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COMPARISON OF BALLISTIC AND NON-BALLISTIC LOWER-BODY RESISTANCE EXERCISE PERFORMANCE. DETERMINING THE POSITIVE LIFTING PHASE

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This study compared differences between ballistic jump squat (B) and non-ballistic back squat (NB) exercise. Vertical ground reaction force (GRF) and barbell kinematics were recorded during B and NB performance with 45% of one repetition maximum, and force, velocity and power averaged over positive lifting phases using traditional peak barbell displacement and positive impulse methods. No significant differences were found between B and NB mean force, velocity, power or relative acceleration duration, challenging common perceptions of B superiority for power development. The positive impulse method significantly increased mean values, and the end of the phase was identifiable from peak velocity, which is common to both B and NB resistance exercise.

KEY WORDS: biomechanics, force plate, kinematics, kinetics, strength, impulse.

INTRODUCTION: Ballistic resistance exercise (B) is often preferred for power development because research has shown that resistance is accelerated for longer and mean force, velocity and power are greater than non-ballistic resistance exercise (NB) equivalents (Newton et al., 1996). However, investigators have demonstrated that differences between B and NB occur largely because of the way in which the positive lifting phase is determined (Frost et al., 2008). Research shows that NB consists of distinct propulsion and braking phases (Sanchez-Medina et al., 2010), which exaggerates lifting phase duration, reducing measures of mean force, velocity and power, and resistance acceleration duration (Frost et al., 2008). A new method of identifying the lifting phase that considers the propulsion phase common to B and NB exercise has been proposed by Frost et al. (2008) but must be refined. The propulsion phase can be derived from the positive impulse (positive net force × time) and is proportional to the resistance's change in momentum. However, investigators recently obtained positive impulse from absolute rather than net force (Frost et al., 2008), violating the correct application of basic mechanical principles. The traditional and alternative approaches (applied to lower-body exercise) are illustrated in Figure 1. The approach described by Frost et al. (2008) (adapted for B) is illustrated in Figure 2. They show the traditional method of identifying the end of the lifting phase from peak displacement (point c), and the correct application of the alternative positive impulse method of identifying the end of the positive lifting phase (point b; the point at which net force decreases to zero), and a third (point b*) the result of using absolute rather than net force. It is critical that any new approach proposed for general application is based on sound theoretical principles. Further, it remains that differences between B and NB have not been established, although B is often favoured over NB (Frost et al., 2008). Therefore, the aims of this study were to establish differences between B and NB, and to establish whether any differences occurred due to the way the positive lifting phase was determined.

METHODS: Ten physically active men (mean (SD) mass: 79.7 (13.6) kg; back squat 1RM: 133.3 (22.1) kg; age: 27 (7) years; resistance training experience: 3 (1.5) years), who were fully familiarized with back squat and jump squat exercise provided written informed consent to participate. During the first of two testing sessions maximum back squat strength (one repetition-1RM) was established. Seven days later, back and jump squat power testing was performed, with participants performing three maximal single lifts in each exercise with loads equivalent to 45% 1RM because it represented a compromise between the load that typically maximizes back squat (Siegel et al., 2002) and jump squat power (Cormie et al., 2007). Participants observed two minutes between each lift.

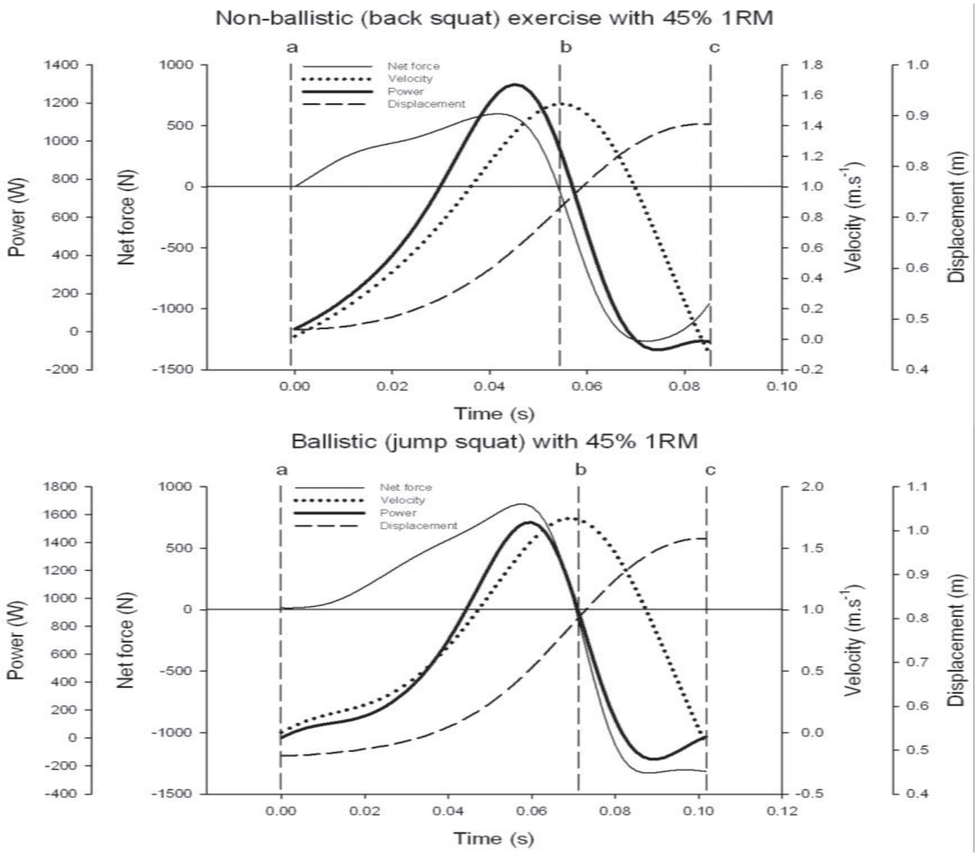

Figure 1: Determination of the positive lifting phase of B and NB resistance exercise using the traditional (peak displacement: point c) and alternative methods (net force = 0: point b). The "braking phase" is between points b and c.

Vertical GRF were recorded from both feet individually by two 0.4 by 0.6 m Kistler 9851 force platforms (Alton, UK) at a sampling frequency of 500 Hz. Simultaneously, two cameras (Basler A602fc-2, Ahrensburg, Germany) positioned 5 m from the right side of the participant filmed a reflective marker attached to the end of the barbell at 100 Hz after first recording a 17-point calibration frame (ViconMotus, Oxford, UK); this was digitized at 100 Hz using ViconMotus 9.2 software. Barbell displacement-time data was filtered using a low (second order) pass Butterworth filter with a cut-off frequency of 6 Hz, and differentiated to determine first velocity then acceleration. Barbell force was then calculated considering both gravitational and barbell acceleration (Hori et al., 2007), and barbell power was calculated by multiplying barbell force by barbell velocity. Summed left and right side GRF, barbell velocity and barbell power were then averaged over the traditional and alternative positive lifting phase for later comparison (see Figure 1). Traditional and alternative positive lifting phase durations were also calculated and relative acceleration duration determined from the time taken to achieve peak barbell velocity.

Differences between B and NB resistance exercise dependent variables of mean GRF, velocity, and power, and relative acceleration, and the influence of the methods shown in Figures 1 and 2 was examined using one-way analysis of variance with post hoc comparisons performed using the Holm-Sidak procedure. All statistical calculations were performed using SPSS version 17.0 for Windows (SPSS, Inc., Chicago, IL) and an alpha value of 0.05 was used to determine statistical significance.

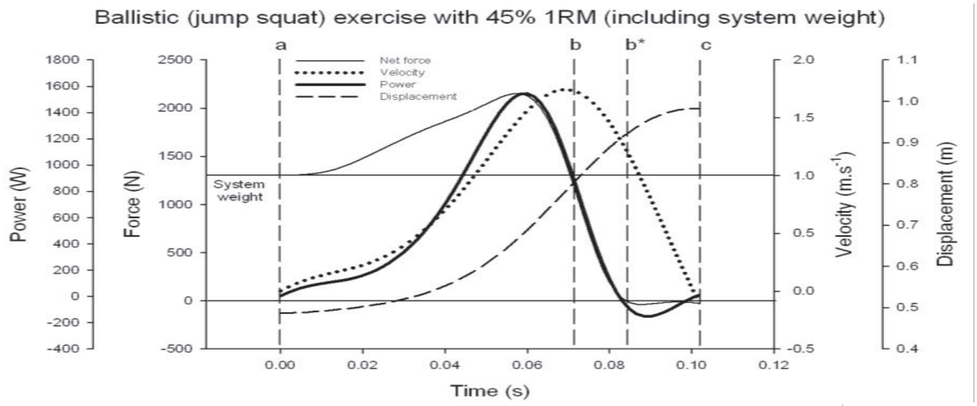

Figure 2: The way Frost et al. (2008) applied the alternative method to B resistance exercise, including barbell and body system weight (adapted for the lower-body). System weight was not subtracted but the end of the propulsion phase was still identified as the point at which force decreases to zero (point b* rather than point b).

RESULTS: Mean (SD) descriptive statistics are presented in Table 1. Except for GRF, there were no significant differences between B and NB dependent variables obtained using the traditional and alternative method of identifying the positive lifting phase.

Table 1:
Mean (SD) ballistic jump squat (B) and non-ballistic back squat (NB) results.

	GRF (N)		Velocity ($m.s^{-1}$)		Power (W)		Relative acceleration (%)	
	B	NB	B	NB	B	NB	B	NB
Traditional	1327.6 (215.8)	1331.1 (238.4)	1.1 (0.4)	0.9 (0.3)	621.7 (211.0)	529.4 (206.9)	68.4 (3.7)	61.3 (16.2)
Alternative	1789.2[a,b] (262.4)	1716.5[c,d] (260.6)	1.0 (0.3)	0.9 (0.03)	886.5 (401.7)	759.5 (406.5)		

a = Alternative B value significantly greater than Traditional B value; b = Alternative B value significantly greater than Traditional NB value; c = Alternative NB value significantly greater than Traditional NB value; d = Alternative NB value significantly greater than Traditional B.

DISCUSSION: This is the first study that has compared performance parameters from B and NB and examined the effect that the way that the positive lifting phase was identified had on them. However, the results were surprising because no significant differences were found between B and NB force, velocity and power using the traditional peak displacement method to determine the positive lifting phase. This does not agree with previous research that has reported differences between B and NB upper-body resistance exercise force, velocity and power of between 14 and 70% (Frost et al., 2008; Newton et al., 1996). Consequently, the effect of excluding the braking phase was minimal, reducing differences in mean velocity by around 4%, but increasing differences in mean GRF by around 3%.
Researchers often recommend B over NB to develop power because of the perception that resistance is accelerated for a greater portion of the positive lifting phase and because greater mean force, velocity and power is generated (Frost et al., 2008). The results of this study suggest otherwise, challenging conventional perceptions about the theoretical underpinnings of B superiority. Therefore, logical progression from this study would be to perform a training study(s) comparing improvements in strength and power from optimal load B and NB training.
The exclusion of the braking phase enables a theoretically more robust method of identifying mechanical demands of B and NB, because the positive or propulsion impulse is common to B and NB. However, theoretical integrity can only be achieved if basic mechanical principles are observed. It is important that strength and conditioning practitioners and investigators

have a sound understanding of the differences between the different methods that were used in this study to determine the positive lifting phase. Further, it is critical that if positive impulse is used to determine the positive lifting phase that it is determined correctly using net rather than absolute force. Only forces that exceed system weight influence system centre of mass kinematics. If GRF is used this applies to the barbell and body system, but if force derived from barbell kinematics is used it only applies to the barbell.

Further, strength and conditioning practitioners and investigators must understand that when net force (GRF or barbell) decreases below zero a number of factors can be observed. First, regardless of whether B or NB is being considered, this point marks the end of resistance acceleration (whether barbell or system centre of mass); second, all displacement of the resistance of interest past this point is an expression of momentum; and third, this point coincides with peak resistance velocity (Figure 1). However, if GRF is used to determine the positive impulse then the peak of the system centre of mass velocity (derived using forward dynamics) will coincide with this point. If net force is derived from barbell kinematics, the end of the barbell positive impulse will correspond with peak barbell velocity. This could be practically applicable to strength and conditioning practitioners who do not have access to a force platform but can access basic motion analysis systems, as the identification of peak barbell velocity will enable the relatively simple, but more theoretically robust way of determining the propulsion phase of the positive lifting phase.

CONCLUSION: This study compared B and NB force, velocity and power averaged across the positive lifting phase that was determined using the traditional peak displacement method and an alternative positive impulse method. The mechanical demands of the different exercise types were not different, and resistance was not accelerated for a greater proportion of the positive lifting phase. We propose that the perception of B superiority may be exaggerated. Of critical importance, the alternative method can be applied by strength and conditioning practitioners who do not have access to a force platform by using peak barbell velocity as an indicator of the end of the positive barbell impulse. This will enable greater accuracy when performance parameters a force, velocity and power are averaged across the positive lifting phase.

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