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Full Length Article

Relationship between velocity and muscular endurance of the upper body

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ABSTRACT

Strength, power and muscular endurance tests have been developed as means of assessing people's physical abilities. However, testing may be expensive or time consuming. A method to reduce the time of physical assessment could be to use predictive algorithms for indirect assessment. The aim of this study will be to determine a relationship between strength, power and muscular endurance in order to identify predictors for an easier and faster assessment.

33 male strength-trained participants (22.8 ± 4.6 years, 172.5 ± 6.7 cm, 68.0 ± 10.6 kg) performed a single pull-up (SPU) and a single push-up (SPH) and a set of pull-ups (EPU) and push-ups (EPH) to exhaustion. The participants were divided into three sub-groups according to their training experience. Force(F), Power(P), Velocity(V) and relative power(R-P), extracted from an accelerometer (500 Hz), were compared between groups (ANOVA) and a subsequent linear regression analysis was performed to identify predictors of the performance measures.

The regression models were able to explain 61% of the variance with the EPU as dependent variable and the V of the SPU as independent variable and 68% of the variance with the EPH as dependent variable and EPU as independent variable. In addition, increased performance measures were found according to training experience, in particular regarding muscular endurance of both the EPU and EPH ($p < 0.001$ and $p < 0.01$, respectively). A significant effect of training experience was also present for the V of the SPU ($p < 0.001$).

The results indicate that a relation between muscular endurance and velocity is present. The generated equations allow to estimate both the number of EPH and EPU from a SPU. The equations may be helpful to reduce the time of assessment for upper body physical evaluation.

1. Introduction

Fitness testing is an essential part of exercise training, in order to evaluate the level of fitness and the adaptations of the general population or more specifically of athletes. Various approaches have been attempted to evaluate performance (Johnson, Lynch, Nash, Cygan, & Mayhew, 2009; Vaara & et al., 2012). The most common are those evaluating maximal strength, which are generally performed against a resistance, where the subjects are asked to lift the maximum amount of weight through a single repetition (1RM). Other are those evaluating muscular endurance, in which the subjects are asked to perform the maximum number of repetitions, generally through calisthenics exercises (Thomas & et al., 2017). The first, in relation to maximal strength, is considered the most reliable method of assessment, however it generally needs specific equipment, such as benches, barbells and weights, which also

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require a familiarization training period for accurately assessing the 1RM. Thus meaning it is expensive and time consuming.

Muscular endurance is generally expressed as the maximum amount of repetitions performed to exhaustion, the maximum number of repetitions within a fixed period of time or as a percentage of the relative 1RM (Folsom-Meek, Herauf, & Adams, 1992; Johnson et al., 2009). The most widely used muscular endurance tests include push-ups and pull-ups for the upper limbs and squats for the lower limbs (Fogelholm & et al., 2006).

Various attempts have been made to simplify physical assessments, trying to relate strength to one's physical characteristics, for example the relation between strength and body mass or more specifically lean body mass, or to understand the relations between different performance measures. In general, the findings of these studies underline positive associations between weight and strength and negative associations between body fat and muscular endurance (Jaric, 2002; Vaara et al., 2012). One of the first relations between strength and muscular endurance was carried out in 1969 (McGlynn, 1969) finding a positive relation (r 0.77) between these two muscular expressions. The author concluded that a strong person had a greater ability to carry out a physical task for a longer period of time. Mayhew, Ball, Arnold, and Bowen (1991) and Invergo, Ball, and Looney (1991) have tried to understand if it was possible to estimate the 1RM on a bench press through the number of push-ups to exhaustion and both however concluded that this latter could not be a precise measure of the weighted exercise. Other authors have also tried to relate the results achieved through a 1RM and the repetitions to exhaustion achieved with a relative percentage of that same 1RM. Such relations have been carried out for a bench press (Brzycki, 1993) and a lat-pull down test (Thomas et al., 2017) for the evaluation of upper body strength. From such associations, predictive equations have been also generated.

It has been shown that individuals able to produce higher levels of force have also a greater ability to generate power. It is based on this close relation that many studies have assessed performance (Baker, 2001; Cronin & Sleivert, 2005; Muehlbauer, Besemer, Wehrle, Gollhofer, & Granacher, 2012; Naclerio, Colado, Rhea, Bunker, & Triplett, 2009). However, all these attempts have tried to relate the results obtained with a weighted exercise (1RM) and a relative percentage of that same exercise, or combining a 1RM with a calisthenics exercise (Thomas & et al., 2015).

To the best of our knowledge few studies have tried to relate strength or power of a body weight exercise, expressed as the maximal amount of energy developed during a single repetition and the number of repetitions to failure of the same bodyweight exercise. Objective assessments of strength activities have been also reported through the use of accelerometers (Conger et al., 2016). These devices are able to measure acceleration, that is generally evaluated on the 3 axis of movement, x, y and z (Li et al., 2016; Sato, Smith, & Sands, 2009). These devices are able to provide measures of energy expenditure, if integrating acceleration over time, or measures of force, power and velocity if integrated with one's body mass and time.

Therefore, the aim of this study will be to identify any possible relations between the strength and power expressed through two common upper body exercises, through the use of an isoinertial accelerometer and the muscular endurance of the same exercises, in order to identify predictors of performance, that will allow a simplification of the assessment of muscular endurance of the upper body.

2. Methods

2.1. Participants

33 male participants regularly practicing upper body strength training (Thomas et al., 2017) were recruited for this study, and separated into 3 groups based on their training experience (Table 1). Each participant completed all of the trials in the same period of the day in two different evaluation sessions. Each participant was informed about the procedures prior to the investigation in accordance with the guidelines of the University Human Subject Review Board. Each participant was informed about the risks and benefits of participating in this study. The study procedures were also approved by the University review board.

2.2. Experimental setting

Training experience (TE) was defined according to the experience each participant had from the beginning of his strength training, expressed in months. Three categories were created. These were defined novice (≤6 month strength training), medium (6month < strength training ≤ 18 months) and expert (> 18 month strength training) (Ribeiro et al., 2015; Ritti-Dias, Avelar, Salvador, & Cyrino, 2011; Weakley et al., 2017). Each participant was tested in two separate days. During the first day, anthropometric measurements, half of the power tests and half of the muscular endurance measures were assessed (relative to the pull-up

Table 1
Anthropometric characteristics of the 3 groups stratified by training experience.

Variables	n	Age (y)	Height (cm)	Weight (kg)	% Body Fat	Neck Circumference (cm)	Waist Circumference (cm)	Hip Circumference (cm)	Arm Span (m)
Total	33	22.8 ± 4.6	172.5 ± 6.7	68.0 ± 10.6	12.8 ± 4.5	35.5 ± 2.2	76.8 ± 6.2	80.2 ± 6.7	1.8 ± 0.1
Novice	10	20.8 ± 10.9	171.4 ± 8.2	63.4 ± 10.9	14.6 ± 3.1	34.6 ± 3.1	74.8 ± 6.6	78.1 ± 6.3	1.8 ± 0.1
Medium	14	23.9 ± 4.5	174.1 ± 6.2	70.8 ± 9.9	12.9 ± 4.4	35.9 ± 1.5	78.3 ± 6.3	82.3 ± 6.9	1.8 ± 0.1
Expert	9	23.6 ± 3.6	170.6 ± 5.2	68.7 ± 10.9	13.0 ± 4.3	35.9 ± 1.8	76.6 ± 5.5	79.1 ± 6.8	1.7 ± 0.1

Data are expressed as means ± SD; No significant differences are present between groups.