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PREVENTION & REHABILITATION: PILOT STUDY

One repetition maximum bench press performance: A new approach for its evaluation in inexperienced males and females: A pilot study

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Summary The aim of this study was to evaluate a new method to perform the one repetition maximum (1RM) bench press test, by combining previously validated predictive and practical procedures. Eight young male and 7 females participants, with no previous experience of resistance training, performed a first set of repetitions to fatigue (RTF) with a workload corresponding to $^{1}/_{3}$ of their body mass (BM) for a maximum of 25 repetitions. Following a 5-min recovery period, a second set of RTF was performed with a workload corresponding to $^{1}/_{2}$ of participants' BM. The number of repetitions performed in this set was then used to predict the workload to be used for the 1RM bench press test using Mayhew's equation. Oxygen consumption, heart rate and blood lactate were monitored before, during and after each 1RM attempt. A significant effect of gender was found on the maximum number of repetitions achieved during the RTF set performed with $^{1}/_{2}$ of participants' BM (males: 25.0 $\pm$ 6.3; females: 11.0x$\pm$ 10.6; $t = 6.2$; $p < 0.001$). The 1RM attempt performed with the workload predicted by Mayhew's equation resulted in females performing 1.2 $\pm$ 0.7 repetitions, while males performed 4.8 $\pm$ 1.9 repetitions. All participants reached their 1RM performance within 3 attempts, thus resulting in a maximum of 5 sets required to successfully perform the 1RM bench press test. We conclude that, by combining previously validated predictive equations with practical procedures (i.e. using a fraction of participants' BM to determine the workload for

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an RTF set), the new method we tested appeared safe, accurate (particularly in females) and time-effective in the practical evaluation of 1RM performance in inexperienced individuals.

Introduction

The one repetition maximum (1RM) technique is largely acknowledged as one of the most valid measurements of maximal strength and it is defined as the maximal weight that can be lifted with a single repetition (Mayhew et al., 2004; LeSuer et al., 1997; Amarante Do Nascimento et al., 2013; Padulo et al., 2012). The 1RM test has been shown to be a reliable strength indicator in various athletic populations (LeSuer et al., 1997; Benton et al., 2013; Seo et al., 2012), and percentages of 1RM are used in sport and exercise to define training loads for conditioning programs (Amarante Do Nascimento et al., 2013; Arazi and Asadi, 2013; Padulo et al., 2014). Apart from being tested directly, the 1RM performance can also be estimated through validated predictive equations when repetition-to-fatigue (RTF) performances are known (LeSuer et al., 1997; Taylor and Fletcher, 2012; Amarante Do Nascimento et al., 2013).

Despite the importance of 1RM testing in evaluating effectively strength performance, the technique of absolute muscle endurance (defined as the maximal number of repetitions that can be performed with a sub-maximal workload) has been increasingly adopted in many sport and exercise contexts as an alternative measure of upper body muscular performance (Mann et al., 2012). Indeed, prescribing fixed sub-maximal intensities has been recently considered as a potentially safer method than 1RM testing to assess muscular performance within resistance training contexts (Ehrman et al., 2010; Paoli and Bianco, 2012). This trend is particularly apparent within the context of recreational resistance training as performed by individuals in commercial gyms. Resistance training practitioners dealing with inexperienced individuals generally consider the 1RM bench press test a time-demanding and risky procedure. Therefore muscular endurance tests based on fixed sub-maximal intensities have been proposed as an alternative to evaluate 1RM performance within fitness contexts (Reynolds et al., 2006). However, it has to be acknowledged that these procedures have been repeatedly shown to under or overestimate both upper and lower body maximal strength (Castillo et al., 2012; LeSuer et al., 1997; Julio et al., 2012). Most of these methods base their 1RM predictions on the number of repetitions to fatigue (RTF) that can be performed with a self-selected weight to lift. Self-selecting a weight to lift can represent a practical issue when tests are performed by inexperienced individuals, such as those attending commercial gyms. Nevertheless, assessing maximal strength accurately and precisely is critical to evaluate current training state and formulate new training programs not only for experienced, but also for inexperienced individuals.

In order to overcome these practical issues, and in order to provide strength and conditioning professionals with practical guidelines for the evaluation of muscular strength of inexperienced individuals, here we designed and tested the effectiveness of a new method to perform the 1RM-bench press test. This method was designed based on previously validated theoretical predictive and practical procedures. Furthermore, we evaluated the physiological demand induced by the 1RM-bench press method we developed, with regards to its effects on oxygen consumption (VO_2), heart rate (HR), blood lactate (BLa) and perceived exertion (RPE). Physiological changes induced by the 1RM test have been poorly studied Scott et al. (2009) and further clarification is needed to understand how maximal efforts affect human performance. Numerous studies have examined the effects of different type of exercises on muscle soreness and damage (e.g. creatine kinase [CK] and lactate dehydrogenase [LDH]) and found increases in muscle injury following exercises (Uchida et al., 2009a, 2009b; Calle and Fernandez, 2010). However, still little is known on the acute effect of the tests used for the evaluation of physical qualities such as maximal strength. Increasing the knowledge on the energetic cost of maximal physical exertion, as well as providing accurate and precise information concerning the metabolic intensity of fitness activities is indeed essential to define the characteristics of fitness and exercise activities aimed at improving life quality while minimizing health risks (Ehrman et al., 2010; Nelson et al., 2007).

The aim of this study was therefore to assess the effectiveness of a newly designed 1RM-bench press method specifically targeted to inexperienced young male and females and to investigate the impact of such method on some metabolic and cardiovascular parameters.

Subjects and methods

Subjects

Eight male (age: 23.5 $\pm$ 2.3 yrs) and seven female (age: 27.9 $\pm$ 10.0 yrs) individuals participated to this study (Table 1). All participants gave their informed consent for participation. The test procedures were explained to each participant. Participants were asked to fill a health screen questionnaire. Inclusion criteria for this study were: 1. no history of cardiovascular disease and muscle-skeletal injuries in the previous 12 months; 2. no previous experience of resistance training. Ethical approval was granted by the University of Palermo Ethical Committee (Department of Sport and Motor Sciences DISMOT).

The principles of the Italian data protection act (196/2003) were observed. All participants provided informed consent. The study was performed in compliance with the Helsinki Declaration.

Table 1 Mean and SD of anthropometric and physiological characteristics of participants.

Variable	Men (n = 8)	Women (n = 7)
Age (yrs)	23.5 ± 2.3	27.9 ± 10.0
Height (cm)	173.9 ± 7.1	159.7 ± 6.7
Weight (kg)	73.7 ± 10.1	57.5 ± 11.2
LBM (%)	82.5 ± 9.0	74.4 ± 6.9
FM (%)	17.3 ± 9.2	25.6 ± 6.9
Resting HR (bpm)	60.6 ± 5.0	76.3 ± 19.1
Resting Sys BP (mmHg)	124.8 ± 16.1	113.4 ± 10.0
Resting Dia BP (mmHg)	67.8 ± 11.6	72.0 ± 9.2
BMR	1742.4 ± 176.8	1407.9 ± 108.1
Handgrip dx	50.8 ± 10.9	28.4 ± 7.5
Handgrip sx	48.5 ± 8.9	25.4 ± 5.0

LBM = Lean body mass; FM = Fat mass; PA = Physical activity; HR = Heart rate; BP = Blood pressure; BMR = Basal metabolic rate.

Design

This investigation used a single-test research design to examine the validity of a newly proposed method to perform the 1RM-bench press test. The method was specifically designed to evaluate upper body strength performance of young male and females with no previous experience of resistance training. The method resulted from combining: a) 2 sets of bench press performed until fatigue using a fixed workload (i.e. Kg) which corresponded to one third, and subsequently to half participants' body mass; with b) a pre-determined 1RM predictive equation [i.e. Mayhew's formula (Mayhew et al., 1992)]; in order to define the exact 1RM-bench press result from a theoretical value. The purpose of combining a 1RM predicting equation with a 1RM test was to estimate as much accurately as possible individuals' "real" upper body maximal strength, while minimizing fatigue and risk of injuries (Amarante Do Nascimento et al., 2013). In order to set up the study, the MOOSE statement (i.e. Meta-analysis of Observational Studies in Epidemiology) was adopted (Samaan et al., 2013; Stroup et al., 2000).

Methodology

All participants were instructed to: 1) refrain from any form of exercise for at least 48 h prior to testing; 2) have fasted 3 h before testing; 3) be well hydrated. All testing procedures were performed between 10 and 12 am to account for diurnal variation. Prior to testing, participants' anthropometrical characteristics, resting blood pressure, HR, body composition and handgrip strength were evaluated and recorded. Participants' height was measured using a stadiometer while body mass was recorded using a digital scale (Seca, Germany). Participants were then asked to sit on a chair in a quiet room for 20 min, before proceeding with resting blood pressure, HR and body composition's evaluation. Systolic and diastolic pressure values were recorded using a digital blood pressure monitor (Omron M10, USA). Resting HR was recorded using an HR monitor (Polar, Finland). Body composition (% lean/fat mass) and basal metabolic rate was assessed for each participant using a single-frequency bio-impedance analyzer (Skylark, BT-905, Korea). Surface electrodes were placed on participants' left hand and foot. Free-fat mass and basal metabolic rate were recorded. Finally, right and left handgrip strength was evaluated using a handgrip dynamometer (Kern map, Sinergica, Italy). The test was performed twice for each hand and the higher values were recorded. After individual anthropometric and baseline values were recorded, participants were instructed to perform the 1RM test using a bench (FASSI Sport, Italy) and a barbell (length 180 cm, weight 8 Kg, diameter 25 mm, FASSI Sport, Italy). To familiarize with the bench press technique, participants were first asked to perform 1 set of 15 repetitions using only the barbell. This initial set was used as a warm-up in preparation to the sub-sequent test. To minimize fluctuations in power output, participants were instructed to lift and lower the bar at a fixed cadence of 2 s for the concentric phase and 2 s for the eccentric phase. Following familiarization and warm-up, participants were asked to perform 1 set of RTF (for a maximum of 25 repetitions) using a workload which corresponded to 1/3 of individuals' body mass. Following a 5-min recovery period, participants were asked to perform 1 set of RTF using a workload which corresponded to $^1/_2$ of their body mass. The outcomes of the "$^1/_2$ body mass" set to fatigue (i.e. weight lifted and repetitions to fatigue) were used to predict the theoretical 1RM using Mayhew's equation (LeSuer et al., 1997; Mayhew et al., 2004, Mayhew et al. 2008); Fig. 1.

Following a 5-min recovery period, the "theoretical" 1RM bench press test was performed using the predicted workload. A maximal effort was required when performing the 1RM attempt. If participants performed more than 1 repetition with the predicted workload, the workload was then increased by 2–5% until failure, for a maximum of 2 successive attempts. As a result, the whole test consisted of a maximum of 5 sets (2 × RTF sets and a maximum of 3 × 1RM attempts) (Fig. 2).

The rest period between each attempt was of 5 min. All 1RM-tests were supervised by the same investigator. Also, the same investigator controlled that each participant maintained proper exercise technique during testing. Before and during the test, VO_2 was recorded using an online gas analyser (Fitmate PRO – COSMED, Italy). Baseline VO_2 was recorded for a 5 min period with each participant lying supine with his or her back on the bench (feet on the floor). At the end of the 5-min baseline recording, each participant began the bench press exercise maintaining the required cadence, while VO_2 continued to be measured throughout the exercise. The online gas analyser was calibrated prior to each test. HR was recorded during the 5-min baseline recording as well as during the exercise test. A blood sample was collected from the fingertip 30 s after the last 1RM-attempt was performed, in order to assess BLa concentration. BLa strips and a handheld lactate analyser were used (Accutrend-Roche, Germany). A standard calibration strip was inserted into the analyser before each measurement. Finally, 1 min after the

$$1RM = \frac{100 \times weight\ lifted}{52.2 + (41.9 \times e^{-0.55 \times repetitions})}$$

Figure 1 Mayhew's equation.

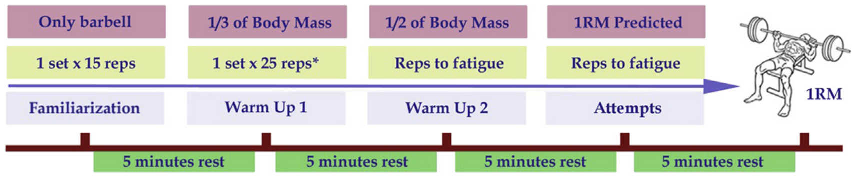

Figure 2 The figure clears the methodological procedures proposed by Bianco; 1 set × 25 reps* = no more than 25 repetitions.

last 1RM attempt was performed, participants were asked to score a session RPE using Borg' scale (Borg, 1982), which corresponded to the effort required by the entire testing session. Participants were familiarized with the RPE scale during the 5 min resting period prior to the 1RM-test. Instructions to each participant were given as follow: *"I am going to ask you to rate your perceived exertion related to the entire session. Use whatever number in the scale seems more appropriate to you to describe how hard/easy the session has been"* (Borg, 1982).

Statistical analysis

Data were collected and then coded using an excel file. Data were first tested for normality of distribution using Shapiro–Wilk's test. Differences between the predicted (Mayhew's equation) and the actual 1RM performance were analysed by means of paired t-tests for the male and female groups.

To investigate the physiological impact of the 1RM method tested on both males and females, descriptive statistics of the main physiological responses were implemented. Also, maximal HR, VO_2, BLa, RPE values, recorded as a result of the 1RM performance, were compared between genders by means of paired t-tests. Bonferroni corrections were considered to account for multiple comparisons.

Estimated marginal means and 95% confidence intervals (CIs) were used to investigate the main difference and data were reported as means and SD and 95% CI.

Differences were considered significant at p value <0.05. STATISTICA software (ver. 8.0 for windows, Tulsa, USA) was used to perform the analysis.

Results

As a result of the 1RM method used in this study, performance-related data for the 1/3 body mass RTF set showed gender-related differences in the maximal number of repetitions performed (i.e. >25 reps in males and 24.2 ± 14.4 reps in females). The 1/2 body weight workload performed with the same technique (RTF) resulted in 25.0 ± 6.3 reps in males and 11.0 ± 10.6 in females, respectively.

The first 1RM attempt based on the predicted workload (i.e. Mayhew's equation) resulted in males performing 4.8 ± 1.9 reps, while females performed 1.2 ± 0.7 reps.

Two (females) participants reached the 1RM as a result of the first attempt; eight (3 males; 5 females) participants reached the 1RM as a result of the second attempt; the remaining five (males) participants reached the 1RM as a result of the third attempt.

Overall, the predicted 1RM performance (i.e. 30.0 ± 6.6 Kg) was not significantly different from the actual 1RM performance (i.e. 29.4 ± 3.8 Kg) in the female group (mean difference = 0.6 Kg; CI = −4.9, 3.7 Kg; paired $t = -0.3$; two-tailed $p = 0.76$) (Fig.3-B). However, in the male group, the predicted 1RM performance (i.e. 58.7 ± 7.8 Kg) was significantly lower than the actual 1RM performance (i.e. 68.6 ± 16.2 Kg) (mean difference = 9.9 Kg; CI = 0.7, 19.0 Kg; paired $t = 2.5$; two-tailed $p = 0.03$) (Fig.3-A). This result indicated that Mayhew's predictive equation underestimated actual 1RM performance in the male group by 14.4% (Table 2).

With regards to the physiological and perceptual impact of the 1RM test, this varied significantly between males and females.

Blood lactate concentration was significantly higher in males (4.2 ± 3.0 mmol/L) than in females (2.6 ± 0.6 mmol/l) ($t = 1.6$; $p = 0.09$). Similarly, session RPE was found to be higher in males (16.1 ± 1.2) compared to females (14.2 ± 38) ($t = 1.6$; $p = 0.08$) (Fig. 4).

No differences in HR and VO_2 between male and females were found as a result of the actual 1RM attempt. During the RTF set performed with 1/3 of participants' body mass, male participants showed a significantly lower HR (91.6 ± 15.7 bpm) than females (130.4 ± 28.9 bpm) ($t = 3.5$; $p < 0.01$) (Fig. 5). During the RTF set performed with 1/2 of participants' body mass, VO_2 was found to be significantly higher in males (8.4 ± 2.3 ml kg min^{-1}) than in females (5.7 ± 0.8 ml kg·min^{-1}) (Fig. 6).

Discussion

The aim of this study was to test the effectiveness of a new method to perform the 1RM-bench press test in inexperienced male and female individuals. This method was based on previously validated theoretical predictive and practical procedures. For the first time, we adopted a percentage of individuals' body mass (i.e. 1/3 and 1/2 BM) to determine the initial workload to perform two RTF sets. The results (i.e. workload and number of reps) of such sets were subsequently used to obtain a prediction of actual 1RM based on Mayhew's equation (LeSuer et al., 1997; Mayhew et al., 2004, Mayhew et al. 2008).

As a result, the first 1RM attempt resulted in all participants being within a range of 0–5 reps from their actual 1RM performance. Overall, all participants reached their 1RM within a maximum of 5 sets (i.e. 2 × RTF sets and a maximum of 3 × 1RM attempts).

Hence, the preliminary outcomes of this study indicated that this newly developed method was safe (i.e. inexperienced males and females were able to perform the test), accurate (i.e. the first 1RM attempt resulted in all

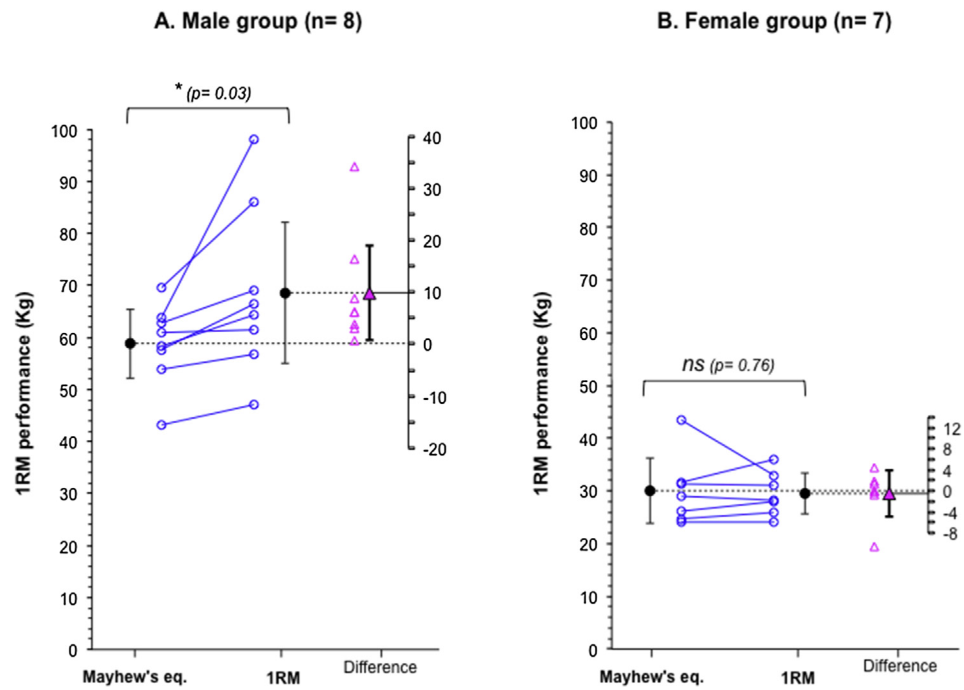

Figure 3 A-B. One repetition maximum bench press performances both in males (A) and females (B). Predicted 1RM (Kg) *vs* achieved (Kg).

participants being within a range of 0–5 reps from their 1RM) and effective (i.e. all participants reached their 1RM within a maximum of 5 sets) in predicting and testing 1RM performance in both males and females individuals with no previous experience of resistance training.

The novelty and implications of such findings are of practical significance within the context of recreational resistance training as performed by general populations in commercial gyms.

The 1RM test is indeed a regularly used procedure in the evaluation of individuals' maximal strength. This is due to the practicality and cost-effectiveness of a test which allows the evaluation of maximal strength during single-joint or multi-joint movements (Ehrman et al., 2010; Nelson et al., 2007; Amarante Do Nascimento et al., 2013). It has been demonstrated that, after prolonged supervised training, this procedure is effective in estimating the maximal strength even in elderly populations (Amarante Do Nascimento et al., 2013; Kemmler et al., 2006). However, one of the main limitations of this procedure is related to the time required to familiarize individuals with the test and to acquire a correct technique (Amarante Do Nascimento et al., 2013; Phillips et al., 2004; Nelson et al., 2007), particularly when the 1RM test is performed by inexperienced individuals (Nelson et al., 2007; Ploutz-Snyder and Giamis, 2001; Benton et al., 2009; Benton et al., 2013).

Trainers and instructors regularly suggest that people with limited resistance training experience should not attempt a 1RM test as an initial component of training plans. Novices are usually trained for 3–6 week with standards strength and conditioning programs that contain exercises performed with a number of sets, repetitions and workloads, which often underestimate the actual

Table 2 Mean and SD of bench press performance of all participants.

	Workload			1RM performance (kg)	
	1/3 BM	1/2 BM	Mayhew's*	Achieved	Δ predicted (%)
		kg			
Men (n = 8)	25.1 ± 3.7	37.6 ± 5.4	59.5 ± 8.2	70.4 ± 16.8	−18.3
Women (n = 7)	19.7 ± 5.0	23.9 ± 8.4	30.0 ± 6.7	29.5 ± 4.1	+01.7
				30_{sec} After 1RM	
		Repetitions		BL post (mmol/l)	RPE post
Men (n = 8)	>25**	25.0 ± 6.3	4.8 ± 1.9	4.2 ± 3.0	16.1 ± 1.2
Women (n = 7)	24.2 ± 14.4	11.0 ± 10.6	1.2 ± 0.7	2.6 ± 0.6	14.2 ± 3.8

BM = Body Mass; Mayhew's* = workload predicted using Mayhew et al. formula; >25** = participants were stopped if able to perform more than 25 repetitions.

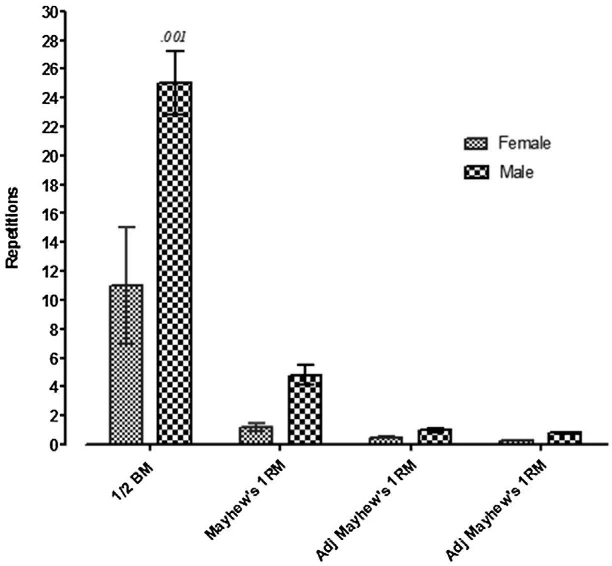

Figure 4 Number of repetitions performed by participants according to theirs workloads. Adj Mayhew's formula = the workload was modified in order to detect the 1RM value.

maximal strength performance. Nevertheless, the evaluation of the 1RM performance is critical in determining appropriate training intensities for individuals who intend to undertake resistance-training programs. For this reason, even in the early stages of training, strength and conditioning professionals often adopt predictive equations in order to determine the maximal performances of their inexperienced clients. However, these predictive equations often under/overestimate actual 1RM performance, thus introducing systematic errors in the early development of training plans (LeSuer et al., 1997; Mann et al., 2012; Mayhew et al., 2011). Such variability in the predictive value of these theoretical methods was confirmed by the results of this study: if Mayhew's equation was used as the only parameter to theoretically determine male participants' 1RM, this would have significantly underestimated their actual performance by 14.4%.

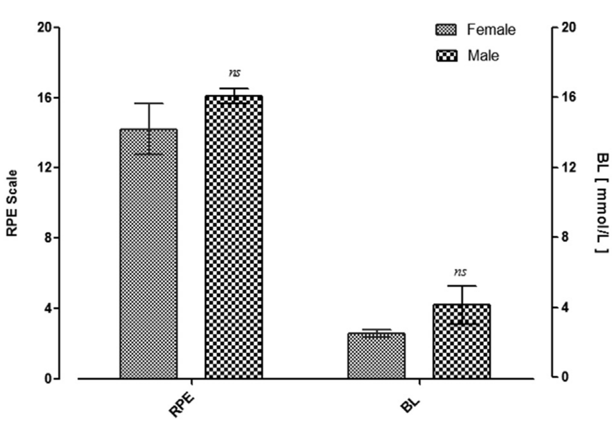

Figure 5 The figure is reporting the RPE and blood lactate values of participants. Data were collected after 1RM performances.

In the light of the above, the possibility to directly test participants' 1RM with the method developed in this study, assured that participants' real upper body maximal strength performed was accurately determined, with a method which revealed to be safe and time-effective (i.e. 3 to 5 sets were required). Hence, here we propose that the method developed could be widely used in the evaluation of the 1RM-performance in the early stages of resistance training programs of inexperienced individuals.

Levinger et al. (2009) have previously reported that one familiarisation session and one testing session separated by 4–8 days could be sufficient for assessing maximal strength in inexperienced individuals. In the present study it was attempted to assess maximal strength within one session, both in order to maximize the effectiveness of testing procedure, as well as to limit the potential influence that previous resistance training experience could have played on 1RM performance in entirely inexperienced individuals. Neural adaptations to 1RM familiarisation sessions (i.e. increase in inter-muscular co-ordination) have been indeed previously observed (Griffin and Cafarelli, 2005; Kraemer et al., 2004), and have been proposed to result from the combinations of different mechanisms (e.g. increase in the maximal rate of force development and capacity to tolerate maximal loads, increased motor unit recruitment, and decreased co-activation of antagonist muscles during execution) (Griffin and Cafarelli, 2005). Therefore, the results of the present study add on previous literature and indicate that 1RM performance can also be assessed within one testing session in inexperienced individuals, according to the method we propose.

From a more fundamental point of view, although limited by a relatively small sample size, the outcomes of this study confirmed that body composition and distribution of muscle mass, and its variability between genders, seems to play a prominent role in strength performance (Johnson et al., 2009). Our male participants showed indeed higher 1RM performances than their female counterparts, likely as a result of their higher lean body mass. In support of this hypothesis, gender differences in strength performance have been previously reported and correlated to the

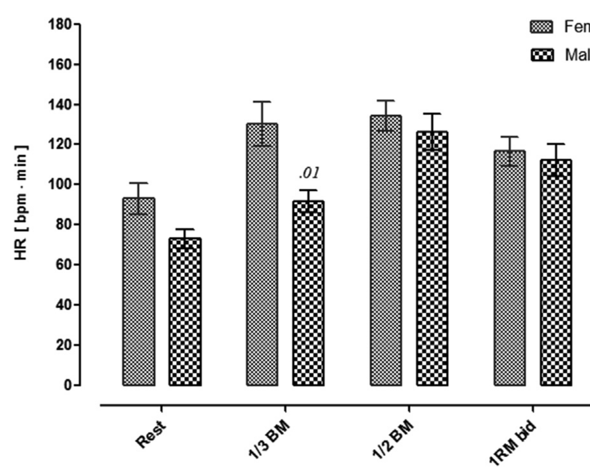

Figure 6 The figure shows heart rate modifications during the experimentation. 1RM bid = immediately after 1RM performance.

presence of larger muscle cross-sectional areas and type I fiber areas in males than females (Miller et al., 1993).

Interestingly, an impact of gender was also observed on BLa and VO_2 during the 1RM testing procedure. The maximal BLa concentration was observed to be on average significantly higher in males than females. Also, VO_2 values were significantly higher in males during the RTF set performed with 1/2 of participants' BM These different physiological responses were hypothesised to be the linked to the higher number of repetitions that male participants were able to perform during the RTF set performed with a workload corresponding to $^1/_2$ of their BM when compared to females (see Fig. 7). Hence, these results provide further evidence to the fact that male individuals are generally stronger relative to lean body mass than females (Miller et al., 1993) and that this is reflected in their maximal as well as endurance (muscular) performance.

Finally, the physiological impact of the 1RM testing procedure proposed in this study, appeared to be primarily neuromuscular (involvement of large number of motor units in high intensity muscular contractions;) with a limited cardiovascular impact.

It should be acknowledged that one of the main limitations of the present study is related to its relatively small sample size. However, these preliminary results provide evidence in support of the safety (i.e. unexperienced males and females were able to perform the test), accurateness (i.e. the first 1RM attempt resulted in all participants being within a range of 0–5 reps from their 1RM) and effectiveness (i.e. all participants reached their 1RM within a maximum of 5 sets) of a method which could already represent a practical and useful tool for the numerous fitness instructors who deal daily with untrained individuals, with very limited experience in strength and conditioning training, attending commercial gyms. Nevertheless, it should be highlighted that the effectiveness of such method applies within the realm of this study and of the characteristic of the participants tested. Indeed, as the participants tested were young adults (age range: ~20 to ~30 years old), any speculation on the possibility to apply such method to different age groups require further testing.

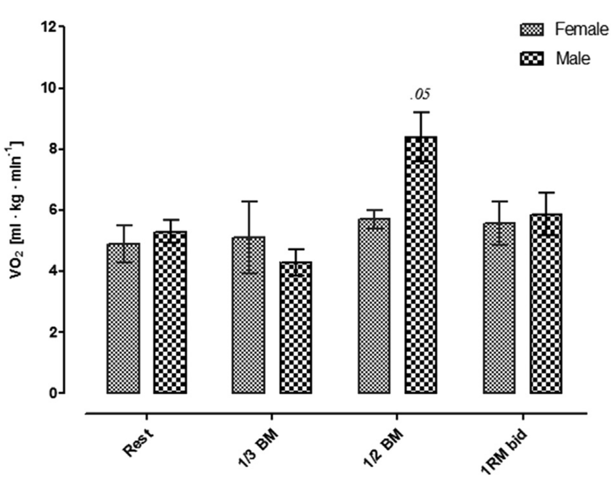

Figure 7 Oxygen consumption modifications during the experimentation. 1RM bid = immediately after 1RM performance.

In conclusion, although further studies exploring this newly developed concept are warranted, the novelty of this study is in the possibility to use an easy-to-access parameter such is body mass, as a way to accurately predict and test 1RM performance with the method we propose. This study confirms that a standardised and supervised procedure to test 1RM bench press performance can be safely administered to inexperienced individuals attending commercial gyms.

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