PREDICTIVE ABILITY OF BODY MASS PARAMETER TO ESTIMATE 4-6 REPETITION MAXIMUM OF UPPER AND LOWER LIMB MUSCLES IN SOCCER PLAYERS

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Abstract

This study aimed to assess the predictive ability of body mass to estimate 4-6 repetitions maximum of pectoral machine, leg extension, and leg press exercises to optimize the one repetition maximum assessment. For this purpose, fourteen male soccer players (age 24.14 ± 4.66 years; body mass 76.52 ± 6.35 kg; height 1.83 ± 0.06 m; training experience 17.71 ± 5.15 years) participated to determine 4-6 repetition maximum according to Brzycki protocol for each exercise in randomized counterbalanced order. A moderate significant correlation was showed between the 4-6 repetition maximum and the body mass (r = 0.440, 0.393 and 0.305) for pectoral machine, leg extension, and leg press exercises, respectively). The analyses showed that body mass weakly explained the three criterion variables (r2: 9-19%). The prediction equations suggested can be used to optimize the one repetition maximum test, but other factors must be considered in further studies to have more accurate 4-6 repetition maximum values.

Keywords*: body weight, estimation performance, functional movement, repetition maximum, strength.*

Introduction

Due to the importance and popularity of the strength sessions for soccer, and the players desire to lift as much weight as possible, the one repetition maximum (1-RM) exercises values are considered as a main indicator of body strength (Caruso et al., 2012; Kim et al., 2002). In strength training programs, physical tests and prescriptions are predicated with the percentage of the RM values (Kim et al., 2002). To simplify, 1-RM represents the maximum amount of load that a person can lift for one correct repetition. Measurement is relatively simple yet risky endeavor that requires a proper warm-up, considerable mental strength, and spotters present to ensure the lifter's safety (Brzycki, 1993). The inherent injury risk associated with 1-RM lifts has led to safer estimations of strength exercises by identifying predictor variables that correlate with exercising performance (Cormie et al., 2011). Such predictor variables include anthropometrical measurement of human body.

Anthropometry serves as a valued predictor of 1-RM loads (García-Ramos, Torrejón, et al., 2018; García-Ramos, Haff, et al., 2018; Keogh et al., 2005, 2007; Noel et al., 2003) and among the many parameters. Body mass has routinely been used to predict pectoral machine and leg press, particularly as a correlate to 1-RM performance (Caruso et al., 2012; Keogh et al., 2007; Mayhew et al., 1993). Positive correlations between body mass and 1-RM exercise loads validate the use of weight classes in sports like soccer (Mayhew et al., 1995, 2004; Mjølsnes et al., 2004; Noel et al., 2003; Wisløff et al., 2004). It has been shown that absolute levels of free fat mass, total body mass, and assessments of muscle thickness or girth, were the best correlates to muscle strength performance in different sports and may typify the ideal body type for soccer (García-Ramos, Torrejón, et al., 2018; Keogh et al., 2007).

The 1-RM test is a very common and useful test to assess strength of an athletes, but sometimes submaximal test is preferred because the direct assessment of 1-RM is unsafe especially for novices (Eston & Evans, 2009). Moreover the 1-RM assessment requires more trials in different days (three), such as choosing the first load for the first trial session, retest with an increased load, and finally confirming the estimated 1-RM. In order to shorten testing sessions, 1-RM assessment can be optimized into two single sessions if multiple repetition maximum (M-RM) strength protocols are used. The M-RM can be defined maximal weight which person can lift over a specified number of repetitions with the correct lifting technique (Baeckle & Earle, 2008). For example, the 4 to 6 repetitions maximum (4-6 RM) is the maximal weight which an athlete can lift between four to six times with the correct lifting technique. Additionally, 1-RM is proven to be valid to prescribe the intensity in strength training protocols (Judge & Burke, 2010; Taylor & Fletcher, 2012).

Therefore, this study aimed to assess the predictive ability of body mass parameter to estimate 4-6 RM of pectoral machine, leg extension and leg press exercises. We assumed that body mass and training status could be useful to predict muscle strength levels (Giroux et al., 2016).

Methods

Experimental design

A cohort-based, counterbalanced, repeated-measures study design was used. The experimental protocol consisted of performing the pectoral machine, leg extension, and leg press exercises on three separate sessions. The first session was carried out to familiarize the participants with the exercise protocol. In the second session, performed after one week, the 4-6 RM strength assessment was performed on a strength training machines (Technogym™, Gambettola, Italy). These three exercises were performed in random counterbalanced order, with 4 min of rest in-between trials on the same exercise, and 10 min of recovery in-between exercises. In the third session, re-tests on 4-6 RM for each exercise was performed to confirm the data collected in the second session. In this session, the 4-6 RM load was directly used, and each participant performed only one trial of 4-6 RM for each exercise. The coefficient of friction between steel for each machine was 0.78 μrd for static friction and 0.42 μrd for dynamic friction (Padulo et al., 2015).

Participants

Fourteen soccer players (Table 1) voluntarily participated in this study. All participants had at least 12 years of soccer practice and trained about nine times per week (1.5 hours per session with an average weekly training volume of ~15 h). The weekly training program also included two strength training sessions. Twenty-four hours before and during the study period, participants were required to abstain from the consumption of medication, alcohol, drugs, dietary supplements that could influence their physical performance or their hormonal balance. Participants were also free from any injury or pain that would have prevent them from giving maximal effort during testing. Informed consent has been obtained from all individuals included in this study. The research has been complied with all the relevant national regulations, institutional policies and in accordance the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board.

Table 1. Participants' characteristics

Sample size (n)	14
Age (years)	24.14 ± 4.66
Body mass (kg)	76.52 ± 6.35
Height (m)	1.83 ± 0.06
BMI (kg/m^2)	22.50 ± 1.03
Experience in soccer (years)	17.71 ± 5.15

Anthropometrics and strength assessment

Body mass was measured using a scale with ± 0.1 kg precision. Body height was measured with an accuracy of one millimeter (Harpenden Portable Stadiometer 603 VR, Holtain LTD, Crosswell, UK). Body mass index was calculated using an equation: body weight (kg) / [body height (m)]2. To determine 4-6 RM of each exercise, participants were evaluated starting with an initial load of 100% body mass for leg extension and leg press exercises, and 50% body mass for pectoral machine. When the participant reached 12 repetitions, each exercise was stopped, and after 4 min of a passive rest, the external load of the exercises was increased. The increased load was 20 kg for lower limb exercises (i.e., leg extension and leg press exercises) and 10 kg for upper limb exercise (i.e., pectoral machine). For each exercise, the test was concluded when the participants reached a maximal number of repetitions between 4 to 6 according to the Brzycki protocol (Brzycki, 1993). The load with which the participants managed to perform 4 to 6 correct and complete repetitions was considered as 4-6RM and used for statistical analyses. During all attempts, the rate of perceived exertion was assessed using Borg scale (1-10) (Eston & Evans, 2009). All exercises were instructed and supervised by the same assassor. Before testing, the participants performed ~15 min of warm-up, which included circumduction, adduction /abduction, and flexion/extension of the upper and lower limbs with self-selected intensity and dynamic stretching. After the warm-up, the participants recovered for ~5 minutes and then began tests. The participants were asked to avoid any intense effort (i.e., the rate of perceived exertion was less than <6.5/10) 72 hours preceding and during the study. To avoid any circadian variations, all sessions were performed in the morning, starting at around 10 am (Drust et al., 2005).

Statistical analysis

All variables were tested for distribution normality using the Kolmogorov-Smirnov test. The results were presented as means ± standard deviations (SD) as distribution were not violated. The Pearson's product-moment correlation coefficient (r) associated with the coefficient of determination (r^2) was used to evaluate the possible associations between 4-6 RM and body mass for each exercise. The magnitude of the correlations was determined using the following scale for interpretation (Hopkins, 2000): trivial (< 0.1), small (0.1-0.3), moderate (0.3-0.5), high (0.5-0.7), very high (0.7-0.9), or practically perfect (> 0.9) (Hopkins et al., 2009). The regressions equations (and the relative standard error of estimate (SEE)) for prediction of the 4-6 RM loads by BM for each exercise were determined by simple linear regression analysis (LRA). Finally, the 4-6 RM load and the respective number of repetitions were used to estimate the 1-RM for each of the 3 exercises using Brzycki equation (Brzycki, 1993). Data analyses were performed using SPSS version 23.0 for Windows (SPSS, Inc. Chicago, IL, USA).

Results and discussion

Pectoral machine

The 4-6 RM for the pectoral machine exercise ranged from 50 to 80 kg (64.64 ± 7.71 kg). These results indicated that the correlation between body mass and 4-6 RM (Figure 1, Panel A) was moderate (r = 0.440; r^2 = 19.4%).

Using the intercept and slope values of the LRA, it was possible to compute the following formula:

4-6 RM (kg) = 0.53 × body mass (kg) + 23.73

SEE = 7.21 kg

The estimated 1 RM for the pectoral machine ranged from 56 to 93 kg (72.47 ± 9.03 kg).

Leg extension

The 4-6 RM for the leg extension ranged from 100 to 160 kg (137.14 ± 18.99 kg). The results for the leg extension exercise indicated that the correlation between body mass and 4-6 RM (Figure 1, Panel B) was moderate (r = 0.393; r^2 = 15.4%).

Using the intercept and slope values of the LRA, it was possible to compute the following formula:

4-6 RM (kg) = 1.17 × body mass (kg) + 47.35

SEE = 18.17 kg

The estimated 1 RM for the leg extension ranged from 109 to 186 kg (155.31 ± 23.11 kg).

Leg press

The estimated 1 RM for the leg press ranged from 210 to 260 kg (237.14 ± 13.26 kg). Finally, the results for the leg press indicated that the correlation between body mass and 4-6RM (Figure 1, Panel C) was moderate (r = 0.305; r^2 = 9.3%).

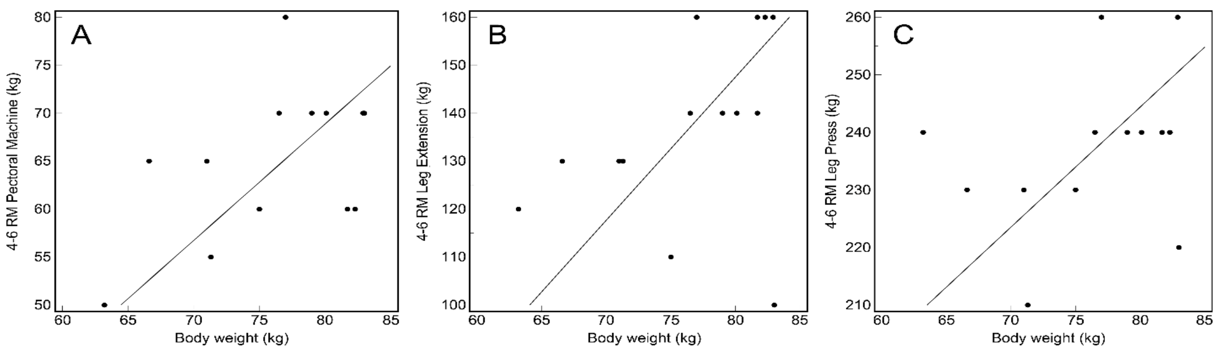
Using the intercept and slope values of the LRA, it was possible to compute the following formula:

4-6 RM (kg) = 0.64 × body mass (kg) + 188.47

SEE = 13.14 kg

The estimated 1-RM for the leg press ranged from 229 to 302 kg (270.77 ± 19.32 kg).

Figure 1. Relationships between body mass and 4 to 6 repetitions maximum (4-6 RM) on Pectoral Machine, Leg Press and Leg Extension.



The aim of the current study was to assess the predictive ability of body mass parameter to estimate 4-6 RM of pectoral machine, leg extension and leg press exercises in soccer players. Unlike previous investigations that examined anthropometry as a correlate to maximal strength exercises (Brechue & Abe, 2002; Keogh et al., 2005, 2007; Mayhew et al., 2004), our study includes participant's performance at submaximal loads. We addressed our study purpose that body mass can predict significant prediction of 4-6 RM for triple functional movements in soccer players with a cohort experimental study design. Based the obtained results from pectoral machine, leg extension, and leg press exercises, it was revealed that body mass had moderate prediction ability to estimate 4-6 RM.

Similar relationships were obtained in the other studies that evaluated the correlation between body mass and 1 RM: for example, when body mass was assessed as a correlate to bench press 1-RM loads in male powerlifters, the relationship was $r = 0.49$ (Keogh et al., 2005). These results suggested that body mass were the best predictors of upper and lower limbs strength (Keogh et al., 2005, 2007). In accordance with previous study (Keogh et al., 2005), similar correlations between body mass and bench press 1-RM load were determined ($r = 0.53 - 0.61$) in college football players (Mayhew et al., 1993, 2004). Thus, our results agree with results from male athletes who routinely need to test or demonstrate their upper and lower-body strength. Namely, body mass acts as a moderate correlate to this criterion, but also other variables should be taken in account when the a priori computation of the 1-RM or 4-6 RM is performed.

However, it is important to note that, unlike body mass and percentage of 1-RM relationships were considered in the current and previous studies (Keogh et al., 2005, 2007; Mayhew et al., 1993), recent investigations revealed that inclusion of body mass as an additional independent variable did not raise the prediction ability of multivariate analyses (Kim et al., 2002; Mayhew et al., 2004). Thus, body mass as a predictor variable does not fully explain criterion variance because initial correlations for submaximal exercises performance (i.e., 4-6 RM) and body mass values were moderate (Kim et al., 2002; Mayhew et al., 2004).

Moreover, body composition variables (e.g., Free fat mass, Fat mass, or skeletal muscle mass) may have been an issue that increase the explanatory ability to estimate 4-6 RM variance in previous studies (Kim et al., 2002; Mayhew et al., 2004; Noel et al., 2003). For instance, to improve their performance, American football athletes in some certain playing positions steadily raise their body mass to yield higher relative gains in body fat mass compared with skeletal muscle mass (Mayhew et al., 2004; Noel et al., 2003). Such practices skew body mass 1-RM relationships, such athletes become heavier but not necessarily stronger (Mayhew et al., 2004). This, in part, accounts for the inability of body mass to increase the load of explained strength variance (Mayhew et al., 2004), whose sample comprised solely of American football players. Mayhew et al. (Mayhew et al., 2004) determined that the most deficient relative bench press efforts came from subjects with the highest body masses and fat percentages. Because skeletal muscle mass, and not fat, improves 1-RM loads, the estimation of 4-6 RM can be influenced by body compositions. Subjects who have the same body mass, but a different percentage of muscle mass and fat mass can obtain different performance in sub-maximal strength tests (Brechue & Abe, 2002; Keogh et al., 2005, 2007; Mayhew et al., 2004).

Conclusion

Based on this study results, the prediction equations that we suggested may allow coaches to measure the 4-6 RM performances in different exercises, corrected by the following simplified linear regression equation specific for each modality of exercises:

- Pectoral machine

4-6 RM (kg) = 53% BM (kg) + 24.

- Leg extension

4-6 RM (kg) = 117% BM (kg) + 47.

- Leg press

4-6 RM (kg) = 65% BM (kg) + 188.

However, theoretical prediction of 4-6 RM using body mass requires caution because of moderate association.

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