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ORIGINAL

Vertical jump peak power estimation in young male gymnasts

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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abstract

Background There is a lack of peak power (PP) estimation for young gymnasts; therefore, the purpose was to derive a new regression equation predicting young gymnasts' PP and to validate and compare it with the previously published ones.

Material/Methods In the study, eighty young male gymnasts (age = 10.9 ±1.98 years; body mass = 33.5 ±7.45 kg) performed a countermovement jump on a force platform. Then, ¼ of the subjects were randomly assigned to a validation group and the rest served to develop a new linear regression equation using their body mass and vertical jump height (VJH).

Results In comparison, PP estimated by the new equation (1439.8 ±479.3 W) showed no significant ($p > 0.05$) differences with the actual PP (1400.8 ±542.8 W), whereas other previously published ones were different ($p < 0.05$). The developed new equation looked as follows: PP [W] = 73.81 x VJH [cm] + 34.66 x body mass [kg] -1617 ($r^2 = 0.75$).

Conclusions According to a small systematic bias (38.97 W), the new equation can be used to predict PP of young gymnastic groups. The newly developed equation fits the actual performance of gymnasts better than the previous published ones.

Key words sport, athletes, gymnastics, countermovement jump, peak power estimation

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INTRODUCTION

The ability to generate rapid force, known as power, is one of the most important capabilities of athletes from various sports, especially those who perform jumps as their sport routine. One of them is artistic gymnastics, where gymnasts perform vault on the apparatus and tumbling passes during the floor exercises [1, 2]. Assessment of athletes' power abilities is mostly conducted either by outputs of the power including the vertical jump height (VJH) or by direct measurements on force platforms. The second method is the most precise but also the most expensive. The method including VJH, which is commonly in use, shows us only the result that depends on the body mass. If two athletes perform jumps at the same height but their body mass is different, they also differ in power. Therefore, researchers apply the linear regression method to estimate the peak power (PP) of individuals by using their vertical jump height and body mass. Some authors incorporate also height of push-off [3, 4] or suggest using the allometric model in estimating peak power [5].

Estimation of power during the vertical jump has been discussed over past years by several authors [6-13], mainly for the healthy untrained men and women, although we can find some studies including children and athletes as well. Such equations could be helpful in estimating gymnasts' peak power and in tracking their training progress; however, many of the authors have used different types of jumps: countermovement or squat jump, with or without arm swing. Moreover, despite the fact that some of them investigated athletes, it should be noted that gymnast are a specific group of athletes with a characteristic somatic build [14, 15] and training routine [16, 17, 18]. At the moment of preparation of this manuscript authors could not find an equation derived specially for gymnasts, neither for adults nor children. The question is, if these previously published equations are suitable for young gymnasts. Authors hypothesized that due to the specific characteristic of gymnastics, i.e. focusing on training of explosive forms of strength and a relatively low body mass of young gymnasts, the previously published equation may not correspond to the actual performance. Therefore, the purpose of the study was to derive a new equation designed for young gymnasts and to compare it with previously developed ones and to validate its accuracy.

MATERIAL AND METHODS

PARTICIPANTS

Eighty young male gymnast (age = 10.9 ±1.98 range: 7–14 years; body mass = 33.5 ±7.45 kg) participated in this study. Participants were recruited during the team championships of Poland in artistic gymnastics and included gymnasts from the whole country. Their training experience ranged from 1 to 8 years.

Such a wide range of age was chosen in order to be suited for the broadest range of young gymnasts, and due to our preliminary studies there were no significant differences in estimating the peak power between individual age-specific samples and this one. Such an approach was also chosen due to the results of Amonette et al. [6], where a similar issue of participants' age disproportion (12-24 years) did not translate to significant changes in the accuracy of peak power estimation in comparison to more narrow age-specific groups.

The study was conducted according to the Declaration of Helsinki and with an assent of the Bioethical Committee of Ludwik Rydygier Collegium Medicum in Bydgoszcz of Nicolaus Copernicus University in Toruń. For each child participating in study, legal guardians gave their informed consent.

The newly developed equation was compared with the equation designed by Sayers et al. [13], Quagliarella et al. [12] and Amonette's et al. [6] for 12–15-year-old athletes and designed for athletes and non-athletes of all ages (overall). Authors chose these equations either because of their popularity or best accuracy among others which had been previously validated [6].

STUDY DESIGN

Authors used a cross-sectional study design and a cross-validation method to develop and validate a new regression equation estimating peak power of a young gymnast. Subjects performed a single session of measurements on a force platform, where the actual values of peak power (PP), vertical jump height (VJH) and body mass (BM) were recorded during a countermovement jump (CMJ). 1/4 of the subjects were independently randomly assigned as a validation sample, whereas the remaining athletes were used to develop a new equation for estimating PP. Afterwards, the equation was cross-validated by the assigned sample, which was later used to compare the accuracy of the developed equation and the other previously published ones.

METHODOLOGY

After 15 min of routine gymnastic warm-up, all athletes performed 3 maximal countermovement jumps on a force platform (Quattro Jump Portable Force Plate System, Kistler Group, Winterthur, Switzerland; sampling rating = 500 Hz) with 1-min rest between each jump. Gymnasts were instructed to hold their hands on the hips during all phases of the jump and to perform countermovement phase to approximately 90° in the knee joint. Before recording and storing the measurements on the computer, each gymnast was familiarized with the procedure.

STATISTICAL ANALYSES

To derive a new equation for estimation of PP of young gymnasts (n = 60), the multiple linear regression method was used. Shapiro-Wilk and Levene's tests were performed to check the normal distribution and homogeneity of variance, respectively. After developing the equation, it was cross-validated with the remaining randomly assigned gymnasts (n = 20). A repeated measures ANOVA test was used to determine if there was a difference between the actually measured peak power on a force platform and that estimated from the new equation and the previously published ones. Power calculation analysis showed a standardized effect of 0.7 (for the difference of ±175 W) with power for this test at 0.83 (n = 20). Reliability of children's CMJ was previously studied in literature and showed intra-class correlation = 0.86 [19] as well as the measures of a force platform used in the study, ICC = 0.84 [20], 0.92–0.98 [21]. Moreover, due to the jumping routine, gymnasts' jumping measurements are characterized by high ICC values: 0.91–0.99 [22]. Finally, to establish the accuracy of the new equation and its usefulness for individual subjects, Bland-Altman plot was made, and the systematic bias and the 95% limits of agreement were established [23].

The statistical significance was considered at $p < 0.05$. All analyses were performed with commercial software: Statistica 10 (Statsoft Inc. Tulsa, OK, USA).

RESULTS

The new equation for gymnasts was developed on the basis of their body mass and the vertical jump height. It is shown in Table 1 as well as the previously published equations. The PP estimated from a random sample of 20 gymnasts with the new and published equations is shown in Table 2.

Table 1. Newly derived and chosen previously published equations developed to estimate peak power

Authors	n	Age	Level of activity	Equation	r^2	SEE
Sayers et al. (CMJ)	108	21.3 ±3.4	Ath and non-ath	(51.9 VJH) + (48.9 BM) - 2007	0.78	561.5
Amonette et al. (overall)	415	15.4 ±2.6	Ath and non-ath	63.6 VJH) + (42.7 BM) - 1846.5	0.92	250.7
Amonette et al. (12–15 years)	242	13.8 ±1	Ath	(61.9 VJH) + (40.8 BM) - 1680.7	0.92	232.6
Quagliarella et al.	117	13.6 ±2.4	Ath	(61.2 VJH) + (52.3 BM) – 1707	0.89	415.4
New equation	60	10.9 ±1.98	Ath (gymnasts)	(73.8 VJH) + (34.7 BM) - 1617	0.75	276.4

Note: Ath = athletes; nonath = non athletes; BM = body mass; CMJ = countermovement jump; SEE = standard error of the estimate; VJH = vertical jump height

Table 2. Actual peak power and one estimated with the newly developed and previously published equations

Authors	Mean ± SD	Systematic bias [W]	95% limits of agreement [W]
Actual Peak Power	1400.8 ±542.8	-	-
Sayers et al. (CMJ)	971.6 ±517.2*	-429.2	±505
Amonette et al. (overall)	1221.3 ±504.2*	-179.4	±480
Amonette et al. (12–15 years)	1279.5 ±485.1*	-121.3	±478
Quagliarella et al.	1624.1 ±568.9*	223.2	±521
New equation	1439.8 ±479.3	39	±480

Note: CMJ = counter movement jump; *significant difference with actual peak power at $p < 0.05$

The repeated measures ANOVA showed a significant difference ($F_{5,95} = 77.63$; $p < 0.0001$) between the measurements. Furthermore, a post-hoc (Tukey) test showed that there was no significant difference between actual PP and the one estimated by the new model ($p = 0.88$), and the rest of the equations were significantly different from the actual PP ($p < 0.05$). Moreover, there was no difference between Amonette's et al. [6] equations for 12–15 years athletes and for overall ($p = 0.58$). To validate the PP estimation for an individual gymnast, results of actual and estimated PP values were plotted using the method of Bland and Altman (Fig. 1). Subsequently, the systematic bias and 95% limits of agreement were calculated and are shown in Table 2.

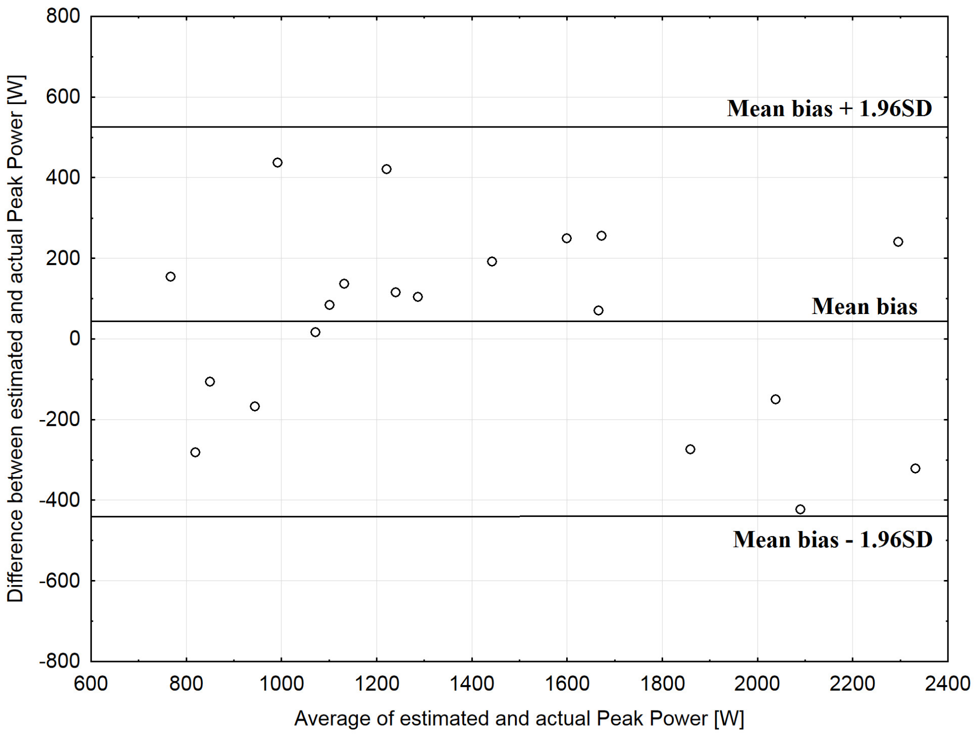

Fig. 1. Bland-Altman plot showing the agreement between the actual peak power and one estimated by the new equation

DISCUSSION

The main finding of the study is the development of a new equation for estimating the PP of young gymnasts. There were no significant differences between the new equation and the actual measurements on a force platform, and the systematic bias was small (39 W). As it was shown, the previously published equations [6, 12, 13] do not fit well the outcome performed by gymnasts. The reason for that, in the case of Sayers's et al. equation, could be due to the fact that the investigation included adults, both athletes and untrained ones instead of children. Moreover, even in the case of Amonette et al. [6] and Quagliarella's et al. [12] research, despite the fact that they also conducted their studies on young athletes, their equations did not manage to match results of our sample.

Artistic gymnastics is a specific sport discipline. Children start their training at an early age and focus their performance on explosive strength rather than on endurance [16, 17]. Findings of some authors suggest that even at an early age gymnasts' neuromuscular coordination system is similar to that of adults [16, 17, 24], probably due to more pronounced activation of fast-twitch motor units. This can influence the characteristics of actual peak power achieved by gymnasts and, consequently, its estimation. However, as it was mentioned before, equation designed from both athletes and non-training adults was also inaccurate in the case of young gymnasts.

Mean values of PP (1400.8 ±542.8 W) of gymnasts in our study were similar to normative data for English school boys [25] at the age of eleven (n = 263; 1473 ±482 W), estimated by Sayers's equation using a contact mat. Gymnasts' mean body mass was 8.4 kg lower than among regular boys, thus gymnasts had to perform their jumps more rapidly, as the maximal VJH in both studies was similar: 26.6 ±4.26 cm and 26.9 ±5.4 cm, respectively. These findings are also similar to data provided by other authors [14, 15]. Bencke et al. compared the CMJ of eleven-year-old boys competing in gymnastics, handball, tennis and swimming. Gymnasts occurred to have the highest maximal VJH and the lowest body mass, although PP (calculated by our equation) did not differ from the other sports, and it was 1829 and 1422 W for elite (n = 11) and non-elite gymnasts (n = 6), respectively. It is consistence with findings that young gymnasts exhibit higher relative to the whole body strength than the absolute values or normalized for particular body parts [16, 26, 27]. It is necessary for them to maintain low body mass [28, 29], thus it is easier to manipulate their body on each gymnastic apparatus. Moreover, as the correlation between body mass and jump peak power is well established [30, 31, 32] this could be another factor, accompanied by the earlier mentioned neuromuscular one, answering why the previously published equations did not fit the actual peak power of young gymnasts. Therefore, developing the new equation for this special group of young athletes seems to be justified.

CONCLUSIONS

The newly developed equation:
"(73.8 x VJH [cm]) + (34.7 x body mass [kg]) - 1617" is more accurate in estimating the peak power of young gymnasts than the previously published ones. It must be mentioned, due to large 95% limits of agreement (±480 W), that the developed equation cannot be used to follow changes in performance of an individual gymnast. Still, it can be a useful tool for artistic gymnastics trainers to compare training groups or to follow their training progress.

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