international contenders that built up their strong presence at the international scene on top of a constant and well-planned strategy in WAGC. These events have achieved to become part of the sports' internal culture and the education system has incorporated them into all the recommended procedures at the international level.

Keywords: *trampoline gymnastics, age group development, history of gymnastics.*

INTRODUCTION

Trampoline Gymnastics is a well-established sport within the Gymnastics environment, comprising four different, but complementary, disciplines: Individual Trampoline (TRA), Synchronized Trampoline (SYN), Tumbling (TUM) and Double Mini-Trampoline (DMT). Since George Nissen initially developed trampoline as an apparatus to perform acrobatic skills back in the 1930s, the evolution and practice of this sport have constantly grown. The first World Championships in Trampoline Gymnastics took place in 1964 at the Royal Albert Hall in London (United Kingdom), reaching its 34th edition in Tokyo (Japan) in November 2019.

The incorporation of Individual Trampoline in the Olympic Games programme in Sydney 2000 became a milestone that changed the way Trampoline Gymnastics was organized at

the national and international levels. At the institutional level, the merge of the International Trampoline Federation (FIT) as a governing body of Trampoline Gymnastics since 1960s and the International Gymnastics Federation (FIG) completed in 1998 and in force since 1999 is key to understanding how the sport has changed in the last two decades.

This article explores the relevance of the World Age Group Competitions (WAGC) in the consolidation of Trampoline Gymnastics. This event - formerly labelled as World Age Group Games and International Age Group Competitions - completed 27 editions, including Tokyo (JPN), as it is usually staged the week after the World Championships. WAGC turned into a necessary key to understand how educational programmes are conceived and developed. Additionally, its relevant turnout in terms of participation makes it a profitable business for local organizers. Historicizing a crucial event to comprehend Trampoline Gymnastics is the gap that this article is trying to cover.

An overview of the geographical distribution of WAGC events returns interesting information about how Trampoline Gymnastics was established as a sport on the international scene. Nine years after the first World Championships took place in London (GBR) in 1974, the International Trampoline Federation (FIT) put into motion its age group competitions.

Table 1
List of WAGC editions, host cities and national federations (1973-2019).

Edition	Year	Host City	NF	Edition	Year	Host City	NF
1st	1973	London	GBR	14th	1999	Sun City	RSA
2nd	1974	San Mateo	USA	15th	2001	Odense	DEN
3rd	1975	Toronto	CAN	16th	2003	Hannover	GER
4th	1976	Cedar Rapids	USA	17th	2005	Eindhoven	NED
5th	1978	Honolulu	USA	18th	2007	Québec	CAN
6th	1984	Kanazawa	JPN	19th	2009	St. Petersburg	RUS
7th	1986	Moulins	FRA	20th	2010	Metz	FRA
8th	1988	Birmingham	USA	21st	2011	Birmingham	GBR
9th	1990	Dillenburg	FRG	22nd	2013	Sofia	BUL
10th	1992	Auckland	NZL	23rd	2014	Daytona Beach	USA
11th	1994	Vila do Conde	POR	24th	2015	Odense	DEN
12th	1996	Kamloops	CAN	25th	2017	Sofia	BUL
13th	1998	Sydney	AUS	26th	2018	St. Petersburg	RUS
				27th	2019	Tokyo	JPN

The first five editions were hosted in English-speaking countries and cities, as leading authorities in FIT (George Nissen, Jeff Hennessy, etc.) used their own contacts to host these events. It should be noted that at this point in time, WAGC were organized at different times and locations than World Championships. After six years of absence, WAGC reappeared in Kanazawa (JPN) in 1984. Since then, all WAGC editions were organized in connection with World Championships, sharing organizing committees and, most of the times, also location and venues. At the institutional level, the frequency of the event changed from two editions per Olympic cycle to three since 2009.

FIG WAGC Rules remained, to a great extent, constant during the analysed period, but some modifications need to be highlighted: a) the increase in the amount of participating gymnasts in Finals from six to eight established in 2009; b) the

fluctuation in the ages' range in the older age group of the event, starting as an open-ended group of 17-and-plus-years old as a FIT legacy to a 17-18 age group between 2005 and 2015, and currently with a 17-21 age group; and c) the absence of a NF limitation to qualify for the Final Round, opening the chance to the four gymnasts in the individual events and the two pairs in the synchronized events to reach their best rank, regardless of what their teammates have accomplished.

As a valid proof of these competitions' success, FIG has already announced the location of the next three WAGC, to be hosted by Baku (AZE) in 2021, Sofia (BUL) in 2022, and Birmingham (GBR) in 2023.

Scientific research on Trampoline Gymnastics is smaller than the one published about other gymnastics and acrobatics disciplines. Its main focus has traditionally been placed on the technical (Farquharson, 2012; Briggs, 2014; Chen, Guo, Gao, An, Wang & Chen, 2016), physiological (Erkut Atilgan, 2012; Jensen, Scott, Krustrup & Mohr, 2013; Arabatzi, 2018) and biomechanical (Blajer & Czaplicki, 2001; Sands, Varmette, Bogdanis, Donti, Murphy Bryce & Taylor, 2019; Sands, Kelly, Bogdanis, Barker, Donti, McNeal & Penitente, 2019) aspects of the sport, together with a significant attention to injuries and other medical concerns (Hammer; Schwartzbach & Paulev 1981; Chalmers, Hume & Wilson, 1994; Ashby, Pointer, Eager & Day, 2015; Rodríguez-Iniesta, 2016).

Contributions exploring the judging system and how scores are built are also common in the specialized literature. Judging performance attracted the interest of researchers as Heinen & Krepela (2016) who paid special attention to age group gymnasts, aiming to find differences in terms of age and gender in the different factors composing a score for a trampoline exercise. Leskošek, Čuk & Peixoto (2018) analysed judging performance during the men's individual trampoline event at 2014 European Championships in Guimaraes (POR). The classical comparison between human and computer judgement is also present (Johns & Brouner, 2012; Johns & James, 2013)

Ferger & Hackbarth (2017) explored the last factor included in the individual trampoline scoring system, the horizontal displacement. This aspect derived in a comparative analysis of different solutions to measure and build up the final score for a gymnast (Ferger, Helm, and Zentgraf, 2020). The introduction of time of flight as a component of the score in individual trampoline in 2010, and of horizontal displacement in both individual and synchronized events fostered analysis about the impact on gymnasts' performances (Harden & Earnest, 2015)

As far as gymnasts' performances are concerned, interesting research has been published in China identifying effective patterns to maximize the effort during competition (Chen, Zhuo, He & Zeng, 2006; Luo & Wang, 2012; Wang, 2013). However, there is an absence of historical articles exploring and explaining how the sport is developing and how results are shaping up the role played by events and national federations (Esposito & Esposito, 2009). Leading academic databases return scarce bibliography on Trampoline Gymnastics, most of them not directly related with the analysis of historical results in competition.

Bortoleto, Carrara & Roveri (2018) conducted an analysis of the Brazilian performance across recent history, devoting part of it to the WAGC participation. This article is the one with a closer relation to our contribution in these pages. Key works to keep memories about Trampoline Gymnastics alive can be found outside Academia, like Dagmar Nissen Munn's history blog (https://trampolinehistory.blogspot.com/), the joint venture between Acrobatic Sports and Trampoline Pundit (http://www.acrobaticsports.com/) or more recently Trampoline Insight, Nuno Merino

and Steven Gluckstein's YouTube Channel. All these projects are valid sources to collect information regarding the past, present and future of Trampoline Gymnastics, although they are not present in the scholarly publications' circuit. Consequently, this article aims to open a historical research stream on Trampoline Gymnastics, collecting significant data and analysing them as a proof of the evolution of the sport.

METHOD

The purpose of this article is to explore the role played by the WAGC in the consolidation of Trampoline Gymnastics. In order to do so, an in-depth analysis of these competitions was conducted, limiting the historical reach to those editions conducted within the FIG authority. Research questions leading this project were:

1. Which NFs have historically dominated WAGC events?
2. Are there differences in these dominances, in terms of disciplines (individual trampoline, synchronized trampoline, tumbling and/or DMT), of gender (boys and girls) and of age?
3. Are WAGC helping to spread Trampoline Gymnastics worldwide?

Data were gathered from diverse online sources, ranging from official FIG book results reporting the last editions to the useful results' open repertoire provided by Gymnastics Canada (http://www.gymcan.org/disciplines/trampoline/results), which covers most of these competitions. Missing information was found on specific websites' archive (GymMedia.com) and by personal contacts with individuals participating at the events. The final database was published as an open access resource in Zenodo (Vicente-Mariño, 2020) and shared with the Trampoline Gymnastics community in order to identify mistakes and provide an accurate and updated resource.

Data collection was limited to WAGC completed under the FIG umbrella, between 1999 and 2019, covering the fourteen editions conducted since the incorporation of Trampoline Gymnastics in the official Olympic Games' programme. The age structure remained almost constant in this period, allowing the longitudinal comparison across time: the only age group affected by modification was the older one, as explained in the introductory section. Statistical data analysis consisted of frequency measures and descriptive information, presented in several graphic visualizations.

RESULTS

WAGC are the entrance door to the elite sports performance for thousands of young gymnasts. The consolidation of the age group programme is meant to be one of the main strengths of Trampoline Gymnastics. Every edition is attracting around 1000 participants, making a significant contribution to the hosts cities and federations to balance their budget in connection to the expenses necessary to run the World Championships the week before. The figures of the last three editions (Sofia 2017, Saint Petersburg 2018 and Tokyo 2019) return a solid turnout of gymnasts able to travel around the world to compete at the highest possible level. Between 1999 and 2019, 57 National Federations (NFs) competed in WAGC, as detailed in Table 2.

Table 2
Participating National Federations at FIG WAGC (1999-2019).

Year	Host City	NF	Participating NF
1999	Sun City	RSA	24
2001	Odense	DEN	32
2003	Hannover	GER	36
2005	Eindhoven	NED	39
2007	Québec	CAN	31
2009	St. Petersburg	RUS	38
2010	Metz	FRA	34
2011	Birmingham	GBR	35
2013	Sofia	BUL	44
2014	Daytona Beach	USA	37
2015	Odense	DEN	39
2017	Sofia	BUL	43
2018	St. Petersburg	RUS	42
2019	Tokyo	JPN	41

Table 3
Continental participation at FIG WAGC (1999-2019).

Continental Union	NF (WAGC editions with registered participation)
African Gymnastics Union (5)	ALG (7), ANG (3), EGY (5), NAM (6), RSA (13)
Asian Gymnastics Union (9)	CHN (7), HKG (2), JPN (14), KAZ (14), KGZ (1), QAT (6), SGP (1), TPE (1), UZB (10)
European Gymnastics Union (33 plus Scotland-SCO)	ARM (2), AUT (8), AZE (8), BEL (14), BLR (13), BUL (12), CZE (13), DEN (13), ESP (13), EST (9), FIN (11), FRA (14), GBR (14), GEO (12), GER (14), GRE (9), HUN (5), IRL (9), ISR (6), ITA (12), LAT (8), LTU (12), MDA (3), MON (1), NED (14), POL (13), POR (14), RUS (14), SCO (1), SLO (1), SUI (9), SWE (12), TUR (6), UKR (10)
Oceania Gymnastics Union (2)	AUS (14), NZL (13)
Pan-American Gymnastics Union (7)	USA (14), CAN (14), BRA (14), MEX (12), ARG (12), BOL (2), COL (1),

Table 4
WAGC medal table (1999-2019).

Rank	NF	Gold	Silver	Bronze	Rank	NF	Gold	Silver	Bronze
1	RUS	135	117	114	19	BEL	2	8	7
2	GBR	56	67	51	20	DEN	2	3	6
3	USA	52	53	59	21	NED	2	2	7
4	JPN	46	41	35	22	BUL	1	7	6
5	BLR	31	25	17	23	RSA	1	4	5
6	FRA	20	14	30	24	UZB	1	3	0
7	CAN	15	23	16	25	MEX	1	2	1
8	POR	15	11	11	26	SWE	1	0	0
9	CHN	12	12	4	27	TUR	1	0	0
10	AUS	11	12	18	28	POL	0	2	8
11	GER	8	11	10	29	GRE	0	1	3
12	BRA	8	7	10	30	ARG	0	0	2
13	ESP	6	4	8	31	IRL	0	0	2
14	UKR	6	3	5	32	ITA	0	0	2
15	KAZ	5	6	4	33	SUI	0	0	2
16	GEO	4	3	1	34	ISR	0	0	1
17	NZL	3	7	6	35	LTU	0	0	1
18	AZE	3	1	0	36	SCO	0	0	1

WAGC has helped Trampoline Gymnastics to increase its global outreach, as taking part in these events sets a lower technical demand on participants, opening doors to new federations. Continental distribution presents a clear prevalence of European countries, a consequence of the centrality of Europe in the consolidation of this sport, together with the active implication of the United States and Canada, at the very first steps taken, and by some strong NFs in the southern hemisphere, namely Australia, New Zealand and, to a lesser extent, South Africa and Brazil.

The Olympic hopes attracted some new federations during the last decades, being necessary to highlight the increasing participation of Latin American and Asian countries, whereas Africa still struggles to join the international scene under a regular basis. This continental distribution is presented in Table 3.

Thirteen NFs (RUS, GBR, USA, JPN, FRA, CAN, POR, AUS, GER, BRA, KAZ, BEL, NED) competed in the fourteen WAGC editions completed under the FIG umbrella, returning a comprehensive overview of NFs with a solid and long-lasting education and development programme in Trampoline Gymnastics. There are another six NFs (BLR, ESP, NZL, DEN, RSA, POL) missing only one WAGC edition in the selected period. These 19 NFs present a strong evidence of counting with a solid Trampoline Gymnastics programme, being labelled as the core ground of this sport, as a guarantee of a continuum in the medium and long term.

WAGC is usually an event where gymnasts are partially – when not totally - facing all the costs of the participation expenses (entry fee, transport, accommodation and maintenance), as most NFs worldwide are limiting their budgets to their senior national teams. This circumstance is behind the intermittent presence of some NFs that are able to compete at some editions but do not have the resources to take part in some others.

Medals' distribution. During the analysed 14 editions, 1350 medals were awarded. 36 NFs have obtained a medal

during these editions, showing an enriching diversity for a sport aiming to reach and maintain a universal presence. 27 NFs managed to step on the first place of the podium, as Figure XX synthetizes:

Russian Federation has showed a solid dominance during these two decades, leading every WAGC medal table since the incorporation of the age group tournament in the FIG calendar. A total of 366 medals means a 27.1% of the awarded prizes. GBR and USA are distantly following RUS, both of them over the 12% of the total count (174 medals GBR; 164 USA). Japan, Belarus, France and Canada compose a second group, ranging from 9% to 4% of all distributed medals, whereas Portugal, China, Australia and Germany fluctuate between 28 and 41 medals in the two decades under consideration.

Although Table 5 can show some fluctuations in time, the dominance of some NFs remained clear and constant during the selected period, returning a valid picture about the correlation of forces in Trampoline Gymnastics' youth gymnasts.

Needless to say that there are up to 21 NFs that have not managed to step on the WAGC podium yet, despite their active participation in these educational event. As mentioned before regarding participation, medals' distribution by continental union returns a clear picture of the historical evolution of this age group event.

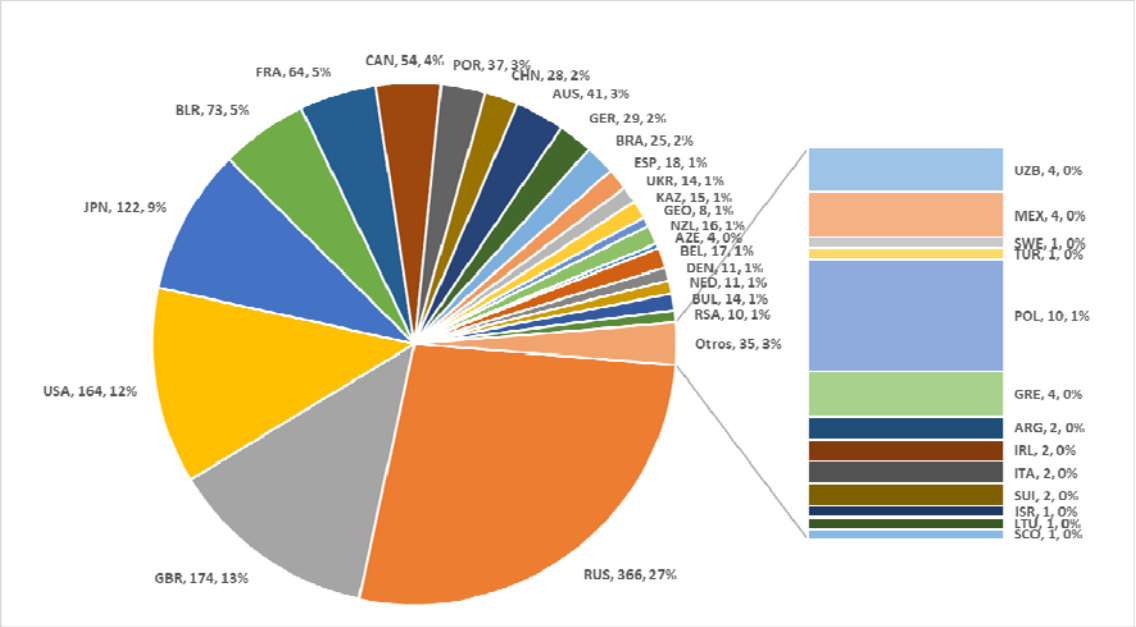

Figure 1. Medals per NF obtained in FIG WAGC in Trampoline Gymnastics (1999-2019).

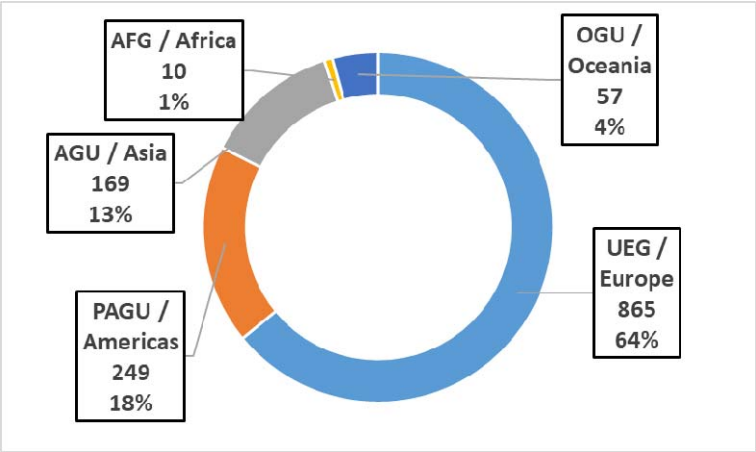

Figure 2. Medals obtained per Continental Union in WAGC (1999-2019).

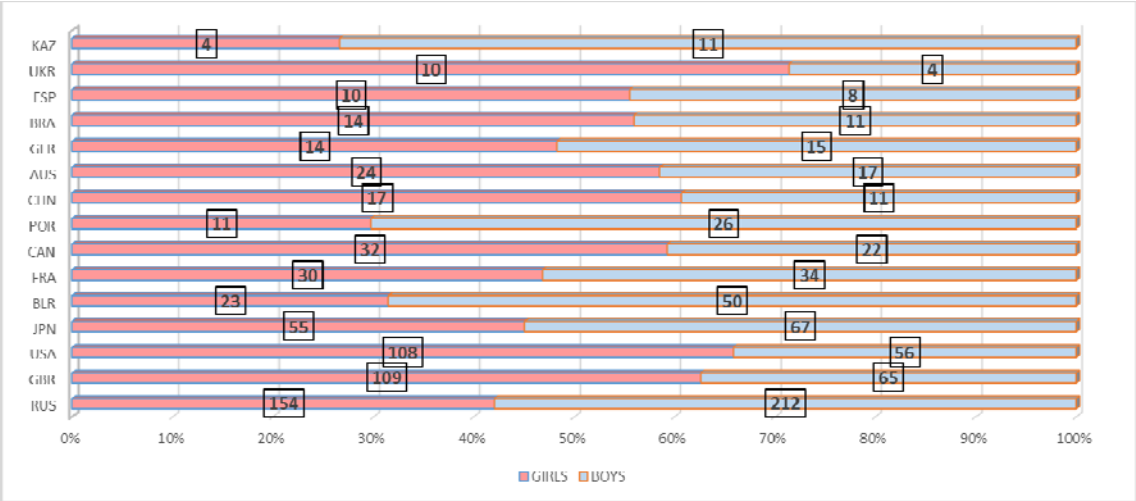

Figure 3. Gender distribution of WAGC medals in Top-15 NFs (N = 1224).

Table 5
Medal distribution between Top 15 NF in WAGC (1999-2019).

	99	01	03	05	07	09	10	11	13	14	15	17	18	19
RUS	13	16	26	33	26	31	28	23	25	23	31	30	34	27
GBR	10	9	15	14	10	9	9	12	9	20	18	16	10	13
USA	19	15	3	11	17	13	13	9	14	16	7	13	9	5
JPN	14	8	8	4	9	9	9	11	8	4	10	6	12	10
BLR	0	5	4	4	1	3	4	2	5	7	10	8	12	8
FRA	15	7	2	3	5	6	3	6	0	2	1	5	3	6
CAN	4	5	5	1	7	5	4	2	7	2	4	4	1	3
POR	4	2	3	3	0	1	3	2	5	6	4	0	2	2
CHN	1	8	5	1	0	0	5	0	6	0	0	0	0	2
AUS	2	4	2	1	5	3	0	3	4	0	2	2	6	7
GER	0	1	2	1	1	1	1	6	3	4	1	2	2	4
BRA	4	3	6	2	0	2	1	3	0	1	1	1	1	0
ESP	0	0	4	1	5	1	1	1	0	1	2	1	1	0
UKR	0	4	3	3	1	2	1	0	0	0	0	0	0	0
KAZ	0	1	2	0	1	1	4	3	1	2	0	0	0	0

Almost two out of three awarded medals (64%) ended up hanging around the necks of gymnasts representing the European continent. American and Asian nations followed the Old Continent in this aggregated level, as NFs representing PAGU obtained 18% of the awarded medals (249) and the four NFs representing AGU that managed to climb to podium positions achieved 13% of the whole medals (169).

The concentration of medals in certain NFs is a signal of the outreach of Trampoline Gymnastics within each continent. Europe is distributing their 865 medals between 24 NFs, whereas in the Americas, 249 medals were obtained by 7 NFs, and in Asia only 4 NFs achieved 169 record. Australia, New Zealand and South Africa are the only Oceanian and African federations stepping up the podium in WAGC history.

Deepening the medal analysis, the 15 top NFs in the medal table were compared in terms of their internal distribution of the 1224 medals they collected out of the total 1350 medals awarded in WAGC events. It is possible to identify different trajectories and strategies among the leading federations in the international scenario.

The most evident is highlighted in red in Table 6, as several national federations are not medalling in some disciplines at all, with some of them not even taking part in these events and developing a national programme on their national soil. This is the evident case in Tumbling and Double Mini Trampoline, both affected by their non-Olympic status. The most impressive performance, however, is coming from the People's Republic of China: this national team has only attended seven of the fourteen WAGC covered, with a reduced number of competing gymnasts who only took part in the individual trampoline event. However, they managed to obtain 28 medals, averaging four per edition and proving an accurate and well-planned strategy oriented towards excellence in their performance and preparation for elite level.

Table 6
Discipline distribution of WAGC medals among Top 15 NFs (N = 1224).

NF	TRA	SYN	TUM	DMT
RUS	84	48	120	114
GBR	34	38	82	20
USA	18	20	51	75
JPN	56	64	0	2
BLR	37	31	5	0
FRA	15	32	17	0
CAN	11	5	5	33
POR	5	6	3	23
CHN	28	0	0	0
AUS	4	8	8	21
GER	8	20	0	1
BRA	2	3	2	18
ESP	3	5	0	10
UKR	7	6	1	0
KAZ	3	3	9	0

Gender distribution of medals within the leading NFs in WAGC confronts us with different scenarios. Kazakhstan, Portugal and Belarus are the three NFs with most of their successes coming from boys' performances (more than 66% of their medals were obtained by male gymnasts), whereas Ukraine, United States and Great Britain are the teams where girls are clinching more medals than their male partners (with 60% or more of the medals obtained by females.

Even this prevalence is not so acute, some NFs (Russian Federation, Japan, France and Germany) are more successful with their boys, while others (Canada, China, Australia, Brazil and Spain) proved to be more effective with their competing girls.

Analysis per discipline. Individual Trampoline is the discipline receiving more attention and a higher funding at the NFs, due to its Olympic status. Consequently, most of the national investment in this sport is addressed to the gymnasts taking part in this event and the highest hopes and expectations are placed on them. Registration figures easily prove that and its priority is something assumed by most of the actors involved in the sport. Russian Federation leads both girls' and boys' overall standings, but Japan is the one holding both second positions in the ranking, comfortably above Great Britain, China and the United States in the girls, and above Belarus, Great Britain and China in the boys. The strength of federations like China and Belarus in the individual trampoline event prove the strategic role played by WAGC in the preparation of gymnasts that will step forward to the senior national team.

Table 7
Internal medal distribution (%) among Top 15 NFs (N = 1224).

NF	GIRLS				BOYS				
	TRA	SYN	TUM	DMT	TRA	SYN	TUM	DMT	TOTAL
RUS	24,7	17,7	27,5	29,9	28,7	15,5	52,0	41,9	29,9
GBR	13,3	14,3	36,6	7,0	8,3	12,0	17,3	5,6	14,2
USA	9,5	8,8	19,6	31,8	1,9	4,9	14,0	15,6	13,4
JPN	14,6	21,8	0,0	0,0	21,0	22,5	0,0	1,3	10,0
BLR	8,2	6,1	0,7	0,0	15,3	15,5	2,7	0,0	6,0
FRA	3,8	9,5	6,5	0,0	5,7	12,7	4,7	0,0	5,2
CAN	4,4	2,0	2,6	11,5	2,5	1,4	0,7	9,4	4,4
POR	1,3	2,0	1,3	2,5	1,9	2,1	0,7	11,9	3,0
CHN	10,8	0,0	0,0	0,0	7,0	0,0	0,0	0,0	2,3
AUS	2,5	2,0	3,3	7,6	0,0	3,5	2,0	5,6	3,3
GER	2,5	6,8	0,0	0,0	2,5	7,0	0,0	0,6	2,4
BRA	0,6	2,0	0,0	6,4	0,6	0,0	1,3	5,0	2,0
ESP	0,6	2,7	0,0	3,2	1,3	0,7	0,0	3,1	1,5
UKR	3,2	3,4	0,0	0,0	1,3	0,7	0,7	0,0	1,1
KAZ	0,0	0,7	2,0	0,0	1,9	1,4	4,0	0,0	1,2
	100	100	100	100	100	100	100	100	100,0

Synchronized Trampoline is under a consistent dominance of Japanese gymnasts, common to boys and girls, that speaks loudly about the relevance attributed to this discipline by this NF. Actually, the numbers of Japan in trampoline events, adding individual and synchronized, place them in the second position behind Russian Federation. The absence of medals in Tumbling and DMT explains, once again, the difference between leading federations in certain disciplines and those federations able to persistently present competitive teams in all disciplines and in all age groups. Following a similar strategy to Japan is Belarus, a federation with an unprecedented success in trampoline events during the last WAGC editions. France and Germany should also be mentioned, as a big part of their overall outcome is also coming from synchronized medals.

The Russian dominance in Tumbling and DMT boys' disciplines is undeniable: obtaining the 52% of the medals in male's Tumbling events during twenty years speaks loudly about a successful technical programme. Similar outcome is observed in DMT, with more than 40% of the medals flying back to Russian soil. This performance is not equalled by girls, as Great Britain in Tumbling and the United States in DMT are leading the historical statistics. Canada, Portugal and Australia rely on a long and solid tradition in DMT to keep their presence among the top NFs in the world of Trampoline Gymnastics.

DISCUSSION AND CONCLUSION

A preliminary analysis of participation in WAGC returns a clear prevalence of European NFs. Promising developments have been identified in both the American (Bortoleto, Carrara & Rovieri, 2018) and Asian Continental Unions, with new NFs reaching WAGC level and joining the experience of leading federations worldwide, such as RUS, USA, CAN and JPN. The FIG investment channelled through the FIG Academies (Fédération International de Gymnastique, 2017) is helping new countries to set Trampoline Gymnastics programmes into motion, and WAGC is always presented as the main first entrance door to the international scene. The constitution of the Oceanian Gymnastics Union in 2019 should be seen as an open door to incorporate new NFs in this geographical area, mainly because the solid experience and tradition encountered in AUS and NZL could lead this development and move Trampoline Gymnastics forward in this area. However, Africa presents an imbalanced distribution, with the traditional presence of RSA, one of the founding federations in the very first steps of the sport, and the intermittent presence of other countries that count with established programmes, but missing budget and stability to consolidate their participation, such as ALG, ANG, EGY or NAM. In any case, targeting a 40 NF participation during the upcoming cycle would be an achievable goal and a good proof of the good health of WAGC in Trampoline Gymnastics.

WAGC performance can be considered as a proxy to understand the recent evolution of Trampoline Gymnastics. The analysis presented in this article returns a clear image about the leading countries worldwide. Russia, Great Britain, USA or Japan are strong contenders. Other NFs relied on a lower presence at WAGC, mainly China, but with some outstanding outcomes. China has topped medal tables in the Olympic discipline, Individual Trampoline, since 2007, under the guidance of a successful generation of gymnasts that are still on top of the World ranking, as Dong Dong (competed in WAGC 2001) or Gao Lei (competed in WAGC 2010). This status quo is not reproduced in Synchronized Trampoline, where the limitations to NF participation (only two pairs can compete) lead to another distribution, with Japan and Belarus proving their vast evolution on

trampolines during the last decade. Tumbling and DMT are clearly dominated by the Russian Federation younger gymnasts, with national federations presenting different strategies in terms of participation and success, privileging one sport over the other, such as France competing only in Tumbling or Australia, Canada or Portugal with a solid and longstanding trajectory in DMT.

More historical and comparative research is necessary to create a critical dialogue about the role played by WAGC in developing Trampoline Gymnastics. The international community share the feeling about its crucial role in development plans of this sport, but scientific literature is still failing to empirically back what is commonly understood among coaches, judges and officials in Trampoline Gymnastics. The scarce published research on this gymnastics sport has prevailed technical and medical matters to the role played by certain events in consolidating a discipline in the long run, as this article claims about World Age Group Gymnastics.

This article calls for more systematic analysis in the future, bringing some challenging questions to the research community interested in Trampoline Gymnastics. First, the analysis of individual trajectories of gymnasts, exploring their performance across time, from its first appearances in WAGC to their main exercises at the elite level. Second, the effects of the Olympic admission of individual trampoline in the Games since Sydney 2000, deepening the emerging inequalities between the four disciplines composing Trampoline Gymnastics. And third, the best way to guarantee a smooth transition between the age group programme to the elite level.

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SHORT HISTORICAL NOTES XX

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.

ALFRED SCHWARZMANN (23 March 1912 Fürth, Germany – 11. March 2000 Goslar, Germany)

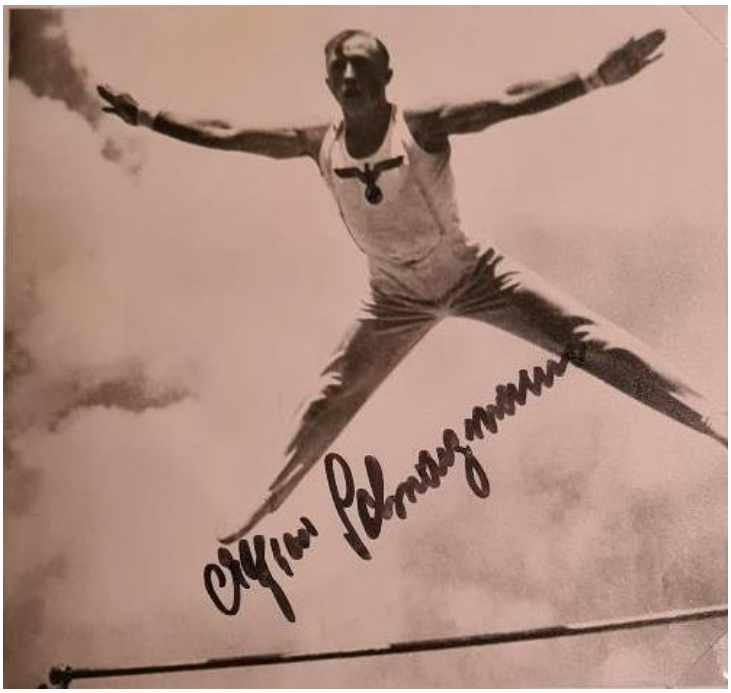
Alfred Schwarzmann was a solder and his first major competition was OG in Berlin where he won 3 gold medals. In 1938 he left military service and began working as a physical education teacher. At the beginning of World War II he was part of the German army and participated as a parachutist in the battles in Poland, France, Italy and Soviet Union. In 1944 he was hospitalized and later came into British custody. After the war, he was still able to prepare for OG in Helsinki and placed 2nd on high bar at the age of 40. Both OG in Berlin and Helsinke were his only two important international appearances.

Results:
Berlin OG 1936

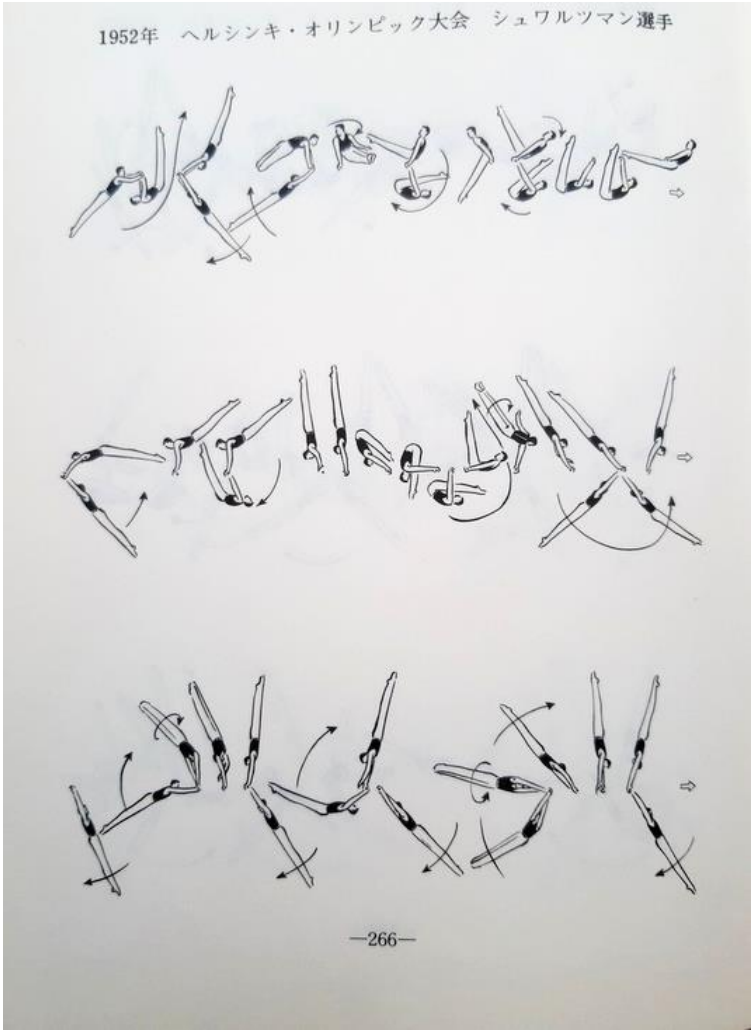
Gold: All Around, Team, Vault;
Bronze: Parallel bars, Horizontal bar

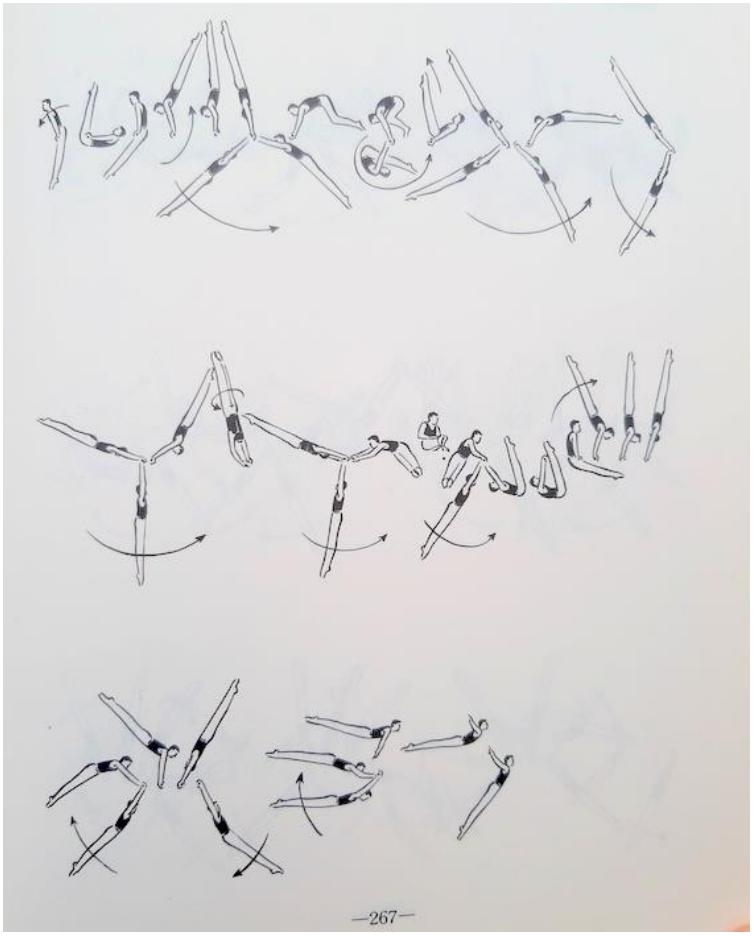
Helsinki OG 1952

Silver: Horizontal bar



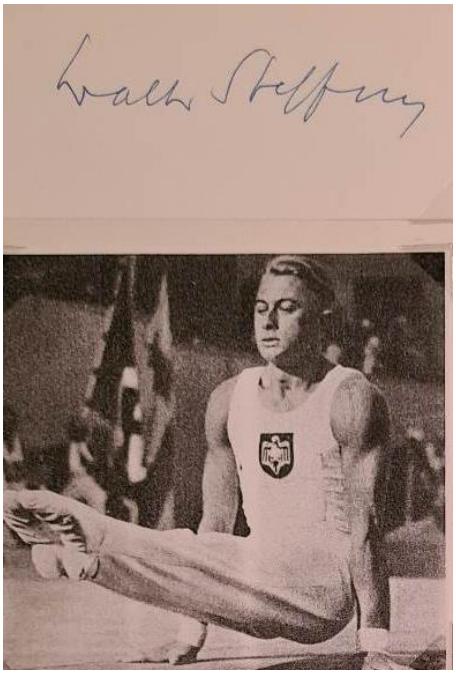
Dismount at OG 1936





Drawing of Alfred Schwarzmann's horizontal bar routine at OG 1952, from the book of prof. A. Kaneko - Technic and methodics on high bar, Tokyo 1970

WALTER STEFANS (26.12.1908 Barnstorf, Germany – 23.8.2006 Bergkamen, Germany



Not much is known about his life, but he competed in WC in 1934 and OG in 1936, where he and his teammates won the team title.

Budapest WC 1934 Bronze: Team, 6th Horizontal bar

Berlin OG 1936 Gold: Team, 5th Vault, 6th Horizontal bar

Slovenski izvlečki / Slovene Abstracts

William A. Sands, Gregory C. Bogdanis, Gabriella Penitente, Olyvia Donti

OCENJEVANJE ZANIMANJA ZA ORODNO TELOVADBO

Kljub podatkom iz svetovnih medijev zanimanje za telovadbo po vsem svetu še nikoli ni bilo ocenjeno. Članstva, nakupi opreme in oblačil, naročnine in drugi podatki so bili uporabljeni kot posredni podatki za merjenje zanimanja in udeležbe pri telovadbi. Pri odkrivanju naštetih trendov bi lahko koristili lahko dostopno orodje za oceno zanimanja za telovadbo. Ta raziskava je skušala uporabiti razmeroma novo orodje za iskanje po svetovnem spletu, imenovano Google TrendsTM (GT), za oceno zanimanja za telovadbo z zapisi iskalnih izrazov, uporabljenih v GoogluTM. Iskanja GoogleTM vključujejo uporabo iskalnih izrazov, ki so zabeleženi in nato dostopni GT. Ker iskanja GoogleTM omogočajo dostop do tem, ki vas zanimajo skoraj povsod po svetu, lahko vsi, ki imajo dostop do spleta, nato uporabljajo Google TrendsTM, GT lahko uporabijo za zbiranje števila in vrst iskanj, ki vključujejo iskalna izraza „moška orodna telovadba“ in „ženska orodna telovadba" Seštevek iskalnih izrazov je bil pridobljen z uporabo filtrov, kot so država, regija in drugi. GT poroča o gibanjih iskalnih izrazov z izračunom relativnega odstotka na podlagi vzorca največjega števila določenih uporab iskalnih izrazov v določenem času. Čeprav je pristop relativnega odstotka nekoliko neroden, se obdelava velikih količin podatkov lahko šteje za dragoceno in sicer nedosegljivo. Rezultate je treba razlagati previdno. Vendar pa je raziskava pokazala množico pomembnih trendov v svetovnem zanimanju za orodno telovadbo.

Ključne besede: mediji, svetovni splet, Google.

Paloma Trucharte, Ignacio Grande

RAZČLENITEV IN PRIMERJAVA VADBENIH OBREMENITEV MED DVEMA SKAPINAMA TELOVADK GLEDE NA ZAZNAVANJE NAPORA IN DEJANSKI NAPOR

Namen raziskave je bil oceniti vadbeni napor pri telovadkah glede lastnega zaznavanja napora (PSE) z izračunom spremenljivke sRPE in različnih drugih spremenljivk. Sodelovalo je deset telovadk (starost: 14,4 ± 2,9 leta; višina: 1,5 ± 0,1 m; masa: 43,3 ± 12,2 kg) in so bile razdeljene v dve skupini glede na njihovo tekmovalno raven in obseg tedenske vadbe: telovadke na visoki ravni (HLG) in telovadke na srednji ravni (MLG). PSE vsake telovadke so beležili vsak dan štiri tedne po koncu vsake vadbe. Skupina HLG je zabeležila bistveno višjo vrednost RPE in sRPE pri posebni telesni pripravi (SST) in pri vsebnosti vzporedne tehnične vadbe (UB) ($p < 0,05$) v primerjavi z MLG. Statistično pomembne razlike so bile ugotovljene tudi pri srednjih vrednostih RPE in sRPE pri primerjavi vsebine vadbe. Poleg tega so opazili neposredno povezavo med obsegom in delovno obremenitvijo. Na koncu so spremenljivke, povezane z nadzorom tveganja poškodb, zagotovile ustrezne informacije, s katerimi so ugotovili, da je imela skupina HLG večje tveganje za poškodbe kot skupina MLG. Zato je sRPE koristno orodje za oceno notranje obremenitve pri vadbi ženske orodne telovadbe. Taki podatki lahko v prihodnosti pomagajo količinsko opredeliti obremenitev pri orodni telovadbi.

Ključne besede: vadba, obremenitev; notranja obremenitev; telovadba.

J.C. Ausmus, Lindsey C. Blom, Sharon Bowman, Jean-Charles Lebeau

POVEZANOST MED DRUŽBENIMI MEDIJI IN MOTNJAMI HRANJENJA PRI TELOVADKAH NA VISOKIH ŠOLAH

Medtem ko so bile povezave med mediji in prehranjevalnimi motnjami ter neurejenimi prehranjevalnimi vzorci pri ženskah v šolah že raziskane, je bilo manj raziskav s športnicami. Le omejene študije so se osredotočile na razmerje med družbenimi mediji in prehranjevalnim vedenjem športnic, ki sodelujejo na lepih športnih prireditvah, čeprav se najvišja stopnja neurejenih prehranjevalnih vzorcev pojavlja v športih, kjer športnice ocenjujejo sodniki in kjer so poudarjene vitkost, vitkost ter lepe spretnosti Raziskava poskuša pojasniti povezave med dojemanjem telesne podobe telovadk, neurejenim prehranjevalnim vedenjem in zaznavanjem telesnih podob športnikov, predstavljenih na družbenih omrežjih. Raziskovan je bil tudi način, kako kritika, predstavljena na družabnih omrežjih, vpliva na neurejeno prehranjevanje. Sodelovalo je prek spletnega anketnega vprašalnika 72 žensk, starih 18-25 let, ki so trenutno tekmovale ali so pred kratkim tekmovale v klubski ali visokošolski orodni telovadbi. Rezultati so ugotovili pomembne povezave med resnostjo kritičnih sporočil o telesnem videzu, čustvenimi odgovori na kritike glede telesnega videza in neurejenim prehranjevalnim vedenjem. V primerih, ko sporočila niso bili podana na družbenih omrežjih, ni bila ugotovljena povezava med resnostjo, čustvenim odgovorom in neurejeno prehranjevalno vedenje.

Ključne besede: Twitter, Facebook, Snapchat, Instagram, motnje hranjenja, športniki, kritika.

Almir Atiković, Edina Kamenjašević

NAPOVEDOVANJE KONČNEGA REZULTATA MNOGOBOJA Z D IN E OCENAMI PRI ŽENSKI ORODNI TELOVADBI

V raziskavi se je preverjalo ali so discipline pri ženskem mnogoboju pri orodni telovadbi enakovredne. Vzorec je vključeval telovadke, ki so sodelovale na kvalifikacijskih tekmovanjih (CI) od leta 2009 do 2019. Cilj naše raziskave je bil ugotoviti vpliv posameznih ocen D in E na posameznem orodju na končni rezultat mnogoboja. Starost med starejšimi narašča od leta 2009 do 2019 za 1,88 leta. V naši analizi smo ugotovili, da so se rezultati, doseženi na vsakem orodju bistveno razlikovali. Povprečni končni rezultati na preskoku so bili bistveno višji kot na vseh drugih orodjih. Zdi se, da sta pomembna napovedovalca uspeha v mnogoboju ocena D in ocena na dvovišinski bradlji in E ocena na gredi. Zanimivo je bilo opaziti, da rezultati na reskoku in parterju niso bili pomembni napovedniki. Vaditelji lahko rezultate uporabijo pri načrtovanju priprave telovadk v mnogoboju, na posameznih orodjih in na tekmovanjih vrst.

Ključne besede: ocenjevanje; tekmovalni nastop, napoved.

Giurka Gantcheva, Yulia Borysova, Nina Kovalenko

VREDNOTENJE IN RAZVOJ UMETNIŠKIH SPOSOBNOSTI 7-8 LETNIH RITMIČARK

Tekmovalna sestava v ritmiki je kratek nastop, ki ima svojo zgodbo. To ocenjujejo sodniki E1 in E2. Sodniške kazni za nezadovoljivo umetniško vrednost so lahko do 5 ali 6 točk. V delih znanstvenikov se vprašanja umetniške vzgoje za 7-8-letne ritmičarke skoraj nikoli ne obravnavajo. Cilj je bil razviti metodologijo za razvoj umetniških sposobnosti 7-8-letnih telovadk. Teoretična analiza in sinteza znanstvene in metodološke literature; vprašalnik (anketa med vaditelji); pedagoško opazovanje, poskus, meritve: strokovne ocene; matematična statistika. V raziskavi je sodelovalo 20 7-8-letnih ritmičark, ki so se od 2 do 3 leta ukvarjale z ritmiko in imajo znanje ravni 2. kategorije. Analiza znanstvenih in metodoloških virov kaže na potrebo po intenzivnejšem raziskovanju razvoja umetniškega vtisa pri vadbi ritmičark. Na podlagi našega vprašalnika je bilo ugotovljeno, da je treba z uporabo prvin obrazne mimike, nastopanja in improvizacije razvijati umetniške sposobnosti mladih ritmičark. Uvedba metodologije za oblikovanje umetniških sposobnosti v vzgojno-izobraževalnem procesu poskusne skupine je nato privedla do povečanja ocen za njihovo tekmovalno sestavo za 1,3 ± 0,12 točke ($p < 0,05$). Stopnja izboljšanja umetniškega znanja v poskusni skupini je bila 18,4%, v nadzorni skupini pa 8% ($p < 0,05$).

Ključne besede: ritmika, umetniške sposobnosti, poskus.

Yaiza Taboada-Iglesias, Águeda Gutiérrez-Sánchez, Diego Alonso-Fernández, Mercedes Vernetta-Santana

TELESNE ZNAČILNOSTI ŠPANSKIH AKROBATK GLEDE NA STAROSTNO KATEGORIJO

Telesne značilnosti v različnih starostih so ključne za uspeh v športu in zaznavanju talentov. To potrjujejo dokazi v nekaterih telovadnih panogah v različnih starostnih kategorijah, vendar za akrobatiko še ni bila izvedena nobena študija. Cilj je bil določiti značilen somatotipa akrobatsk za vsako starostno skupino in ugotoviti, ali obstajajo razlike med njimi in med vlogami v vsaki starosni skupini. Vzorec je sestavljalo 54 gornjih akrobatk (X = 11,23 let; 29,62 Kg) in 75 spodnjih akrobatk (X = 14,46 let; 50,48 Kg). Somatotip smo izračunali z uporabo metode Heath-Carter za določitev mezomorfije, endomorfije in ektomorfije vsake skupine. Izvedena statistična analiza je obsegala opisno in primerjalno razčlenitev, ki temelji na zlasti vrsti somatotipa in povprečni razširjenosti somatotipa na splošno. Rezultati so pokazali, da je bila mezomorfija najpomembnejša v vseh kategorijah in vlogah. V vsaki skupini so navedli različne razvrstitve somatotipov, vendar je treba poudariti tudi pomen ektomorfije pri gornjih in endomorfije pri spodnjih akrobatkah. Pomembne razlike so bile ugotovljene pri mezomorfiji (gornje: p = .012; Spodnje: p = .026) in ektomorfiji v obeh vlogah (gornje p = .036; spodnje p = .001). Kljub ugotovljenim pomembnim razlikam med nekaterimi kategorijami to ni sledilo prememu starostnemu razvoju. Zato ni mogoče sklepati, da se je somatotip razvijal s starostjo, saj je to morda posledica športne usmeritve. Vendar je bilo potrjeno, da je mezomorfija, tako kot v drugih telovadnih disciplinah, prevladujoč del v vseh kategorijah in vlogah.

Ključne besede: akrobatika, položaj, starost.

Elpida Skaltsa, Vasiliki Kaioglou in Fotini Venetsanou

RAZVOJ RAVNOTEŽJA PRI OTROKIH, KI SODELUJO V RAZLIČNIH SPROSTITVENIH GIBALNIH DEJAVNOSTIH

Ravnotežje, pomembna gibalna sposobnost, je osnova za izvajanje različnih gibanj in omogoča sodelovanje v skupnih otroških dejavnostih. Raziskave kažejo, da lahko športna udeležba pripomogla k razvoju ravnotežja pri otrocih. Cilj raziskave je bil ugotoviti ali lahko sodelovanje pri različnih sprostitvenih telesnih dejavnostih povzroči razlike v sposobnosti otrokovega ravnotežja. Natančneje, 138 otrok, starih od 5 do 11 let (Mage = 8,4 ± 1,3), razvrščenih v štiri skupine glede na dejavnost, v kateri so se udeležili (košarka, atletika, ritmika, sodobni ples), je bilo ocenjeno z merskim postopkom gibalne skladnosti za otroke. Pearsonove povezave so bile uporabljene za odkrivanje povezav rezultatov ravnotežja s starostjo, višino, indeksom telesne mase (BMI) in so pokazale pomembne povezave za BMI ($p < .001$). Analiza kovarijance (kovariate: BMI), ki so bile izračunane na ocenah otrokovega ravnotežja, so pokazale statistično pomembne učinke skupine ($p < .001$). Sidakovi testi so pokazali, da so otroci, ki sodelujejo pri ritmiki, presegli vse ostale tri skupine; medtem ko so tisti, ki se udeležujejo košarke, imeli najslabše ocene. Zdi se, da bi vrsta telesne dejavnosti, pri kateri otrok sodeluje, lahko pomembno prispevala k razvoju njegovega ravnotežja. Zdi se, da telesne dejavnosti, ki zajemajo izvajanje različnih ravnotežnih nalog, kot je ritmika, otrokom ponujajo večje možnosti za izboljšave na tem področju v primerjavi z otroki, ki se ukvarjajo z dejavnostmi z nizkimi ravnotežnimi zahtevami. Ta ugotovitev poudarja potencial, ki je na voljo vaditeljem: lahko prispevajo k razvoju ravnotežja otrok z izvajanjem športnih programov, ki ciljajo na te človeške sposobnosti.

Ključne besede: skladnost gibanja, ravnotežje, košarka, atletika, ples, ritmika.

Christina Argyrou, Stylianos Spinos, Vasileios Karfis in Fotini Venetsanou

KATERE PROSTOČASNE DEJAVNOSTI TELOVADBA, GRŠKI TRADICIONALNI PLES IN TENIS DAJEJO NAJPOZITIVNEJŠE PSIHOLOŠKE ODGOVORE?

Udeležba v prostočasni telesni dejavnosti (PA) naj bi bila pozitivno povezana z duševnim zdravjem. Namen te študije je bil raziskati akutne psihološke odzive odraslih, ki sodelujejo v različnih vrstah prostega časa PA (telovadba; grški tradicionalni ples; tenis). Skupno je sodelovalo 277 odraslih, starih od 18 do 65 let ($M = 35,9$, $SD = 12,76$ let), ki so se udeležili grškega tradicionalnega plesa ($n = 89$), telovadbe ($n = 88$) ali tenisa ($n = 100$). Da bi lahko preučili morebitne spremembe pozitivnega počutja udeležencev, psihološke stiske in zaznane utrujenosti, je bila pred in po vadbi zgoraj omenjenih programov uporabljena lestvica osebne izkušnje vadbe (SEES). Analiza variance 3 (skupina [telovadba proti grškemu tradicionalnemu plesu proti tenisu]) X 2 (čas [pred preizkusom proti po poizkusu], ki je bila opravljena na lestvici SEES (pozitivno počutje; psihološka stiska; utrujenost) je pokazala pomembne izboljšave pozitivnega počutja za vse udeležence ($p < .001$, $\eta 2 = .25$) in statistično pomembno sovplivanje (čeprav niso praktičnega pomena) med skupino in časom v pozitivnem počutju ($p < .001$, $\eta 2 = .068$), psihološke stiske ($p < .05$, $\eta 2 = .02$) in utrujenost ($p < .05$, $\eta 2 = .033$), pri čemer so udeleženci telovadbe predstavili najbolj optimalne rezultate, ki so jim sledili grški tradicionalni ples. Potrebno je spodbujanje odraslih, da se pridružijo prostočasni telesni vadbi zaradi njihove (psihološke) koristi za zdravje.

Ključne besede: pozitivno počutje; psihološke stiske; zaznana utrujenost.

Jorge Luiz Novaes Santos Júnior, Rívia da Silva Passos, Alinne Alves Oliveira, Jonas R. Dias da Silva, Ramon Silva Souza1, Rafael da Silva Passos, Marco Machado, Alexander J. Koch, Rafael Pereira

VPLIV VARNOSTNIH JERMENČKOV NA MIŠIČNO SILO, BOLEČINO PRI VZDRŽEVANJU VESE

Raziskovan je bil vpliv varnostnih jermenčkov na zaznavanje bolečine in napora med izvajanjem veljavne naloge na visokem drogu, ki povzroči utrujenost mišic podlakti in tudi upad moči oprijema po nalogi. V načrtu navzkrižne študije je bilo merjenih 15 zdravih in telesno dejavnih prostovoljcev, ki so na visokem drogu izvedli statične zadrževanja telesne mase (8 krogov 20-sekundnega bremena in 10 sekund počitka). Načrt vadbe je bil izveden z varnostnimi jermenčki in brez njih. Zabeležili smo zaznavanje bolečine in napora med nalogo. Najvišje vrednosti sile roke in eksplozivne sile (tj. stopnja razvoja sile [RFD] in kontraktilni impulz [CI] pri 30 do 200 ms) so bili pridobljeni iz krivulj sila-čas. Vrednosti največje sile in eksplozivne sile so bili za statistično analizo normalizirani (tj. POS / PRE). Uporaba varnostnih jermenčkov znatno oslabi zaznavanje bolečine ($p < 0,05$) z zmerno do veliko vrednostjo učinka ($d = 0,52$), vendar med nalogo ni spremenila zaznavanja napora niti ni spremenila vršne sile, RFD ali CI. Uporaba jermenčkov zmanjša zaznavanje lokalne bolečine med statičnimi položaji, vendar ne spremenijo zaznavanja napora med nalogo in tudi ne sposobnosti za silo prijema takoj zatem.

Ključne besede: vadba z različnimi obremenitvami, stopnja razvoja sile, varnost, telovadba.

Bárbara de Paula Ferreira1, Nathálya Gardênia de Holanda Marinho Nogueira1, Guilherme Menezes Lage1, João Roberto Ventura de Oliveira2, Tércio Apolinário-Souza3

VLOGA MISELNE VADBE PRI ZMANJŠEVANJU POZABLJANJA PRI IZVAJANJU TELOVADNIH PRVIN

Vzporedno s delovanjem spomina deluje tudi pozabljanje, zato je pomembno poznati delovanje ohranjanja ustreznih podatkov ali učenja v spominu. Vadbeni pogoji lahko vplivajo na hitrost pozabljanja, poudarjanje ali slabitev spomina. Telesna vadba se je izkazala za učinkovito pri zmanjševanju pozabljanja, vendar vloga miselne vadbe še ni povsem znana. Raziskovana je bila vlogo miselne vadbe na hitrost pozabljanja gibalnih znanj. Štiriindvajset udeležencev s povprečno starostjo 26,13 let (± 3,04) obeh spolov je bilo razdeljenih v tri skupine: (a) skupina z miselno vadbo (MPG); (b) skupina s telesno vadbo (PPG), ki je miselno ali telesno izvajala stojo na rokah in (c) nadzorna skupina (CG), ki prvine ni izvajala. Rezultati niso pokazali razlike med stopnjo pozabljanja MPG in PPG. Prav tako so imeli stopnje pozabljanja nižje od CG. Zato je menimo, da je miselna vadba tako učinkovita kot telesna vaja za zmanjšanje stopnje pozabljanja gibalnih znanj, kar daje prednost ohranjanju gibalne predstavnosti v spominu. Verjetno so v razmerah telesne in miselne vadbe skupni mehanizmi, ki upočasnjujejo procese pozabljanja.

Ključne besede: stoja na rokah, pozabljivost, utrditev spomina, miselne dejavnosti.

Miguel Vicente-Mariño

SVETOVNA TEKMOVANJA MLADIH NA PROŽNIH PONJAVAH KOT RAZVOJNI STEBER ZA SKOKE NA PROŽNIH PONJAVAH: REZULTATI NACIONALNIH ZVEZ MED LETI 1999 IN 2019

Skoki na prožnih ponjavah so odkar sta se Mednarodna zveza za skoke na ponjavah (FIT) in mednarodna telovadna zveza (FIG) leta 1999 združili, sta rast in širitev skokov na ponjavah ostali nespremenjeni. V tem obdobju je vredno omeniti vlogo svetovnih tekmovanj mladih (WAGC), saj je bil ta dogodek uveljavljen kot glavna vhodna pot v za nacionalno zvezo, ki želi doseči vrhunsko mednarodno raven. Prva izdaja teh tekmovanj sega v leto 1973 v Londonu in zadnja 27. v Tokiu novembra 2019. Namen je pojasniti ključno vlogo WAGC pri razvoju in utrjevanju tega olimpijskega športa z izvajanjem poglobljene razčlenitve podatkov o udeležbi in razdeljevanju medalj v zadnjih tekmovanjih, ki so vse potekale pod okriljem FIG. Za širšo sliko teh tekmovanj je predstavljena sestava glede na vrsto, spol in discipline. Rezultati poudarjajo očitno prevlado Ruske federacije in skupine mednarodnih posameznikov, ki so svojo močno prisotnost na mednarodnem prizorišču zgradili s stalno in dobro načrtovano strategijo v WAGC.

Ključne besede: skoki na prožnih ponjavah, razvoj, starostne skupine, zgodovina.

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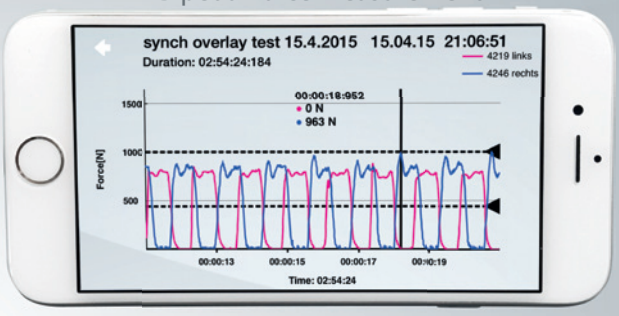

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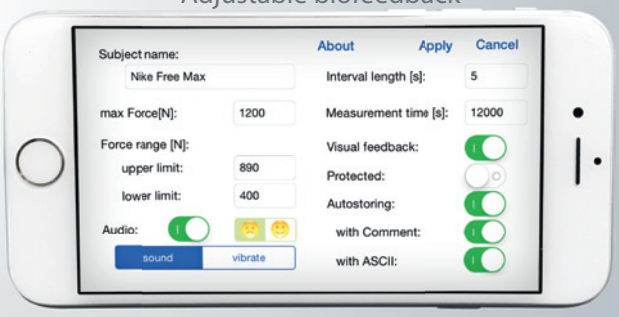

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