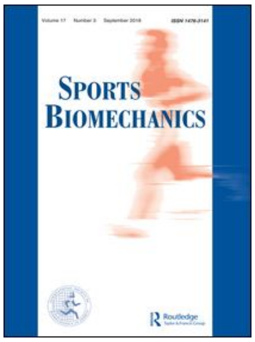

Sports Biomechanics

ISSN: 1476-3141 (Print) 1752-6116 (Online) Journal homepage: http://www.tandfonline.com/loi/rspb20

Differences in the one-repetition maximum and load-velocity profile between the flat and arched bench press in competitive powerlifters

Amador García-Ramos, Alejandro Pérez-Castilla, Francisco Javier Villar Macias, Pedro Á. Latorre-Román, Juan A. Párraga & Felipe García-Pinillos

SPORTS BIOMECHANICS
https://doi.org/10.1080/14763141.2018.1544662

ARTICLE

Differences in the one-repetition maximum and load-velocity profile between the flat and arched bench press in competitive powerlifters

Amador García-Ramos[a,b], Alejandro Pérez-Castilla[a], Francisco Javier Villar Macias[c], Pedro Á. Latorre-Román[c], Juan A. Párraga[c] and Felipe García-Pinillos[d]

[a]Department of Physical Education and Sport, Faculty of Sport Sciences, University of Granada, Granada, Spain; [b]Department of Sports Sciences and Physical Conditioning, Faculty of Education, CIEDE, Catholic University of the Most Holy Concepción, Concepción, Chile; [c]Department of Corporal Expression, University of Jaen, Jaen, Spain; [d]Department of Physical Education, Sports and Recreation. Universidad de La Frontera, Temuco, Chile

ABSTRACT

This study aimed to compare the one-repetition maximum (1RM) and the velocity outcomes obtained against the same absolute and relative (%1RM) loads between the flat and arched bench press (BP) variants. Eleven competitive male powerlifters were evaluated in one session with the flat BP (natural lumbar arch and moderate scapular retraction) and in another session with the arched BP (pronounced lumbar arch and scapular retraction). An incremental loading test was used to determine the 1RM as well as the barbell's velocity against the different external loads. The main findings revealed that the 1RM did not significantly differ between the flat (115.9 ± 17.9 kg) and arched (115.7 ± 18.4 kg) BP variants (p = 0.942, effect size = 0.01), while there were no significant differences between BP variants either for the velocity outcomes obtained against the individual loads nor for the velocities associated with each %1RM (p > 0.05). These results suggest that competitive powerlifters do not necessarily present their higher 1RM performance using the arched BP variant. Finally, both BP variants could be used interchangeably when using movement velocity for testing upper-body strength as well as for prescribing the load during velocity-based resistance training routines.

ARTICLE HISTORY
Received 31 May 2018
Accepted 29 October 2018

KEYWORDS
Linear position transducer; powerlifting; maximal strength; velocity-based resistance training

Introduction

Muscular strength is an important health-related quality for the whole population (Behringer, Vom Heede, Yue, & Mester, 2010; Peterson, Rhea, Sen, & Gordon, 2010). Muscular strength is also positively associated with sport performance (Suchomel, Nimphius, & Stone, 2016). The most effective method to increase muscular strength is resistance training (Ratamess et al., 2009) and, consequently, many studies have been conducted to examine the effect of the manipulation of different resistance training

CONTACT Amador García-Ramos amagr@ugr.es

variables (e.g., type of exercise, intensity, movement velocity, etc.) on muscular strength development (Cormie, McGuigan, & Newton, 2010; González-Badillo, Rodríguez-Rosell, Sánchez-Medina, Gorostiaga, & Pareja-Blanco, 2014). A great variety of exercises can be used during resistance training programs. The bench press (BP) is one of such exercises that can be used to enhance upper-body strength (González-Badillo et al., 2014; Hoff & Almåsbakk, 1995). Different BP variants, which could consist of the use of different implements (e.g., barbells or dumbbells) (Welsch, Bird, & Mayhew, 2005), execution techniques (e.g., concentric-only or eccentric-concentric BP) (Pérez-Castilla, Comfort, McMahon, Pestaña-Melero, & García-Ramos, 2018), grip width (Clemons & Aaron, 1997), etc., are commonly used to accentuate training variation and, consequently, further enhance upper-body strength.

The barbell is the implement most used to perform the BP exercise for both testing and training purposes (García-Ramos et al., 2018; González-Badillo et al., 2014). Specifically, one of the tests performed during powerlifting competitions consists of lifting the maximum possible load during the barbell BP exercise. Powerlifters can choose between two variants of the BP exercise during their competitions: the flat BP (i.e., natural lumbar arch and moderate scapular retraction) and the arched BP (i.e., pronounced lumbar arch and accentuated scapular retraction). The main differences between both techniques are the reduction in the vertical displacement of the barbell and the possibility of exerting a higher force with the legs during the arched BP as compared to the flat BP (Kristiansen, Madeleine, Hansen, & Samani, 2015). Due to the reduction in the range of movement and the recruitment of more muscles, most powerlifters are using the arched BP variant during their competitions. However, to the best of our knowledge, no study has compared the one-repetition maximum (1RM) between the flat and arched BP variants in powerlifters.

The velocity achieved against a given absolute load has been used to assess performance during several resistance training exercises (González-Badillo et al., 2014; Pareja-Blanco, Rodriguez-Rosell, Sanchez-Medina, Gorostiaga, & Gonzalez-Badillo, 2014; Pérez-Castilla, García-Ramos, Padial, Morales-Artacho, & Feriche, 2018). In this regard, it would be important to elucidate whether the velocity outputs achieved against the same absolute load differ between the flat and arched BP. Comparable velocity outputs between both BP variants would suggest that practitioners could choose indistinctly between the flat and arched BP when testing upper-body strength through movement velocity. The possible differences between the flat and arched BP variants either in the 1RM or in the velocity achieved against the same absolute loads could influence their load-velocity profiles (i.e., the velocity associated to each %1RM). Previous studies have proposed generalised group equations to estimate the %1RM from movement velocity during the flat BP exercise (González-Badillo & Sánchez-Medina, 2010). However, it has been recently shown that the load-velocity profile could be dependent on the type of BP performed (e.g., concentric-only *vs.* eccentric concentric; traditional *vs.* ballistic) (García-Ramos, Pestaña-Melero, Pérez-Castilla, Rojas, & Haff, 2018a). Therefore, it would be necessary to explore whether the load-velocity profile differs between the flat and arched BP variants. This information could be useful for athletes using the velocity-based training approach during their resistance training routines.

To address these research gaps, the 1RM and the velocity of the barbell against a range of loads were assessed in the present study during the flat and arched BP variants. Specifically, the aims of the present study were to compare the 1RM strength and the velocity outcomes obtained against the same absolute and relative (%1RM) loads between the flat and arched BP variants. Since the arched BP is expected to reduce the range of movement and involve the leg muscles during the lift (Kristiansen et al., 2015), it was hypothesised that the arched BP would provide higher 1RM values than the flat BP. Because of the lack of similar studies, no specific hypotheses regarding the possible differences in the velocity reached against the same absolute loads or in the load-velocity profile were formulated.

Methods

Participants

Eleven male powerlifters (age: 23.7 ± 2.8 years; body height: 1.77 ± 0.06 m; body mass: 86.7 ± 12.8 kg; BP 1RM relative to body mass: 1.35 ± 0.20; powerlifting training experience: 4.82 ± 1.11 years) participated in this study. Selection criteria included having at least 3 years of experience in powerlifting training and being able to lift a load higher than their body mass in the BP exercise. All powerlifters were in the preparation phase for a national powerlifting event at the time of the study. Participants reported no chronic diseases or recent injuries that could compromise testing performance. They were instructed to avoid any strenuous exercise the two days preceding each testing session. Participants were informed of the study procedures to be utilised and signed a written informed consent form prior to initiating the study. The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board of the University of Jaén.

Experimental design

A repeated-measures design was used to compare the 1RM and load-velocity profile between the flat and arched BP variants. In a randomised order, participants were evaluated in one session with the flat BP and in another session with the arched BP. The two sessions were separated by 48–72 h. An incremental loading test following a standard procedure was used during both testing sessions to determine the 1RM as well as the barbell's velocity against the different external loads applied during the test (García-Ramos et al., 2018). Testing sessions were performed at the same time of the day for each participant (± 1 h) and under similar environmental conditions (~ 22° C and ~ 60% humidity).

Testing procedures

Each testing session began with a 10 min standardised warm-up, which included jogging, dynamic stretching, arm and shoulder mobilisation, and 1 set of 10 repetitions with an external load of 18 kg (mass of the unloaded Smith machine barbell) in the tested BP variant. Afterwards, a standard incremental loading test was applied (García-Ramos, Pestaña-Melero, Pérez-Castilla, Rojas, & Haff, 2018b). The initial external load of the incremental loading test was set at 18 kg and was progressively increased in 15 kg increments until the attained mean propulsive velocity (MPV) was lower than 0.50 m/s. From that moment, the load was progressively increased in steps of 5 to 1 kg until the 1RM load was achieved. The magnitude of the increment was decided by the chief investigator after reaching a consensus with the participant. For the lighter loads (MPV > 1.0 m/s) three repetitions were executed at each load, two for the medium (0.65 m/s ≤ MPV ≤ 1.0 m/s), and only one for the heavier loads (MPV < 0.65 m/s). Intra-set rest was 10 s and inter-set rest was 5 min. The average number of sets and repetitions were 7.8 ± 1.3 and 12.9 ± 1.8, respectively. Two trained spotters were present on each side of the bar to ensure safety. Participants received velocity performance feedback immediately after each repetition to encourage them to perform all repetitions at the maximal intended velocity. The specific characteristics of the two BP variants evaluated are provided below (Figure 1):

-Flat BP: Participants initiated the task holding the bar with hands apart at a slightly greater width than the shoulders and their elbows fully extended. From this position, they lowered the bar to touch the chest, hold this position for approximately 1–2 s and then pressed the bar as fast as possible until their elbows reached full extension. Proper technique included the standard five-point body contact position (head, upper back and buttocks firmly on the bench with both feet flat on the floor) with the intention of minimising the arch of the lower back.

-Arched BP: The execution technique was identical to the flat BP, with the only difference that participants were instructed to maintain the arched lower back and

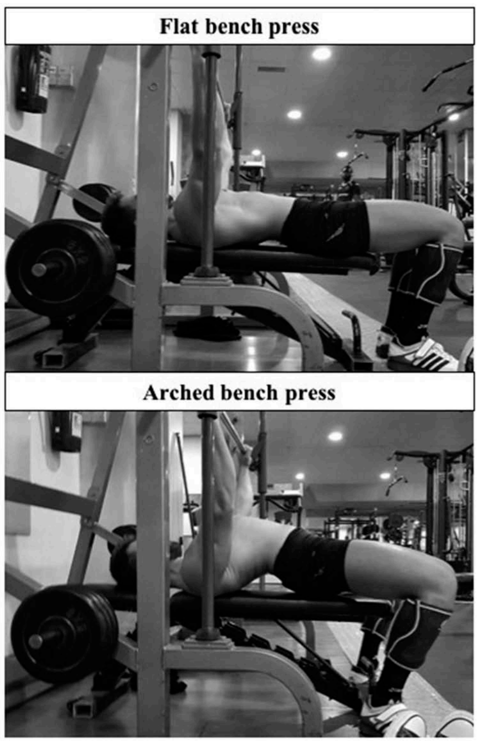

Figure 1. Representation of the flat (upper image) and arched (lower image) bench press variants.

retracted shoulders. They had to drive the heels into the ground as hard as possible to reinforce this position. This technique was supervised by an experienced strength and conditioning coach during all lifts.

Measurement equipment and data analysis

Height (Seca 202, Seca Ltd., Hamburg, Germany) and body mass (Tanita BC 418 segmental, Tokyo, Japan) were assessed in the first testing session. A Smith machine (Technogym, Barcelona, Spain) coupled with a linear velocity transducer (T-Force System; Ergotech, Murcia, Spain) which sampled the velocity of the barbell at a frequency of 1,000 Hz was used in both testing sessions. The high reliability and validity of the T-Force system has been previously reported (González-Badillo & Sánchez-Medina, 2010). The mean velocity (i.e., the average velocity from the start of the concentric phase until the bar reaches the maximum height; MV), MPV (i.e., the average velocity from the start of the concentric phase until the acceleration of the bar is lower than gravity [-9.81 m/s^2]) and maximum velocity (i.e., the maximum instantaneous velocity value reached during the concentric phase; Vmax) of all repetitions were recorded (García-Ramos et al., 2018b). The Smith machine was used to increase the precision of velocity measurements by restricting the displacement of the barbell to the vertical direction. Only the repetition with the highest MPV of each loading condition was used for statistical analyses.

Statistical analyses

Data are presented as means and standard deviation, while the Pearson's multivariate coefficient of determination (r^2) are presented through their median values and range. Prior to any statistical analysis, the normal distribution of the data was confirmed by the Shapiro-Wilk test ($p > 0.05$). The 1RM strength as well as the velocity outcomes were compared between both BP variants through paired samples *t* tests and the Hedge's *g* effect size (ES). The scale used for interpretation the magnitude of the ES was: negligible (< 0.2), small (0.2–0.5), moderate (0.5–0.8) and large (≥ 0.8) (Cohen, 1988). The vertical displacement of the barbell as well as the MV, MPV and Vmax attained against a light (≈ 30%RM), medium (≈ 60%RM) and heavy load (≈ 90%RM) were compared between both BP variants. Note that the absolute load closer to the aforementioned %1RM were compared between the flat and arched BP variants. The velocity (i.e., MV, MPV and Vmax) attained at each %1RM (i.e., from 20%1RM to 100%1RM in 5% increments) were obtained from the individual load-velocity profiles by means of linear regression models (Balsalobre-Fernandez et al., 2017; García-Ramos et al., 2018a). The goodness of fit was assessed by r^2 and the standard error of the estimate (SEE). Significance was accepted at $p \leq 0.05$. All statistical analyses were performed using the software package SPSS (IBM SPSS version 22.0, Chicago, IL, USA).

Results

No significant differences in the vertical displacement of the barbell nor in velocity outcomes were observed between the flat and arched BP variants for any loading condition (Table 1). Similarly, no significant differences were observed between the

Table 1. Comparison of the vertical displacement of the barbell and velocity variables attained at three common absolute loads between the flat and arched bench press (BP) variants.

Load	BP variant	Displacement (cm)	MV (m/s)	MPV (m/s)	Vmax (m/s)
≈ 30%RM	Flat BP	46.6 ± 6.82	1.04 ± 0.10	1.10 ± 0.11	1.84 ± 0.22
	Arched BP	44.7 ± 4.15	1.03 ± 0.07	1.09 ± 0.07	1.84 ± 0.17
≈ 60%RM	Flat BP	43.4 ± 4.40	0.66 ± 0.08	0.69 ± 0.09	1.10 ± 0.16
	Arched BP	41.6 ± 3.38	0.65 ± 0.09	0.68 ± 0.10	1.10 ± 0.14
≈ 90%RM	Flat BP	38.5 ± 3.35	0.29 ± 0.09	0.29 ± 0.09	0.53 ± 0.15
	Arched BP	38.1 ± 3.54	0.30 ± 0.05	0.30 ± 0.05	0.57 ± 0.11

1RM, one-repetition maximum; MV, mean velocity; MPV, mean propulsive velocity; Vmax, maximum velocity. No significant changes were observed ($p > 0.05$). The results represent mean and SD.

flat and arched BP for the 1RM strength (115.9 ± 17.9 kg *vs*. 115.7 ± 18.4 kg, $p = 0.942$, ES = 0.01) as well as for the MV (0.13 ± 0.05 m/s *vs*. 0.17 ± 0.05 m/s, $p = 0.088$, ES = −0.77) and Vmax (0.34 ± 0.13 m/s *vs*. 0.38 ± 0.10 m/s, $p = 0.160$, ES = −0.33) recorded at the 1RM attempt (Figure 2).

Strong linear relationships between velocity variables and relative load (%1RM) were observed for both BP variants ($r^2 = 0.974$ [0.936, 0.979]) (Figure 3). The individual load-velocity relationships obtained from the three velocity variables also proved to be very strong for both the flat ($r^2 = 0.989$ [0.946, 0.997]) and arched ($r^2 = 0.989$ [0.956,

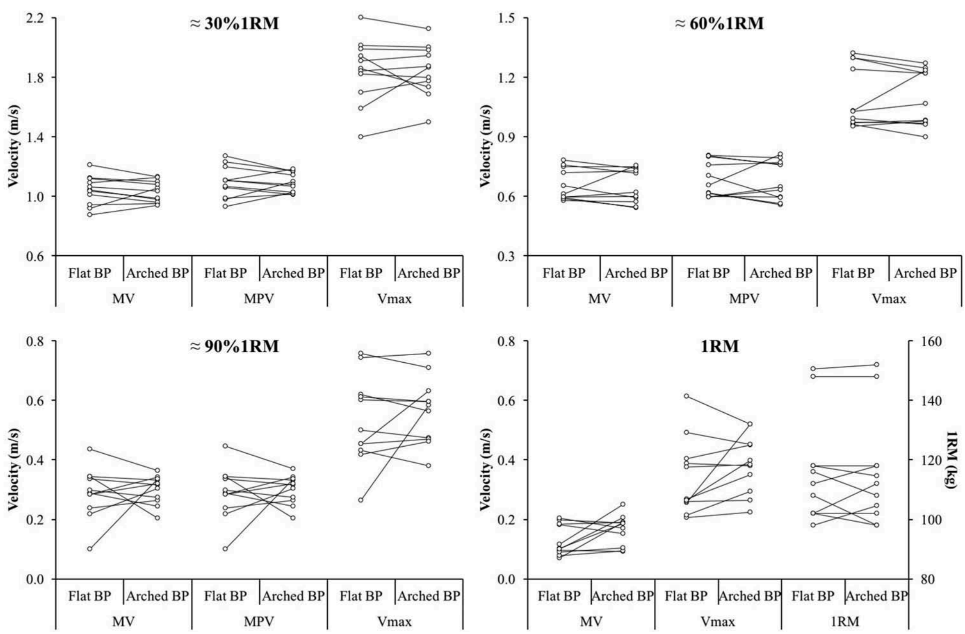

Figure 2. Individual comparisons between the flat and arched bench press (BP) variants. The three velocity variables (mean velocity [MV], mean propulsive velocity [MPV] and maximum velocity [Vmax]) are compared between both BP variants for the 30%1RM (upper-left panel), 60%1RM (upper-right panel) and 90%1RM (lower-left panel) loading conditions. The one-repetition maximum (1RM) as well as the MV and Vmax recorded during the 1RM attempt were also compared (lower-right panel). Note that in the 1RM attempt the MV values are the same than MPV values because there is no braking phase (i.e., the acceleration of the barbell is always higher than 9.81 m/s^2).

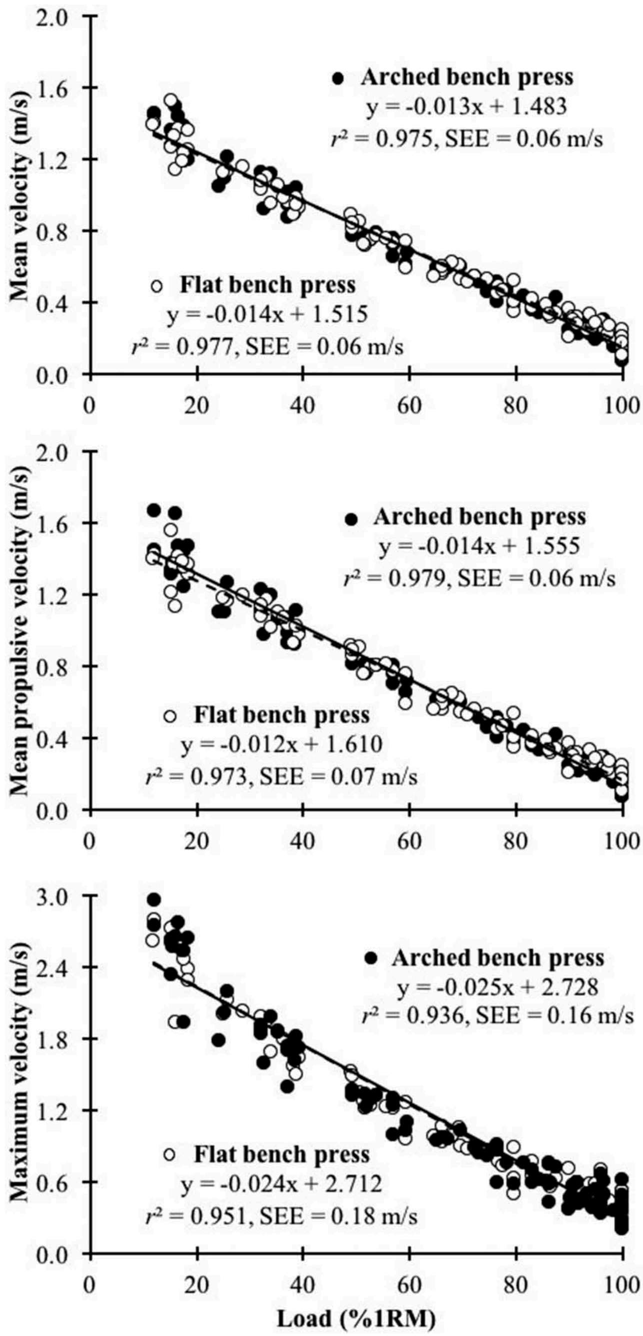

Figure 3. Relationship between the relative load (%1RM) and mean velocity (upper panel), mean propulsive velocity (middle panel) and maximum velocity (lower panel) during the flat (straight line) and arched (dashed line) bench press variants. r^2, Pearson's multivariate coefficient of determination; SEE, standard error of the estimate.

0.998]) BP variants. No significant differences ($p > 0.05$, ES < −0.70) for the MV, MPV and Vmax associated with each %1RM were observed between the flat and arched BP variants (Table 2).

Discussion and implications

This study was designed to compare the 1RM value and the load-velocity profile between two BP variants commonly used during powerlifting resistance training programmes and competitions. The arched BP did not significantly decrease the range of motion, assessed as the vertical displacement of the barbell, as compared to the flat BP (mean differences < 2 cm). The main findings of this study revealed that the 1RM value, the velocity achieved when lifting the same absolute load, and the load-velocity profile were not significantly different between the flat and arched BP. These results highlight that not all competitive powerlifters maximise their performance using the arched BP. Therefore, it would be necessary to identify the individual optimal technique that maximises BP performance.

This study attempted to gather information about the differences between two BP variants commonly used during resistance training programmes (flat and arched BP). It should be noted that while the flat BP (i.e., participants lying flat on the bench with protruded shoulders) is the BP variant most commonly performed by untrained individuals, experienced powerlifters typically use the arched BP (i.e., participants lying with an arched back and retracted shoulders) (Kristiansen et al., 2015). It is also known that both BP variants promote distinctive muscle activity patterns; the arched BP shows a higher activity of the vastus lateralis muscle and the flat BP of the anterior deltoid muscle (Kristiansen et al., 2015). Similarly, it is sometimes stated that an excessive arching of the back could lead to low back pain, while the flat BP could be more harmful for the shoulders (Kolber,

Table 2. Comparison of the velocity variables attained against each relative load (%1RM) between the flat and arched bench press (BP) variants.

	MV (m/s)		MPV (m/s)		Vmax (m/s)	
Load (%1RM)	Flat BP	Arched BP	Flat BP	Arched BP	Flat BP	Arched BP
20	1.24 ± 0.07	1.22 ± 0.07	1.31 ± 0.09	1.28 ± 0.07	2.22 ± 0.19	2.23 ± 0.15
25	1.17 ± 0.06	1.16 ± 0.06	1.24 ± 0.08	1.21 ± 0.07	2.09 ± 0.18	2.11 ± 0.14
30	1.10 ± 0.06	1.09 ± 0.06	1.17 ± 0.08	1.14 ± 0.06	1.97 ± 0.17	1.99 ± 0.13
35	1.03 ± 0.06	1.03 ± 0.05	1.09 ± 0.07	1.07 ± 0.06	1.85 ± 0.16	1.87 ± 0.12
40	0.96 ± 0.05	0.96 ± 0.05	1.02 ± 0.07	1.00 ± 0.05	1.73 ± 0.15	1.74 ± 0.11
45	0.90 ± 0.05	0.89 ± 0.04	0.94 ± 0.06	0.93 ± 0.05	1.61 ± 0.14	1.62 ± 0.11
50	0.83 ± 0.05	0.83 ± 0.04	0.87 ± 0.06	0.86 ± 0.05	1.49 ± 0.13	1.50 ± 0.10
55	0.76 ± 0.04	0.76 ± 0.04	0.80 ± 0.05	0.79 ± 0.04	1.36 ± 0.12	1.38 ± 0.09
60	0.69 ± 0.04	0.70 ± 0.03	0.72 ± 0.05	0.72 ± 0.04	1.24 ± 0.11	1.26 ± 0.09
65	0.62 ± 0.04	0.63 ± 0.03	0.65 ± 0.04	0.65 ± 0.04	1.12 ± 0.10	1.14 ± 0.09
70	0.55 ± 0.04	0.56 ± 0.03	0.58 ± 0.04	0.58 ± 0.04	1.00 ± 0.10	1.02 ± 0.09
75	0.49 ± 0.04	0.50 ± 0.03	0.50 ± 0.04	0.51 ± 0.04	0.88 ± 0.10	0.90 ± 0.09
80	0.42 ± 0.03	0.43 ± 0.04	0.43 ± 0.03	0.44 ± 0.04	0.76 ± 0.09	0.78 ± 0.09
85	0.35 ± 0.03	0.37 ± 0.04	0.36 ± 0.03	0.37 ± 0.04	0.64 ± 0.10	0.66 ± 0.09
90	0.28 ± 0.03	0.30 ± 0.04	0.28 ± 0.03	0.30 ± 0.04	0.51 ± 0.10	0.54 ± 0.10
95	0.21 ± 0.03	0.23 ± 0.05	0.21 ± 0.03	0.23 ± 0.05	0.39 ± 0.10	0.42 ± 0.11
100	0.14 ± 0.04	0.17 ± 0.05	0.13 ± 0.03	0.16 ± 0.05	0.27 ± 0.11	0.30 ± 0.11

1RM, one-repetition maximum; MV, mean velocity; MPV, mean propulsive velocity; Vmax, maximum velocity. No significant differences were observed ($p > 0.05$). The results represent mean and SD.

Beekhuizen, Cheng, & Hellman, 2010; Siewe et al., 2011). The main difference of the present study with respect to the aforementioned studies is that it was focused on comparing different performance variables (i.e., the 1RM value and the velocity outputs attained under the same absolute [kg] and relative [%1RM] loads) between the two BP variants.

The 1RM is the main variable used for prescribing the loads during resistance training programmes (Ratamess et al., 2009). In addition, the 1RM is commonly assessed as an indicator of maximal dynamic strength capacity (Verdijk, van Loon, Meijer, & Savelberg, 2009). More specifically, one of the disciplines of powerlifting competitions consists of the assessment of the 1RM in the BP exercise. It is important to note that in the present study it was hypothesised that the arched BP would provide a higher 1RM value than the flat BP for three main reasons: (I) it was expected that the arched BP would reduce the range of movement helping to overcome the sticking region (Elliott, Wilson, & Kerr, 1989), (II) the arched BP seems to promote a higher activation of the legs during the lift (Kristiansen et al., 2015), and (III) the majority of powerlifters use the arched BP during their training routines and competitions. However, contrary to our hypothesis, no significant differences were found in the 1RM value between the flat and arched BP variants. These findings do question the general belief regarding the superiority of the arched BP over the flat BP for lifting heavier loads during the BP. However, it is also important to consider that no significant differences in the vertical displacement of the barbell was observed between both BP variants (only 0.4 cm less displacement was observed for the arched BP with the 90%1RM load). Future studies should be conducted with more experienced powerlifters and preferably using a free-weight barbell to elucidate whether under these conditions the range of motion can be effectively reduced using the arched BP variant. However, it should be kept in mind that the results of the present study suggest that the BP variant does not meaningfully influence the range of motion, 1RM, or velocity measurements.

A common aim of many resistance-training programmes is to create a training adaptation that allows the athlete to produce more force with the same absolute load, or in other words, develop higher velocities while moving the same absolute load (García-Ramos, Haff, Padial, & Feriche, 2018). In this regard, the proliferation of measurement tools such as the linear position transducer has popularised the assessment of muscular strength through movement velocity (Harris, Cronin, Taylor, Boris, & Sheppard, 2010). For example, the change in the velocity achieved against the same absolute load has been recently used to evaluate the effect of training interventions (González-Badillo et al., 2014; Pérez-Castilla, García-Ramos et al., 2018). The results of the present study show for the first time that, regardless of the load lifted (light [≈ 30% 1RM], medium [≈ 60%1RM] or heavy [≈ 90%1RM]), the velocity outputs do not differ between the flat and arched BP variants. Therefore, although the muscle synergies are known to differ between the flat and arched BP variants (Kristiansen et al., 2015), no meaningful differences in velocity outcomes should be expected between both BP variants when lifting the same absolute load. The practical application of these findings would be that, when upper-body strength is assessed through movement velocity, athletes could choose freely between the flat or arched BP variants because both of them provide comparable velocity outcomes.

The monitoring of movement velocity is being increasingly used as a practical and objective method of prescribing the load during resistance training programmes (González-Badillo, Marques, & Sánchez-Medina, 2011; González-Badillo & Sánchez-Medina, 2010). The use of movement velocity to prescribe the load is justified by the strong relationship observed in many resistance training exercises between movement velocity and the %1RM (Balsalobre-Fernández, García-Ramos, & Jiménez-Reyes, 2017; Conceição, Fernandes, Lewis, Gonzaléz-Badillo, & Jimenéz-Reyes, 2016; García-Ramos et al., 2018b). In this regard, since both the flat and arched BP variants are typically included during powerlifting resistance training programmes, it was of interest to compare the load-velocity profile (i.e., the velocity associated with each %1RM) between both BP variants. It should be noted that previous studies have shown that the load-velocity profile differs between different BP variants (e.g., concentric-only BP *vs.* eccentric-concentric BP) as well as between different populations (e.g., young men *vs.* middle-aged men, or young men *vs.* young women) (Fernandes, Lamb, & Twist, 2018; García-Ramos et al., 2018a; Torrejón, Balsalobre-Fernández, Haff, & García-Ramos, 2018). In contrast to the aforementioned studies, no meaningful differences in the velocity associated with each %1RM between the flat and arched BP variants in competitive powerlifters were detected in the present study. This result was consistent regardless of the velocity variable considered (MV, MPV or Vmax). Therefore, for individual participants, a given velocity output should represent a similar %1RM for both BP variants.

Finally, a number of limitations and directions for future research should be addressed. It should be noted that the powerlifters assessed in the present study were not able to significantly reduce the vertical displacement of the barbell during the arched BP as compared to the flat BP. It remains to be elucidated whether powerlifters of higher competitive level could hold a more pronounced lumbar arch further reducing the range of movement, which could bring differences in the performance variables (i.e., 1RM and velocity outputs attained against submaximal loads). There is also the possibility that the absence of significant differences between both BP variants could be explained due to the use of a Smith machine, while all the powerlifters evaluated in the present study routinely use the free-weight BP exercise. In view of these limitations, future studies should compare the 1RM and the load-velocity profile between both BP variants taking into consideration the BP expertise of the study sample (from untrained individuals to elite level powerlifters), being desirable to conduct these assessments with the most commonly used free-weight BP exercise.

Conclusions

The 1RM and the velocity achieved against the same absolute loads do not significantly differ between the flat (i.e., natural lumbar arch and moderate scapular retraction) and arched (i.e., pronounced lumbar arch and accentuated scapular retraction) BP variants in competitive powerlifters. Consequently, the velocity associated with each %1RM is practically the same for both BP variants. It is important to note that 4 out of 11 powerlifters meaningfully increased their 1RM value using the flat BP variant. The findings of the present study question the general belief of powerlifters about the benefits of arching their backs when performing the BP exercise.

Acknowledgments

We would like to thank all the participants who selflessly participated in the study.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Amador García-Ramos http://orcid.org/0000-0003-0608-8755
Alejandro Pérez-Castilla http://orcid.org/0000-0001-5535-2087

References

Balsalobre-Fernández, C., García-Ramos, A., & Jiménez-Reyes, P. (2017). Load–Velocity profiling in the military press exercise: Effects of gender and training. *International Journal of Sports Science & Coaching*, *13*, 743–750. doi:10.1177/1747954117738243

Balsalobre-Fernandez, C., Marchante, D., Baz-Valle, E., Alonso-Molero, I., Jimenez, S. L., & Munoz-Lopez, M. (2017). Analysis of wearable and smartphone-based technologies for the measurement of barbell velocity in different resistance training exercises. *Frontiers in Physiology*, *8*, 649. doi:10.3389/fphys.2017.00649

Behringer, M., Vom Heede, A., Yue, Z., & Mester, J. (2010). Effects of resistance training in children and adolescents: A meta-analysis. *Pediatrics*, *126*, e1199–e1210. doi:10.1542/peds.2010-0445

Clemons, J. M., & Aaron, C. (1997). Effect of grip width on the myoelectric activity of the prime movers in the bench press. *Journal of Strength and Conditioning Research*, *11*, 82–87. doi:10.1519/00124278-199705000-00005

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (Chapter 8, 2nd ed., pp. 286–288). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Conceição, F., Fernandes, J., Lewis, M., Gonzaléz-Badillo, J. J., & Jimenéz-Reyes, P. (2016). Movement velocity as a measure of exercise intensity in three lower limb exercises. *Journal of Sports Sciences*, *34*, 1099–1106. doi:10.1080/02640414.2015.1090010

Cormie, P., McGuigan, M. R., & Newton, R. U. (2010). Adaptations in athletic performance after ballistic power versus strength training. *Medicine and Science in Sports and Exercise*, *42*, 1582–1598. doi:10.1249/MSS.0b013e3181d2013a

Elliott, B., Wilson, G., & Kerr, G. (1989). A biomechanical analysis of the sticking region in the bench press. *Medicine & Science in Sports & Exercise*, *21*, 450–462. doi:10.1249/00005768-198908000-00018

Fernandes, J. F. T., Lamb, K. L., & Twist, C. (2018). A comparison of load-velocity and load-power relationships between well-trained young and middle-aged males during three popular resistance exercises. *Journal of Strength and Conditioning Research*, *32*, 1440–1447. doi:10.1519/JSC.0000000000001986

García-Ramos, A., Haff, G., Padial, P., & Feriche, B. (2018). Reliability of power and velocity variables collected during the traditional and ballistic bench press exercise. *Sports Biomechanics*, *17*, 117–130. doi:10.1080/14763141.2016.1260767

García-Ramos, A., Haff, G., Pestana-Melero, F., Perez-Castilla, A., Rojas, F., Balsalobre-Fernandez, C., & Jaric, S. (2018). Feasibility of the two-point method for determining the one-repetition maximum in the bench press exercise. *International Journal of Sports Physiology and Performance*, *13*, 474–481. doi:10.1123/ijspp.2017-0374

García-Ramos, A., Pestaña-Melero, F., Pérez-Castilla, A., Rojas, F., & Haff, G. (2018b). Mean velocity vs. mean propulsive velocity vs. peak velocity: Which variable determines bench press relative load with higher reliability?. *Journal of Strength and Conditioning Research*, *32*, 1273–1279. doi:10.1519/JSC.0000000000001998

García-Ramos, A., Pestaña-Melero, F. L., Pérez-Castilla, A., Rojas, F. J., & Haff, G. G. (2018a). Differences in the load-velocity profile between 4 bench press variants. *International Journal of Sport Physiology and Performance*, *13*, 326–331. doi:10.1123/ijspp.2017-0158

González-Badillo, J. J., Marques, M. C., & Sánchez-Medina, L. (2011). The importance of movement velocity as a measure to control resistance training intensity. *Journal of Human Kinetics*, *29*, 15–19. doi:10.2478/v10078-011-0053-6

González-Badillo, J. J., Rodríguez-Rosell, D., Sánchez-Medina, L., Gorostiaga, E. M., & Pareja-Blanco, F. (2014). Maximal intended velocity training induces greater gains in bench press performance than deliberately slower half-velocity training. *European Journal of Sport Science*, *14*, 772–781. doi:10.1080/17461391.2011.643924

González-Badillo, J. J., & Sánchez-Medina, L. (2010). Movement velocity as a measure of loading intensity in resistance training. *International Journal of Sports Medicine*, *31*, 347–352. doi:10.1055/s-0030-1249083

Harris, N. K., Cronin, J., Taylor, K.-L., Boris, J., & Sheppard, J. (2010). Understanding position transducer technology for strength and conditioning practitioners. *Strength and Conditioning Journal*, *32*, 66–79. doi:10.1519/SSC.0b013e3181eb341b

Hoff, J., & Almåsbakk, B. (1995). The effects of maximum strength training on throwing velocity and muscle strength in female team-handball players. *Journal of Strength and Conditioning Research*, *9*, 255–258. doi:10.1519/00124278-199511000-00011

Kolber, M. J., Beekhuizen, K. S., Cheng, M. S. S., & Hellman, M. A. (2010). Shoulder injuries attributed to resistance training: A brief review. *Journal of Strength and Conditioning Research*, *24*, 1696–1704. doi:10.1519/JSC.0b013e3181dc4330

Kristiansen, M., Madeleine, P., Hansen, E. A., & Samani, A. (2015). Inter-subject variability of muscle synergies during bench press in power lifters and untrained individuals. *Scandinavian Journal of Medicine & Science in Sports*, *25*, 89–97. doi:10.1111/sms.12167

Pareja-Blanco, F., Rodriguez-Rosell, D., Sanchez-Medina, L., Gorostiaga, E. M., & Gonzalez-Badillo, J. J. (2014). Effect of movement velocity during resistance training on neuromuscular performance. *International Journal of Sports Medicine*, *35*, 916–924. doi:10.1055/s-0033-1363985

Pérez-Castilla, A., Comfort, P., McMahon, J. J., Pestaña-Melero, F. L., & García-Ramos, A. (2018). Comparison of the force-, velocity- and power-time curves between the concentric-only and eccentric-concentric bench press exercises. *The Journal of Strength and Conditioning Research*, Advance online publication. doi:10.1519/JSC.0000000000002448

Pérez-Castilla, A., García-Ramos, A., Padial, P., Morales-Artacho, A. J., & Feriche, B. (2018). Effect of different velocity loss thresholds during a power-oriented resistance training program on the mechanical capacities of lower-body muscles. *Journal of Sports Sciences*, *36*, 1331–1339. doi:10.1080/02640414.2017.1376900

Peterson, M. D., Rhea, M. R., Sen, A., & Gordon, P. M. (2010). Resistance exercise for muscular strength in older adults: A meta-analysis. *Ageing Research Reviews*, *9*, 226–237. doi:10.1016/j.arr.2010.06.001

Ratamess, N., Alvar, B., Evetoch, T., Housch, T., Kibler, W., Kraemer, W., & Triplett, N. (2009). American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Medicine and Science in Sports and Exercise*, *41*, 687–708. doi:10.1249/MSS.0b013e3181915670

Siewe, J., Rudat, J., Röllinghoff, M., Schlegel, U. J., Eysel, P., & Michael, J. W. P. (2011). Injuries and overuse syndromes in powerlifting. *International Journal of Sports Medicine*, *32*, 703–711. doi:10.1055/s-0031-1275302

Suchomel, T. J., Nimphius, S., & Stone, M. H. (2016). The importance of muscular strength in athletic performance. *Sports Medicine*, *46*, 1419–1449. doi:10.1007/s40279-016-0486-0

Torrejón, A., Balsalobre-Fernández, C., Haff, G. G., & García-Ramos, A. (2018).The load-velocity profile differs more between men and women than between individuals with different strength levels. *Sports Biomechanics*. Advance online publication. doi:10.1080/14763141.2018.1433872

Verdijk, L. B., van Loon, L., Meijer, K., & Savelberg, H. H. C. M. (2009). One-repetition maximum strength test represents a valid means to assess leg strength in vivo in humans. *Journal of Sports Sciences*, *27*, 59–68. doi:10.1080/02640410802428089

Welsch, E. A., Bird, M., & Mayhew, J. L. (2005). Electromyographic activity of the pectoralis major and anterior deltoid muscles during three upper-body lifts. *Journal of Strength and Conditioning Research*, *19*, 449–452. doi:10.1519/14513.1