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MECHANICAL, METABOLIC, AND PERCEPTUAL EFFECT OF A BENCH PRESS LEADING TO FAILURE WITH RELATIVELY LIGHT WORKLOADS

EFECTO MECÁNICO, METABÓLICO Y PERCEPTUAL DE UN PRES DE BANCA HASTA EL FALLO MUSCULAR CON CARGAS DE TRABAJO RELATIVAMENTE BAJAS

Juan A. Párraga-Montilla[1], Pedro A. Latorre Román[1], José Carlos Cabrera-Linares[1], Víctor Serrano Huete[2], Rafael Moreno Del Castillo[1], Pedro Jiménez-Reyes[3]

[1] Department of Didactic of Music, Plastic and Corporal Expression, University of Jaén, Jaén, España

[2] Department of Physical Education Didactics and Health (TECNODEF group), International University of La Rioja, Logroño, España

[3] Centre for Sport Studies Neuromove, King Juan Carlos University, Madrid, España

Correspondence:
José Carlos Cabrera Linares, jccabrer@ujaen.es

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Bench Press to Failure With Light Loads

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Abstract

The aim of this study was to examine the mechanical (number of repetitions per set, movement velocity, countermovement jump height, and handgrip strength), metabolic (lactate, uric acid, and ammonia concentrations), and perceptual (Omni-Res perceived exertion) effects of a bench press exercise performed to failure with a relatively light workload (≈50% 1RM) during a single session and over subsequent days. Twenty-five participants took part in this study. Muscular failure was reached during three sets of the bench press exercise. The workload corresponded to a mean propulsive velocity of 1 m·s#¹. The results showed that mean propulsive velocity decreased as the number of repetitions and sets increased ($p < 0.001$). The number of repetitions also decreased across sets ($p < 0.001$). Lactate concentration and OMNI-RES values increased progressively with each set ($p < 0.001$). In conclusion, the observed reductions in mechanical performance and the high metabolic stress suggest that training to failure should not be frequently implemented in resistance training programs.

Keywords: Bench press, resistance training, velocity-based training, training to failure.

Resumen

El objetivo de este estudio fue analizar el efecto mecánico (número de repeticiones por serie, velocidad de movimiento, altura del salto con contramovimiento y fuerza de agarre), metabólico (concentraciones de lactato, ácido úrico y amoníaco) y perceptual (esfuerzo percibido OMNI-RES) de un press de banca realizado hasta el fallo con una carga relativamente ligera (≈50% de 1RM) en una única sesión y en días posteriores. Veinticinco participantes formaron parte del estudio. El fallo muscular se alcanzó durante tres series de press de banca. La carga de trabajo correspondió a una velocidad propulsiva media de 1 m·s#¹. Los resultados mostraron que la velocidad propulsiva media disminuyó a medida que aumentaban el número de repeticiones y de series ($p < .001$). El número de repeticiones también disminuyó entre series ($p < 0.001$). Los valores de lactato y OMNI-RES aumentaron progresivamente con cada serie ($p < 0.001$). En conclusión, la disminución del rendimiento mecánico y el elevado estrés metabólico observados sugieren que el entrenamiento hasta el fallo no debería implementarse con frecuencia en programas de entrenamiento de fuerza.

Palabras clave: Entrenamiento basado en la velocidad, entrenamiento de fuerza, entrenamiento hasta el fallo muscular, pres de banca.

Introduction

One of the most widely carried out and effective methods to improve health and fitness is resistance training (RT) (Kraemer et al., 2002; Lloyd et al., 2014). Training intensity (training to failure or not, order of exercise, inter-set recovery…) and volume (repetitions per sets, sets per session, training frequency…) are variables that need to be controlled and/or modified to achieve the desired objectives (Tan, 1999). Consequently, RT is highly challenging to programme (Bird et al., 2005; Kraemer & Ratamess, 2004).

The training to failure method has been one of the most used in training programmes when the objective is to maximize maximum strength and muscle mass gains (Drinkwater et al., 2005; Morton et al., 2016). During RT, one of the variables that to a greater degree determines the mechanical and metabolic response of the body is the number of repetitions that the subject can perform in a set before reaching muscle failure (Sánchez-Medina & González-Badillo, 2011). It should be noticed that complete each set until muscle failure (high loads – low reps) induces a breakdown of homeostasis, increasing the time needed to recover from stress at the neuromuscular, hormonal and metabolic levels such as lactate and ammonia (Morán-Navarro et al., 2017). Despite its widespread use, recent researchhas shown that training to failure is not necessary to achieve the adequate stimulus that allows the athlete to increase their performance and muscle mass (Fisher & Steele, 2017; Ogasawara et al., 2013). It is a relatively new perspective of RT since training to failure requires high physical and mental demands, which can lead to injuries, overtraining and/or psychological burnout (Schoenfeld, 2010). Furthermore, RT to failure has an effect at neuromuscular level since different metabolite accumulations appear in the blood modifying the basal level of ammonia and blood lactate, which are two markers of phosphocreatine depletion and glycogen. They are effective markers of muscle fatigue and metabolic load caused by RT. Notice that the changes in both metabolic markers depend on rest time between sets, time under tension, number of sets, number of repetitions, load, and work volume (Rogatzki et al., 2014).

In this sense, previous research has been carried out with the objective of determining the effects of a training to failure method have neuromuscular implications after a single session, also subsequent days (González-Badillo et al., 2016; Morán-Navarro et al., 2017). In this regard, Párraga-Montilla et al. (2020) concluded that training to failure (back squat exercise) induces muscle fatigue that is sustained through 24–48 hours after the session. It is important to note that in the study of Párraga-Montilla et al. (2020) the rest time between sets was reduced from five minutes (it is the usual rest time in failure training programs) to three minutes which is a reduction of 2 minutes with respect to the aforementioned studies. This reduction in rest time is more in line with the recommendation for increasing muscle mass through hypertrophy, which is approximately between 1 and 3 min (Schoenfeld et al., 2016). Nevertheless, it is important to emphasize that a greater gain in strength is obtained when the repetitions are performed at maximum speed while maintaining the correct execution of the movement (González-Badillo & Sánchez-Medina, 2010). In this sense, previous research has concluded that training to failure with light loads produces similar muscle gain and less fatigue to those performed with loads close to 1 repetition maximum (1 RM) (Dos Santos et al., 2021).

Consequently, to better understand the effects that training to failure produces, as well as the variables that could have an influence on it, in this study, the effects of a training to failure causes on athletes after a single session, and subsequent days at mechanical (number of repetitions per set, movement velocity, countermovement jump [CMJ] height, and handgrip strength), metabolic (lactate, uric acid, and ammonia concentrations), and perceptual (OMNI-RES perceived exertion) variables was evaluated. The OMNI-RES scale was chosen over other scales since it is a scale which has verbal and visual descriptors distributed from 0 to 10 (0 implies non effort at all, and 10 implies maximum effort) (Robertson et al., 2003). These properties of OMNI-RES scale make it easier to use and understand by fitness practitioners (Robertson, 2004).

The authors chose the Bench Press (BP) exercise since it is a movement that is usually included in RT, also in several sports apart from strength sports exclusively. Moreover, it is used in tests that involve the upper body (arms, shoulders, chest) (García-Ramos et al., 2016). BP is a basic exercise used when the objective is to increase muscle mass and develop maximum strength in the upper body (Castillo et al., 2012). In the same way, BP can be implemented in those phases of training where the main goal is to increase muscular strength and force production in the upper body as well as a transition to those ballistic movements of more explosive nature used in different sports (Soriano et al., 2017). In addition, previous research has shown that low-load RT induces similar hypertrophic changes to those RT that is performed with a high load if enough external workout load is lifted (Buckner et al., 2017)

Therefore, the aim of this study was to examine the mechanical (number of repetitions per set, movement velocity, CMJ height, and handgrip strength), metabolic (lactate, uric acid, and ammonia concentrations), and perceptual (OMNI-RES perceived exertion) effect of a BP performed to failure with relatively light workload (≈50% 1 RM) in a single session and subsequent days. Our initial hypothesis is that performing BP to failure with a relatively light workload will negatively affect mechanical, metabolic, and neuromuscular responses immediately after the first session and in the subsequent days (24-48 hours).

Materials and Methods

Participants

A total of 25 athletes (19 men and 6 women), participated in this study. The inclusion criteria were: (1) being physically active with regular participation in resistance training; (2) a minimum training frequency of ≥4 days per week; (3) at least 2 years of continuous experience in the bench press exercise; (4) no use of drugs or substances with potential ergogenic effects or that could influence physical performance; (5) commitment to refrain from performing additional physical exercise outside the experimental protocol during the study period; and (6) absence of musculoskeletal injuries in the 6 months prior to the start of the study.

A written informed consent form was signed before starting the study. In addition, The study adhered to the ethical standards outlined in the Declaration of Helsinki (2013) and was approved by the institutional ethics committee.

Procedure

In the current study, we follow the protocol used by Párraga-Montilla et al. (2020). Nevertheless, we chose the BP rather than the back squat exercise. We use the load associated with a mean propulsive velocity (MPV) of 1 m·s -1. This equates to a workload ≈50% of 1 RM (Pallarés et al., 2014). This workload is relatively low compared to those commonly used in training to failure (≈70-90% 1 RM). Likewise, the rest between sets was reduced to 3 min. This represents a reduction of 2 min with respect to the usual rest in training to failure (>5 min). The changes made in terms of workload as well as in the rest time between sets represent the main difference with other studies that have been carried out in this context (Drinkwater et al., 2005; Izquierdo-Gabarren et al., 2010).

The study was carried out for three consecutive days. On the first day (D1), participants performed the training session. On the second (D2) and third day (D3) they performed one set of 6 repetitions.

First day of the Study (D1)

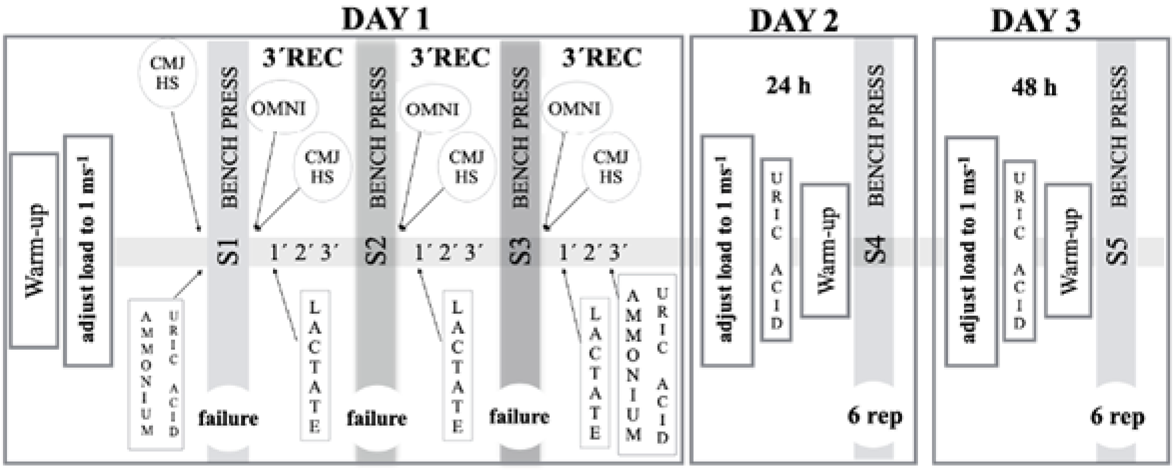
When the participants arrived at the laboratory, the study protocol was explained (Figure 1) and encouraged them not to do any type of physical exercise during the three days of the study. Anthropometric data of the participants, height, weight, and body composition were measured (Table 1). Before starting the protocol, we collected a blood sample to obtain the baseline values of ammonium and uric acid. After that, the participants completed a standardized warm-up consisted on five minutes of jogging, joint mobility, arm mobility, push press, and some BP sets with a light load to avoid any injury. Subsequently, the athletes completed a test (5 sets with 15s rest inter-sets with a load corresponding to 1 MPV load of 1 m·s-1) on BP to related to an MPV of 1 m·s#[1] (1 MPV load). The load was adjusted in D1 and was maintained during D2 and D3. Thus, it was possible to compare and analyse the MPV differences inter-sets and between sessions. The fastest repetition, as well as the slowest, were discarded and the mean value of all the other repetitions was taken for statistical analysis.

The initial load was 10 kg (barbell without any extra kilograms), and we increased the workload with 5 kg discs (SALTER®). After the workload was determined, the participants executed 5 repetitions as fast as they could against the workload with a 15-second rest between sets.

Before starting the training session, handgrip strength (both hands) and CMJ measurements were performed three different times. In both cases, the best result obtained was selected for statistical analysis.

Figure 1

Experimental Protocol



Note. CMJ: Countermovement jump; HS: Handgrip strength; S1, S2, S3: Set 1, set 2, set 3 performed to failure. S4: Set 4; S5: Set 5; OMNI: Omni perceived exertion scale (0-10).

The training session consisted of three BP sets to failure (S1, S2, and S3) with a 3 min rest inter-set. The load for each participant corresponded to that which they were capable of mobilizing at a velocity of 1 m·s-1 (load 1 MPV ≈ 50% 1 RM) (Sánchez-Medina et al., 2014). In each set, participants were verbally encouraged to execute the repetitions at the maximum possible velocity, maintaining a correct execution technique. To perform the BP movement, the barbell descended in a continuous movement until it touched the chest, the upward movement began and it finished when the elbows were fully extended (i.e., "touch and go" movement) (Pallarés et al., 2014).

The rate of perceived exertion OMNI-RES scale; number of repetitions; % loss of speed (between repetitions and between sets); the load in the maximum repetition; the handgrip strength (both hands) and CMJ height were evaluated at the end of each set. Blood lactate was extracted from the index fingertip of the participants one minute after completing each set to failure on D1. We gauged ammonium and uric acid concentrations after session on D1 (3 min after the last repetition). On days 2 and 3, this measurement were obtained using the same protocol just before starting the warm-up corresponding to the session.

Second (D2) and Third day (D3) of the Study

The workload was adjusted to each of the participants (same load as D1) and samples of ammonium and uric acid were taken at rest (i.e., before starting the warm-up). The same time slot as in D1 was maintained, as well as the environmental conditions of the laboratory (22º C and 65% humidity). Before starting the warm-up protocol, the uric acid and lactate concentration were measured. Subsequently, one set (S4, and S5) of 6 repetitions were performed in BP with the same execution protocol as in D1. This procedure was repeated on D3.

Materials

Body Composition

We measured height (TANITA HR-001 portable height rod), weight and body composition data (Body Mass Index, %fat, fat mass%, lean body mass%, muscle mass%, and bone mass %) before starting the warm-up (TANITA SC 330-S scale, Tanita Corporation, Tokyo, Japan).

Mechanical Measures of Fatigue

a) Set of repetitions to failure. The number of repetitions of each set was recorded for later analysis using a linear velocity transducer (T-Force System, ERGOTECH Consulting. S.L. © 2008) attached to the side of the barbell.

b) Velocity achieved against the 1 MPV load. The MPV was recorded with a linear velocity transducer (T-Force System, ERGOTECH Consulting. S.L. © 2008) attached to one side of the bar.

c) Jump height. The height of each jump was evaluated with the Optogait system (Microgate, Bolzano, Italy). The evaluation was made prior to the start of set 1 on day 1 (i.e., after warming-up). Subsequently, it was immediately remeasured at the end of each set to failure that was performed on D1. This allowed us to evaluate jump height losses in each of the sets executed. Participants performed three CMJ in each time and a 10 s rest between each jump was allowed. The mean value of the two highest jumps was used for statistical analysis.

d) *Handgrip strength*. The handgrip strength (HS) test was used to examine upper-body muscle strength. This test involves using a hand dynamometer with an adjustable grip (TKK 5101 Grip D; Takey, Tokyo Japan). The optimal grip span was calculated with the formula suggested by a previous study (Ruiz et al., 2006). Each participant performed this test twice with each hand. Participants needed to fully extend their arm so that it formed a 30° angle relative to their trunk. The maximum score (kg) for each hand was recorded, and the mean score of left and right hand was used in the subsequent analysis.

Metabolic Measures of Fatigue

a) Blood lactate concentration. We used a Scout Lactate portable meter (SensLab GmbH, Leipzig, Germany). It was calibrated before each set according to the manufacturer's recommendations.

b) Uric acid. Uric acid was measured using a portable meter (UASure®).

c) Ammonia. We used a portable analyser (PocketChem Ba Pa-4130, A. Menarini Diagnostics, Florence, Italy) to measure it.

Perceptual Measure of Fatigue

OMNI-RES scale. The OMNI-RES scale (Robertson et al., 2003) was shown immediately at the end of each set to failure that the participants completed on D1. The OMNI-RES scale ranges from 0 to 10, where 0 is a very easy effort and 10 is an extremely hard effort. We gave to the participants' guidance about this scale since the value of it should be in relation to overall tiredness instead of muscle involved in the BP exercise exclusively.

Statistical Analysis

Data were analyzed using SPSS Statistics v.24.0 for Windows (Chicago, USA). First, the normal distribution test (Kolmogorov–Smirnov) and the homogeneity test (Levene) were conducted on all the data. The results are expressed as means and standard deviation (SD). Differences between sets (S1 vs. S2 vs. S3) and session's days (D1 vs. D2 vs. D3) were analyzed using analysis of variance repeated measures ANOVA adjusted by Bonferroni post hoc test. The significance level was set at $p<0.05$ and the confidence interval was 95%.

Results

Descriptive characteristics of the participants are presented in Table 1. Men presented higher values than women in height, body mass, lean body mass, muscle mass, and bone mass ($p < 0.001$). Women showed higher values in body fat percentage ($p < 0.001$) and fat mass ($p = 0.003$). No significant differences were observed between groups for age ($p = 0.49$) or BMI ($p = 0.06$).

Table 1

Anthropometric Data of the Participants

	Total (n=25)	Men (n = 19)	Women (n = 6)	*p*-value
Age (years)	23.9 ± 5.23	24.3 ± 4.9	22.6 ± 6.5	0.49
Height (m)	1.72 ± 7.40	1.75 ± 5.3	1.63 ± 5.7	<0.001
Weight (kg)	70.9 ± 9.13	74.23 ± 6.9	60.53 ± 7.6	<0.001
BMI (Kg/m2)	23.7 ± 1.89	24.1 ± 1.8	22.5 ± 1.8	0.06
% Fat	15.5 ± 7.50	12.4 ± 5.2	25.4 ± 4.3	<0.001
Fatmass (%)	10.8 ± 5.04	9.3 ± 4.1	15.7 ± 4.9	0.003
Lean bodymass (%)	60.1 ± 10.63	64.9 ± 6.7	44.8 ± 3.5	<0.001
Musclemass (%)	57.1 ± 10.15	61.7 ± 6.4	42.5 ± 3.3	<0.001
Bone mass (%)	3.0 ± 0.52	3.2 ± 0.3	2.2 ± 0.2	<0.001

Note. Data are represented as *Mean* ± *SD*; BMI: Body Mass Index.

Mechanical Measures of Fatigue

Table 2 shows descriptive values recorded for each of the variables analysed. The number of repetitions decreased from S1 to S3 (p<0.001). No significant differences were found in CMJ among sets to failure performed in D1, nor between sessions (i.e., D1, D2, and D3) (p>0.05). Regarding hand grip strength, no differences were found between sets in the right hand (p = 0.098), and left hand (p = 0.340), nor among sessions (i.e., D1, D2, and D3) (p>0.05).

Table 2

Descriptive Values of the Analyzed Variables (Mean ± SD)

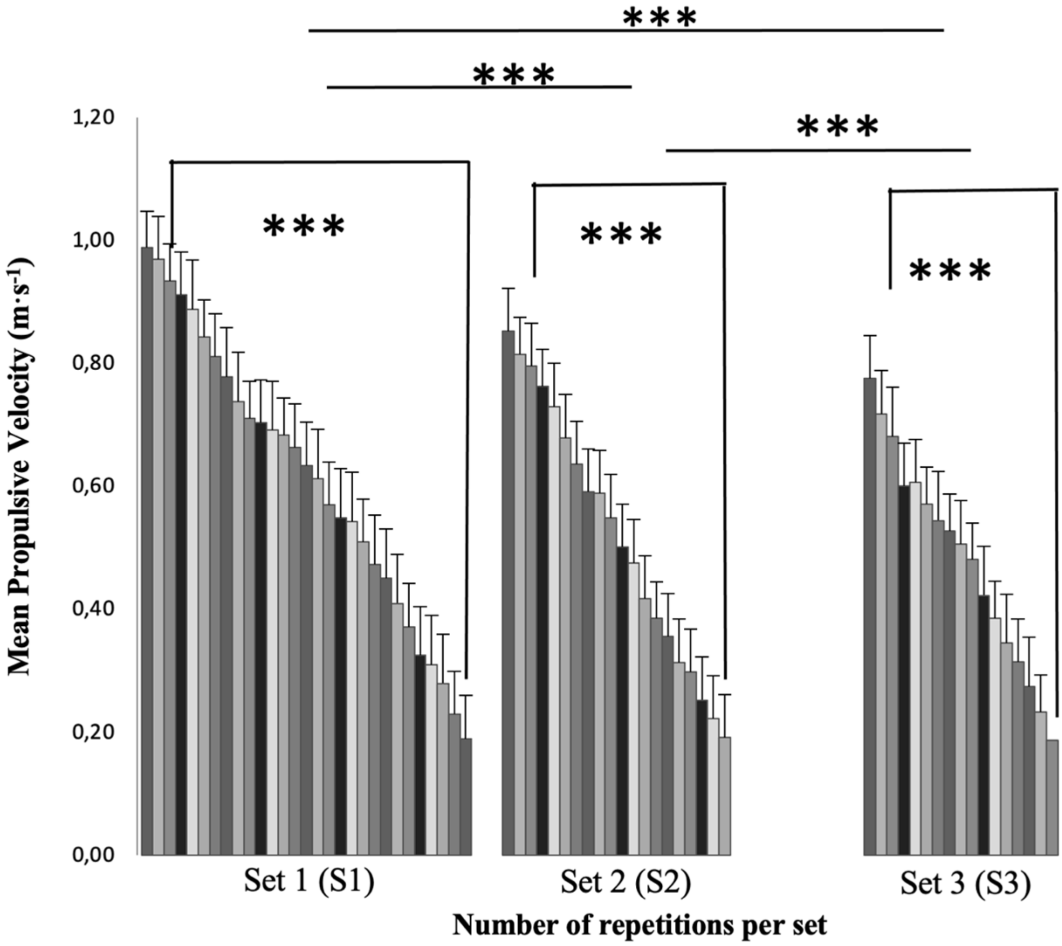
	D1				D1	D2	D3	
	S1	S2	S3	p-value		*Mean ± SD*		*p-value*
Load-Velocity 1ms-1	1.01 ± 0.06	0.90 ± 0.14	0.95 ± 0.13	<0.001	0.95 ± 0.09	0.90 ± 0.14	0.95 ± 0.13	0.001
Nº repetitions (n)	27.96 ± 10.88	20.74 ± 7.79	16.58 ± 5.74	<0.001				
CMJ (cm)	27.32 ± 5.23	27.43 ± 3.58	27.59 ± 5.43	0.620	27.38 ± 5.28	27.30 ± 5.69	27.03 ± 5.64	0.518
HS (left) (Kg)	41.55 ± 8.58	40.75 ± 9.48	41.58 ± 9.21	0.340	41.29 ± 8.93	41.38 ± 10.14	41.81 ± 9.40	0.325
HS (right) (Kg)	43.47 ± 9.22	43.45 ± 8.94	43.49 ± 9.14	0.998	43.47 ± 8.94	43.83 ± 10.46	43.33 ± 10.25	0.825
OMNI-RES	6.83 ± 1.43	7.61 ± 1.13	8.65 ± 1.36	<0.001				
Lactate (m·mol/l)	5.47 ± 1.40	6.87 ± 2.18	7.59 ± 1.90	<0.001				
Uric Acid(µg/dl)	5.45 ± 1.56		5.46 ± 1.30		5.46 ± 1.12	5.9 ± 1.41	5.41 ± 1.30	0.186
Ammonium (µg/dl)	50.34 ± 11.37		155.37 ± 56.52					

*Note.*S1, S2 and S3: Set 1, Set 2, and Set 3 performed to failure respectively during the training session on day 1; D1, D2 and D3: Day 1, day 2 and day 3 respectively; HS: Handgrip Strength; CMJ: Countermovement Jump; OMNI-RES: Omni perceived exertion scale (0-10)

Furthermore, the starting MPV was reduced as the number of repetitions and sets increased (p< .001). Significant differences were found inter-sets (p<0.001) and intra-sets (p<0.001). However, no significant differences were found in the MPV among the final repetitions (0.19 m·s-1) of each set (figure 2).

Figure 2

Mean Propulsive Velocity (MPV) of Each Repetition and set



Note. *** = p<0.001.

Metabolic Variables

We found significant differences in blood lactate ($p<0.001$), with levels increasing at the end of each set. S1 had lower values compared to S2 ($p<0.05$) and S3 ($p<0.001$), nevertheless, no significant differences were found between S2 and S3 ($p>0.05$). Ammonia concentration peaked at the end of the session on D1 (i.e., after Set 3). Regarding uric acid, levels remained high during the three days, with the highest value observed on D2 (5.90 ± 1.41 μg/dl); however, no significant differences were found among D1, D2, and D3 ($p = 0.186$).

Perceptual Variable

Regarding to OMNI-RES values, the highest values were presented at the end of the S3. Significant differences were found between S1 and S2 ($p<0.05$), between S2 and S3 ($p<0.01$), also between S1 and S3 ($p<0.001$).

Discussion

Therefore, the aim of this study was to examine the mechanical (number of repetitions per set, movement velocity, CMJ height, and handgrip strength), metabolic (lactate, uric acid, and ammonia concentrations), and perceptual (OMNI-RES perceived exertion) effect of a BP performed to failure with relatively light workload (≈50% 1 RM) in a single session and subsequent days. Our initial hypothesis is that performing BP to failure with a relatively light workload will negatively affect mechanical, metabolic, and neuromuscular responses immediately after the first session and in the subsequent days (24-48 hours). The main findings of this study were that a BP leading to failure induces high mechanical and metabolic stress after a training session and its maintenance during subsequent days (24–48 hours).

Taking into consideration the reduction in the output of the mechanical variables analysed as well as the high metabolic stress that training to failure produces, and the time to recovery after training session, suggests that the frequent use of training to failure should be reduced in athlete's programmes. The results that we obtained are in concordance with previous studies (González-Badillo et al., 2016; Gorostiaga et al., 2014).

During the training session, the initial MPV and the MPV of the consecutive repetitions were decreased as the sets performed increased. Similarly, the number of repetitions performed in each set decreased progressively due to mechanical and neuromuscular fatigue (Sánchez-Medina & González-Badillo, 2011). Considering these resultsleads us to believe that when the athlete performs a training to failure with a relatively light load in terms of his/her 1 RM, this same load represents a greater effort and therefore a greater % of their 1 RM compared to the previous sets. In this regard, the starting MPV decreased in the second set and the third set in relation to the first one. The differences in the starting MPV represent 50%, 55% and 60% (1 RM), respectively (González-Badillo & Sánchez-Medina, 2010). The variations produced in the MPV allow us to know the degree of fatigue generated in the athlete during the resistance training session in an objective way (González-Badillo et al., 2011).

CMJ is a movement by which we can determine the neuromuscular state of the lower limbs in the athlete. A greater loss in jump height implies greater fatigue (Claudino et al., 2017; Jiménez-Reyes et al., 2016; Sánchez-Medina & González-Badillo, 2011). In the current study, no significant differences were found in the CMJ height (inter-sets nor between sessions). To a large extent, these results may be due to the lack of involvement of the lower limbs in an exercise such as the BP. With regard to handgrip strength, it should be noted that despite being a valid and reliable method to determine the neuromuscular state of the upper limbs (Bautmans & Mets, 2005), no significant differences were found in the evaluations performed. These results may be due to the difference that exists when athletes perform a BP compared to an exercise that involves a manual grip (e.g., biceps curl).

Consequently, the results of our research support the idea that MPV is a reliable (González-Badillo & Sánchez-Medina, 2010), objective (Jidovtseff et al., 2011), and economical method (Balsalobre-Fernández et al., 2017) that can be used to assess the level of fatigue induced by resistance training (to failure or not) at any time during the session (Jovanović & Flanagan, 2014; Sánchez-Medina & González-Badillo, 2011). With regard to the use of the CMJ, as well as the handgrip strength, these do not provide relevant data that determine the neuromuscular fatigue of the upper body when training to failure is performed. For that reason, they can be omitted from the evaluations as performance indicators and recovery from a bench press to failure.

With regard to the metabolic variables analysed (i.e., lactate concentration, ammonia and uric acid), all of them increased their values after the training session. Lactate concentration progressively increased with the number of sets performed; this means that the training session was performed at a high intensity (Domínguez et al., 2018; González-Badillo & Sánchez-Medina, 2010). Uric acid increased at the end of the first session and remained elevated during the 24 and 48 hours after. Likewise, the ammonium concentration experienced an increase of 310% at the end of the training session compared to the basal value limit basal value (Sánchez-Medina & González-Badillo, 2011). The high values of ammonium concentration are due to the reduction level of purines, mainly, it is caused by the depletion of muscular deposits of ATP (Gorostiaga et al., 2014).

In consequence, the results obtained are in line with those obtained in previous studies (Párraga-Montilla et al., 2020; Sánchez-Medina & González-Badillo, 2011) since they indicate that training to failure produces high metabolic stress. The protocol used in the current study (light load ≈50% 1 RM) allowed the achievement of a high number of repetitions in each set, causing ammonium and lactate concentrations to increase to a greater extent than in those protocols in which workloads close to 1 RM (≈90% 1 RM) are used and therefore fewer repetitions per sets are performed. These high concentrations are in line with the study by Párraga-Montilla et al. (2020) and Rogatzki et al. (2014), although those studies they used a back squat instead of a BP.

Limitations

An important limitation in our study is that we did not rank the participants according to the training program they were doing before starting our research (i.e., CrossFit, power training, hypertrophy, training to failure...). This could modify the physiological response of the subject since a great change in the training routine could cause a different physiological response in the analysed variables (e.g., hypertrophy training to training to failure).

Another limitation is the workload used. We use "relatively light" loads, which is the main difference from those usually used in the RT to failure (≈50% 1 RM vs ≈90% 1 RM). Bearing in mind that the RT to failure with different loads (≈80% 1 RM vs ≈50% 1 RM) produces similar increases in force (Fisher & Steele, 2017), we consider it necessary to carry out future research to ascertain the fatigue generated (acute and delayed) in these same variables when RT to failure is performed with lighter workloads (<50% RM).

Despite these limitations, the present study has several strengths. First, it provides a comprehensive analysis by simultaneously examining mechanical, metabolic, and perceptual responses to resistance training to failure, offering an integrative perspective rarely addressed in the literature. Second, the use of velocity-based training (i.e., MPV) as a control and monitoring variable enhances the accuracy and ecological validity of the protocol, allowing precise quantification of training intensity and fatigue. Third, the inclusion of both acute (intra-session) and delayed (24–48 h) measurements provides valuable insight into the time course of fatigue and recovery following training to failure with light loads. Finally, the use of a commonly performed exercise such as the bench press increases the practical applicability of the findings for coaches and practitioners in resistance training contexts.

Conclusions

To conclude, we can argue that training to failure can be a negative stimulus for the athlete when it is implemented frequently in their training programme because it might lead to injuries, overtraining, and therefore a decrease in performance. As an alternative to training to failure, Schoenfeld & Grgic (2019) propose its use only in the last set. In this way, the total volume of the session will not be compromised. Future studies are necessary to confirm whether this protocol causes the same adaptations as a training leading to failure with the traditional method.

Practical Applications

BP performed to failure with relatively light loads (≈50% 1RM) causes an acute (decreases mechanical performance) and delayed effect (high metabolic stress 24 and 48 hours later). Taking into account the mechanical and metabolic variations observed in this study, as well as the perceptual ones (Omni-res), the authors discourage performing training to failure frequently. It induces high stress (mechanical and metabolic), and the subjective perception that the athlete perceives once the session is over can lead to injury, overtraining, and/or physiological burnout. Nevertheless, we consider that training to failure could be a suitable option for athletes who need to increase their muscle strength (i.e., bodybuilding, powerlifters…). In this case, we recommend ensuring a total recovery (at least 48 hours for muscle such as pectoral) between sessions that involve the same muscle groups.

Likewise, our results support the use of MPV as a reliable, safe and economical method to evaluate the performance of the session (at the beginning, during and end). In the same way, OMNI-RES scale can be used to establish the state of fatigue of the athlete at any point during the session. On the contrary, the use of CMJ and handgrip strength is not recommended to evaluate performance during BP to failure since their influence is negligible and they do not provide relevant data for the athlete.

To sum up, MPV can help coaches and athletes to decide when they should stop the training session based on the decrease in performance, taking these variables as a reference. What is more, its evaluation is easy, fast, economical, and it does not require qualified personnel to evaluate the results beyond the professionals of the sports sciences.

Ethics Committee Statement

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee: University of Jaén (registration code: CEIH 201014-3, November 21, 2014).

Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

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Authors' Contribution

Conceptualization: J.A.P.M., V.S.H., & P.J.R.; Methodology:J.A.P.M., P.J.R., & J.C.C.L.; Software:P.J.R., & P.Á.L.R.; Validation:R.M.C., J.C.C.L., & V.S.H.; Formal Analysis:P.Á.L.R., J.A.P.M., &P.J.R.; Investigation:R.M.C., & V.S.H..; Data Curation: J.C.C.L., R.M.C., P.J.R.,& P.Á.L.R.; Writing – Original Draft: J.C.C.L., R.M.C., V.S.H. & J.A.P.M.; Writing – Review & Editing: J.A.P.M., P.Á.L.R. J.C.C.L., & P.J.R. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

The data that support the findings of this study are available from thecorresponding author upon reasonable request.

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