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ORIGINAL RESEARCH

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# Is the handgrip strength influential factor on the competition result in elite male artistic gymnasts?

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## Abstract

High handgrip strength in men's artistic gymnastics is crucial, mainly for improving performance and to potentially prevent injuries, as well as for the fact that gymnasts body movements are around immovable apparatuses (pommel horse, rings, parallel bars and high bar) for the extended period of time. Since there are not so many studies that have dealt with this topic and on actual competition, we have aimed to examine the handgrip strength influence on the competition result in elite male artistic gymnasts. The sample of participants were conducted of 37 elite male artistic gymnasts (8–21 years old), from 8 different countries as national team competitors at the International Competition "Laza Krstić and Marica Dželatović" held in Novi Sad, Serbia. Basic anthropometric measurements were included (body height, body weight and Body Mass Index (BMI)), along with training experience and handgrip strength measurement (both dominant and nondominant hand). Kolmogorov-Smirnov Z test ($p < 0.05$) was used for distribution normality, along with regression analysis with Model 1 (participants age, training experience, body height, body weight and BMI), Model 2 (Model 1 + dominant handgrip strength) and Model 3 (Model 1 + nondominant handgrip strength). SPSS v.20 was used for all statistical analysis. Our study have revealed that there is significant influence of all 3 Models on the parallel bars final result ($p = 0.033$; $p = 0.049$; $p = 0.031$, respectively), in terms of all set of variables, whereas body weight Beta scores (28.6%; 30.3%; 32.7%, respectively) moslty explains the results. Both dominant and nondominant handgrip strength are influential factors only on the parallel bars final result. Since both hands are contributing equally, bilateral training is necessary. In order to expand the knowledge on this topic and completely understand the influential factors, future studies are needed on this sample. Regardless of our main findings, our results should be taken with caution.

## Keywords

Relative strength; Handgrip strength; Artistic gymnastics; Result influence

## 1. Introduction

As the one of the most watched sports at the Olympic Games, artistic gymnastics is also one of the basic sports that requires elegance, rationality of movement and outstanding strength while performing required elements or compositions at wide range of apparatuses. As an important feature of sport, the competition itself can be seen as a consequence of sports activities, while achieving success represents its main goal [1]. Furthermore, achieving success is determined by a greater number of different factors (planning, programming and training management) and defining these factors is a key for achieving it [2]. In addition, success also depends on the functional relationship (quality of cooperation) between the gymnast and the coach, as well as on the potential and actual quality of the gymnast himself [3]. Since artistic gymnastics performance is determined by the balance of the physical fitness and the rigorous technical abilities necessary on each apparatus [4], this can be related to the fact that strength is also a necessary factor for the elements realization, learning process, progression and emphasizing the overall technical work [5–7].

If we look from a practical point of view, a high handgrip strength in men's artistic gymnastics is required, mainly for improving performance and potentially prevent injuries, as well as for the fact that gymnasts body movements are around immovable apparatuses (pommel horse, rings, parallel bars and high bar) for the extended period of time [8–10]. Furthermore, according to the Bohannon *et al.* [11] in order to assess index


  

performance in athletes, as well as in sports medicine, handgrip strength is mostly used parameter. Elements biomechanics have showed that impact on handgrip exists, whereas recorded loads on the hands are over 13 G [9]. Hence, overcoming resistance during hanging exercises and in support demands significant strength, which has an influence on muscular system [12].

There are some studies that have dealt with handgrip strength validity, reliability and standardization of the testing protocols across a range of populations [13–17], as well as in athletes [18, 19], but there are a limited published researches available in artistic gymnastics performance. According to the authors knowledge, only one study has identified very large correlation (r = 0.81) between handgrip strength and endurance in gymnasts that are competing on the rings [20].

In addition, there is also an insufficient knowledge on the handgrip strength as an important factor for successful performance. Ruprai *et al*. [20] have revealed that handgrip strength and endurance is significantly better in rings performers compared to the nonexercising control group. Eric *et al*. [21] have revealed that presence of palmaris longus doesn't affect the handgrip strength in gymnasts, as well as the unilateral palmaris longus absence is correlated to increased handgrip strength. Kolimechkov *et al*. [22] have identified that there is no statistical difference between left and right hand in pre-school and primary school children who practices artistic gymnastics, whereas Sterkowicz-Przybycień *et al*. [12] have observed effect of age category in seniors *vs*. juniors gymnasts ($p < 0.001$).

Since there are not so many studies that have dealt with this topic and on actual competition, there is a call for new studies. Hence, we have aimed to examine the handgrip strength influence on the competition result in elite male artistic gymnasts.

## 2. Materials and methods

### 2.1 Participants

The participants sample were conducted of elite male artistic gymnasts (N–37), 8–21 years old, who have voluntary participated in the testing. They were from 8 different countries (Bulgaria, Bosnia and Herzegovina, Croatia, Denmark, Greece, Saudi Arabia, Serbia and United Arab Emirates) as national team competitors at the International Competition "Laza Krstić and Marica Dželatović" held in Novi Sad, Serbia. In-close participants descriptive statistics is presented in the Table 1.

The study was also realized in accordance with the Declaration of Helsinki for the study on humans [23]. Based on participants age, they were divided into 5 categories:

(1) First category (<10 years old);
(2) Second category (11–12 years old);
(3) Third category (13–14 years old);
(4) Fourth category (15–16 years old);
(5) Fifth category (17–21 years old).

### 2.2 Measurements

Body height was measured to the nearest 0.1 cm using a Martin anthropometer GPM 101 (GPM GmbH, Bachenbülach, Switzerland), whereas body weight to the nearest 0.1 kg using a calibrated weight (Model 3306 ABV; Avery Ltd., Crosswell, UK). BMI was additionally calculated using a BMI formula ($kg/m^2$). In order to examine the handgrip strength, the calibrated Baseline Hydraulic hand dynamometer (Item# 12-0241, LiTE-200ib. Capacity-red, White Plains, NY, USA) was used. Dynamometer reliability were also presented elsewhere [24–27]. The gymnasts had to stand still and with their extended arm, their main task was to squeeze the dynamometer as hard as possible at given signal, without any arm flexions nor violating the body position. The task is competed after the examiner reads the result in kilograms at the dynamometer scale. This test was repeated three times with both hands and the best result of both dominant and nondominant hand were taken into consideration.

### 2.3 Procedures

All athletes and coaches were previously familiar with the complete procedure and all tests were performed in the competition hall at the qualifications phase. Prior to the tests, the athletes had to warm-up first (general and specific exercises), which lasted approximately 20 min. and right after, the tests were realized in exact order, body height, body weight and handgrip strength measurement. Thereafter, we have used the official bulleting results (sum of "D" and "E", which makes the final score "∑") from the pommel horse, rings, parallel bars and high bar, and based on the pre-defined statistics, the necessary results were additionally calculated.

### 2.4 Statistical analysis

A wide range of descriptive parameters were obtained (minimal and maximal result, range, skewness, kurtosis, mean and standard deviation). Furthermore, in order to examine the distribution normality, Kolmogorov-Smirnov Z test ($p < 0.05$) was used, along with regression analysis Model 1 (participants age, training experience, body height, body weight, BMI), Model 2 (Model 1 + dominant handgrip strength) and Model 3 (Model 1 + nondominant handgrip strength). SPSS v.20 (IBM Corp., Chicago, IL, USA) was used for all statistical data processing.

## 3. Results

Descriptive statistics and normality distribution results were presented in the Table 2, while regression Models results, for all set of variables and for each variable separately according to the models, are presented in the Tables 3,4,5.

Only final result on the pommel horse, rings, relative values of handgrip strength (both dominant and nondominant) and total apparatus result have normally distributed results, whereas parallel bars and high bar final result are the opposite. This can also be explained by the skewness and kurtosis's values, as well as the Kolmogorov-Smirnov Z test. Furthermore, the reason for the obtained results is the participants age, which for descriptive statistics is in the range of 8–21 years.

The results are showing that whole set of variables of Model 1 are influential factor on the parallel bars final result ($p$ = 0.033), which is proved based on the Beta coefficient on the body weight (Beta = 28.6%). It is worth mentioning body

**TABLE 1. Participants descriptive statistics.**

| | Participants age | Training experience (yr) | Body height | Body weight | BMI |
|---|---|---|---|---|---|
| Min. | 8 | 2 | 1.21 | 21.8 | 14.86 |
| Max. | 21 | 13 | 1.82 | 77.4 | 24.71 |
| Mean ± SD | 12.43 ± 3.38 | 5.59 ± 3.01 | 150.46 ± 16.59 | 42.68 ± 14.55 | 18.21 ± 2.52 |

*Legend: Min, minimal result; Max, maximal result; SD, standard deviation; BMI, body mass index.*

**TABLE 2. Descriptive statistics and normality distribution results.**

| | Min. | Max. | Ran. | Skew. | Kurt. | Mean ± SD | KS | *p* |
|---|---|---|---|---|---|---|---|---|
| PHOR | 2.30 | 12.00 | 9.70 | –1.78 | 4.59 | 9.38 ± 1.91 | 0.851 | 0.464 |
| RING | 5.00 | 12.90 | 7.90 | –1.19 | 1.79 | 10.08 ± 1.75 | 1.067 | 0.205 |
| PBAR | 2.60 | 12.80 | 10.20 | –2.23 | 5.23 | 10.22 ± 2.11 | 1.628 | 0.010 |
| HBAR | 1.10 | 12.30 | 11.20 | –1.99 | 3.68 | 9.30 ± 2.53 | 1.711 | 0.006 |
| HAGRD | 0.42 | 0.92 | 0.50 | 0.36 | 0.01 | 0.64 ± 0.11 | 0.702 | 0.708 |
| HAGRND | 0.42 | 0.91 | 0.49 | 0.28 | –0.12 | 0.62 ± 0.12 | 0.414 | 0.996 |
| ∑ | 14.70 | 48.75 | 34.05 | –1.77 | 4.47 | 38.98 ± 6.65 | 1.002 | 0.268 |

*Legend: PHOR, pommel horse final result; RING, rings final result; PBAR, parallel bars final result; HBAR, high bar final result; HAGRD, handgrip strength relative values (dominant hand); HAGRND, handgrip strength relative values (nondominant hand); ∑, total apparatus result; Min, minimal value; Max, maximal value; Ran, range; Skew, skewness; Kurt, kurtosis; SD, standard deviation; KS, Kolmogorov Smirnof Z test; p, statistical significance of KS.*

**TABLE 3. Regression analysis Model 1.**

| | | Model 1 | | | | | |
|---|---|---|---|---|---|---|---|
| | | PA | TE | BH | BW | BMI | *p* |
| PHOR | | | | | | | |
| | Beta | 0.673 | –0.342 | –0.542 | 0.560 | –0.254 | 0.411 |
| | *p* | 0.403 | 0.646 | 0.620 | 0.749 | 0.758 | |
| RING | | | | | | | |
| | Beta | 0.356 | 0.198 | –0.269 | –0.399 | 0.400 | 0.617 |
| | *p* | 0.642 | 0.781 | 0.796 | 0.812 | 0.612 | |
| PBAR | | | | | | | |
| | Beta | 0.035 | –0.227 | –1.888 | 2.855 | –0.996 | 0.033 |
| | *p* | 0.964 | 0.751 | 0.079 | 0.097 | 0.214 | |
| HBAR | | | | | | | |
| | Beta | –0.103 | –0.614 | –1.495 | 2.908 | –0.981 | 0.067 |
| | *p* | 0.890 | 0.377 | 0.147 | 0.081 | 0.205 | |
| ∑ | | | | | | | |
| | Beta | 0.259 | –0.352 | –1.396 | 2.071 | –0.658 | 0.092 |
| | *p* | 0.744 | 0.633 | 0.202 | 0.237 | 0.421 | |

*Legend: PHOR, pommel horse final result; RING, rings final result; PBAR, parallel bars final result; HBAR, high bar final result; ∑, total result; PA, participants age; TE, training experience (years); BH, body height; BW, body weight; BMI, body mass index; Beta, standardized value of regression coefficient; p, significance level.*

**TABLE 4. Regression analysis Model 2.**

| | | Model 2 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | PA | TE | BH | BW | BMI | HAGRD | *p* |
| PHOR | | | | | | | | |
| | Beta | 0.590 | –0.391 | –0.325 | 0.140 | –0.005 | 0.167 | 0.650 |
| | *p* | 0.403 | 0.646 | 0.620 | 0.749 | 0.758 | 0.569 | |
| RING | | | | | | | | |
| | Beta | 0.269 | 0.145 | –0.040 | –0.844 | 0.663 | 0.177 | 0.887 |
| | *p* | 0.732 | 0.841 | 0.971 | 0.645 | 0.461 | 0.527 | |
| PBAR | | | | | | | | |
| | Beta | 0.068 | –0.206 | –1.976 | 3.027 | –1.098 | –0.068 | 0.049 |
| | *p* | 0.732 | 0.841 | 0.971 | 0.645 | 0.461 | 0.527 | |
| HBAR | | | | | | | | |
| | Beta | –0.174 | –0.656 | –1.310 | 2.548 | –0.769 | 0.143 | 0.169 |
| | *p* | 0.820 | 0.355 | 0.233 | 0.160 | 0.382 | 0.600 | |
| ∑ | | | | | | | | |
| | Beta | 0.196 | –0.390 | –1.231 | 1.750 | –0.468 | 0.128 | 0.201 |
| | *p* | 0.810 | 0.604 | 0.292 | 0.361 | 0.616 | 0.661 | |

*Legend: PHOR, pommel horse final result; RING, rings final result; PBAR, parallel bars final result; HBAR, high bar final result; ∑, total result; PA, participants age; TE, training experience (years); BH, body height; BW, body weight; BMI, body mass index; HAGRD, relative values of handgrip strength (dominant hand); Beta, standardized value of regression coefficient; p, significance level.*

**TABLE 5. Regression analysis Model 3.**

| | | Model 3 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | PA | TE | BH | BW | BMI | HAGRND | *p* |
| PHOR | | | | | | | | |
| | Beta | 0.593 | –0.433 | –0.205 | 0.041 | 0.003 | 0.202 | 0.707 |
| | *p* | 0.467 | 0.568 | 0.862 | 0.983 | 0.997 | 0.439 | |
| RING | | | | | | | | |
| | Beta | 0.360 | 0.202 | –0.285 | –0.374 | 0.388 | –0.009 | 0.649 |
| | *p* | 0.647 | 0.782 | 0.803 | 0.837 | 0.653 | 0.970 | |
| PBAR | | | | | | | | |
| | Beta | 0.099 | –0.153 | –2.159 | 3.273 | –1.203 | –0.163 | 0.031 |
| | *p* | 0.900 | 0.834 | 0.065 | 0.079 | 0.169 | 0.518 | |
| HBAR | | | | | | | | |
| | Beta | –0.171 | –0.692 | –1.207 | 2.464 | –0.762 | 0.173 | 0.188 |
| | *p* | 0.821 | 0.330 | 0.276 | 0.167 | 0.362 | 0.477 | |
| ∑ | | | | | | | | |
| | Beta | 0.231 | –0.383 | –1.280 | 1.892 | –0.570 | 0.070 | 0.172 |
| | *p* | 0.775 | 0.613 | 0.282 | 0.318 | 0.524 | 0.789 | |

*Legend: PHOR, pommel horse final result; RING, rings final result; PBAR, parallel bars final result; HBAR, high bar final result; ∑, total result; PA, participants age; TE, training experience (years); BH, body height; BW, body weight; BMI, body mass index; HAGRND, relative values of handgrip strength (nondominant hand); Beta, standardized value of regression coefficient; p, significance level.*

weight Beta coefficient on the high bar (Beta = 29.1%), but without overall statistical significance ($p = 0.081$).

The results are also showing that whole set of variables of Model 2 are influential factor on the parallel bars final result ($p = 0.049$), which is proved based on the Beta coefficient on the body weight (Beta = 30.3%). Just like from the Model 1, it is also worth mentioning body weight Beta coefficient on the high bar (Beta = 25.5%), but without overall statistical significance ($p = 0.160$).

Furthermore, the results are also showing that whole set of variables of Model 3 are influential factor on the parallel bars final result ($p = 0.031$), which is proved based on the Beta coefficient on the body weight (Beta = 32.7%). Just like from the Model 1 and 2, it is also worth mentioning body weight Beta coefficient on the high bar (Beta = 24.6%), but without overall statistical significance ($p = 0.167$).

Although there is no statistical significance in the rest of apparatuses, as well as in the total result, the given results are in accordance with Beta values, since there are negative values in most cases.

## 4. Discussion

The study aim was to examine the handgrip strength influence on the competition result in elite male artistic gymnasts. The main study findings are that there is statistical significant influence of all 3 Models on the parallel bars final result ($p = 0.033$; $p = 0.049$; $p = 0.031$, respectively), in terms of all set of variables.

According to the Sterkowicz-Przybycień *et al*. [12], maximal handgrip strength depends on the body weight, which is most likely based on the comparisons between lighter and heavier gymnasts. Upper body strength is more dominant in older ones, compared to the younger ones and this statement is also confirmed by the Paunović *et al*. [28] who have revealed that there is an influence of relative strength on the competition result, but without statistical significance ($R^2$adjust = 11%; $p = 0.653$). Furthermore, the same study indicated that the Beta coefficient of upper body strength have the greatest influence on the result (Beta = 49.9%), and this is mainly because there is a great need for difficult element realization, based on the competition category. In our case, we have revealed that there is a significant influence of the handgrip strength in all three Models ($p = 0.033$; $p = 0.049$; $p = 0.031$, respectively) on the parallel bars result. According to the authors knowledge, only one study has conducted similar research [29], but the sample were collegiate women's artistic gymnasts. Although they have presented nonsignificant correlations between handgrip strength and competition result, their obtained results could be partially in accordance with ours. Beside gender and age differences, these results should be taken with caution, because we have measured the competitor's handgrip strength and then compared the result right after the realized competition, while the mentioned study have measured handgrip strength and then did the correlation from results of each competitor's average score across competitive season. In terms of Model 1, our results can be explained by the fact that younger gymnasts tend to do a common hanging elements (upper arm hang, simple basket or even stretched salto backward at the end of the parallel bars as a dismount). If we add weak upper body strength and short hand length, this furthermore brings the more tenseness to the handgrip, in order to realize the necessary elements. In terms of Model 2 and 3, the Beta coefficient in body weight have presented the usage of both dominant (Beta = 30.3%) and nondominant (Beta = 32.7%) handgrip strength. In that case, our results are in accordance with Čuk [9], who have stated that hand loads are over 13G on apparatuses that contains the "hanging" or "swinging" phases. In order for the gymnast to do a most common and more difficult "swing" elements on parallel bars, such as Moy, Tippelt, Giant swing, Basket to handstand *etc.*, the additional grip safety is necessary. This means that before every performance on parallel bars, the gymnast is allowed to prepare the bars by adding water or honey (or mixing both) before adding chalk (*i.e.*, Magnesium Carbonate) on a places where some of mentioned elements are going to be realized [30]. For additional handgrip safety in routine realization, we can say that the handgrip endurance is also important [20] and in practice, it is referred to the both hands, because the parallel bars elements are realized with/on both dominant and nondominant hands, which we also proved. Likewise, according to Nipp *et al*. [29] absolute strength is needed, but from the aspect of the sports nature, relative strength in both dominant and nondominant hands appears to be more essential.

Sterkowicz-Przybycień *et al*. [12] considers that seniors have twice as greater experience than juniors, so it is expected to assume that age factor have the effect. In our study, training experience range variated from 2–13 years, but according to the presented Models, the factors are only influential on the parallel bars final result ($p = 0.033$; $p = 0.049$; $p = 0.031$, respectively). In order to understand the obtained results, we must take into consideration that there are a lot of individual performers, in regard to all-arounders, which is in accordance with the samples that have taken for the study of Nipp *et al*. [29]. The weekly number of training sessions differs, whereas individual performers usually trains once a day, while all-arounders trains twice and according to some authors [31], even three times a day. Hence, upgrading the handgrip endurance in both hands are vital part in trainings [20], as we already mentioned earlier. The rationale for the obtained results could be understood as physical, where handgrip strength should be present at the optimal level, as well as physiological, where the number of contractile protein increases during adaptation period, along with the enzymes and stored nutrients [32]. Furthermore, bigger hand muscles develop first, then the smaller ones after [33], and for handgrip strength, the smaller muscle strength is necessary, which is another physiological perspective that must be considered. Although a sufficient handgrip strength is necessary, more important factor are sport-specific movements that require high technical precision and accuracy, where coordination, timing and sequencing of hand's forces and pressures to an object (in our case, bar/s or pommels) are important than the applied handgrip strength [8]. With that being said, beside good methodical training, mimicing the competition environment and gaining the handgrip endurance at trainings at the same time are necessary.

Body height (182 *vs*. 121 cm) and body weight (77.4 *vs*.

21.8 kg) have showed a natural preponderance of older gymnasts, in regard to younger ones, respectively, whereas greater component of mesomorphy can be noticed in older ones. As a result, we can assume that the older ones somatotype (balanced mesomorph) differs from younger ones (ectomorphic mesomorph), which can be relatable to Sterkowicz-Przybycień *et al*. [12]. As we have already mentioned, there were gymnasts that competed all-around and there were also gymnasts that have competed on the several apparatuses or even on only one [29]. This is also confirmed in practice, since there are differences in regard to the body component, where gymnasts that compete pommel horse or even parallel bars only, tend to be higher and lighter, while rings and vault performers are usually shorter and more muscular. But in regard to previous statement, Paunović *et al*. [34, 35] have identified nonsignificant influence (for all set of variables) of upper body relative strength on the vault ($R^2$adjust = 4.4%; $p$ = 0.258) and rings ($R^2$adjust = 21.6%; $p$ = 0.217) final result, which can be partially in accordance with our obtained results. This could be understood even more if we have measured the hand length, just like Ruprai *et al*. [20], but we haven't. But since we haven't examining the somatotype parameters influence nor hand length, mentioned facts should be taken into consideration, while future studies are needed in order to understand the results rationale.

## 5. Study strength and limitations

One of this study's strengths is its novelty, where the results were obtained on the International competition and on a difficult-to-access group of gymnasts. Furthermore, our results have presented that both dominant and nondominant handgrip strength are influential factors only on parallel bars result, which means that both hands contribute equally to success and that unilateral training is not needed in artistic gymnastics training, but bilateral, which is the main practical application of the study. On the other hand, there are study limitations. During the test realization, the gymnasts haven't used a chalk during testing, *i.e.*, Magnesium Carbonate, which is according to Halilaj *et al*. [36] influential factor on the handgrip strength result. Also, we didn't take into consideration the gymnasts who were all-around nor individual apparatus performers, as well as the eventual judging biases on the results. Since this is a very first study on this topic, another big limitation is the fact that there were not so many published studies to compare the results with.

## 6. Conclusions

Based on the obtained results, we can conclude that both dominant and nondominant handgrip strength are influential factors only on the parallel bars final result. Since both hands are contributing equally, bilateral training is necessary. Despite the fact that there were only few published studies to compare the studies with, our results should be taken with caution. In order to expand the knowledge and completely understand the influential factors, this study can be a good framework and foundation for future ones.

### AVAILABILITY OF DATA AND MATERIALS

All analyzed data during this study are included in this published article.

### AUTHOR CONTRIBUTIONS

MP, DĐ, DM, SV and PV—conceptualization, resources; MK and GS—methodology; NČ and MT—software; DVH and RB—validation; AM and EJ—formal analysis; MK and LM—investigation, writing-review and editing; SŽF and MT—data curation; DVH—writing-original draft preparation; NČ and RB—visualization; AM, SŽF and EJ—supervision; GS—project administration. All authors have read and agreed to the published version of the manuscript.

### ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Ethical Board of the Faculty of Sport and Physical Education, University of Niš (approval number: 04-969/2), as well as from the competition organizers. The participants and participants' parents, in the case of them under 16, were provided with a written informed consent for inclusion, before they participated in the study.

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### CONFLICT OF INTEREST

The authors declare no conflict of interest.

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