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The impact of power clean ability and training age on adaptations to weightlifting-style training

An original investigation conducted via the University of Queensland

By

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ABSTRACT

The purpose of this investigation was to determine whether weightlifting actions are a viable method for improving athletic performance amongst weaker, inexperienced lifters when compared to individuals with a greater power clean result, and hence weightlifting ability and experience. Two groups of males with distinctly different power clean performances (higher performance (HP): $N = 8$; BM = 78.1±4.0 kg; 1RM PC = 1.08±0.09 kg·BM^{-1}; lower performance (LP): $N = 8$; BM=82.6±14.0 kg; 1RM PC=0.78±0.1 kg·BM^{-1}) and resistance training age (HP: resistance training experience=3.5±1.2 years; LP: resistance training experience=1.44±1.50 years) undertook 10 weeks of training involving weightlifting derivatives, in addition to supplemental ballistic and plyometric exercises. Testing of athletic performance (represented by measures derived from the countermovement jump) occurred at baseline, after five weeks of training, and after ten weeks of training. Both groups significantly improved across the majority of outcome variables following training (Hedges g=0.98–2.55, $P \leq 0.01$-0.05). Only the HP participants experienced significant changes at mid-test (g = 0.99–1.27, $P \leq 0.01$-0.05), while no significant changes were revealed between mid- and post-test in this group. In contrast to this, the LP participants displayed a significant improvement in relative impulse (g=1.39, $P<0.01$) and rate of force development (g=1.91, $P<0.01$) during this final period ($P<0.01$). As weaker, inexperienced lifters underwent a significant and meaningful enhancement in maximal neuromuscular measures following weightlifting derivative focused training, practitioners should consider early implementation of such exercises. However, it is important for coaches to note that a delayed training effect might be present in weaker, less experienced lifters.

Keywords: maximal strength, resistance training, athletic performance, maximal power

INTRODUCTION

Maximal neuromuscular expressions (i.e velocity, power, force and rate of force development (RFD)) are considered the most influential muscle functions across a multitude of sports (2, 5, 18, 19, 25). As such, the development of these qualities is of great relevance to sports scientists and strength and conditioning coaches, with numerous methods of training used to develop these attributes. While traditional strength training, ballistic and plyometric training, in addition to weightlifting movements and their derivatives have all been shown to increase neuromuscular capabilities and performance in athletic tasks (6, 27), previous literature has displayed greater overall results when training with weightlifting movements (1, 4, 17, 29, 30).

Traditional strength training exercises (e.g. back squat) tend to emphasise force production, primarily resulting in increases in the ability to exert higher forces at relatively low velocities. Such methods may be limited due to a period of deceleration during the latter half of the concentric phase, although this does decrease at higher loads (23). In contrast, ballistic and plyometric tasks generally result in force being produced quickly (<250 ms) during relatively high velocity movements, at the expense of training under high external loads. In addition, a mixed methods approach which differentially trains all aspects of the force-velocity spectrum may be preferential (13). For example, a change in the emphasis between force and velocity can be accomplished in a periodized training plan by combining strength and plyometric training in a mixed methods approach.

The use of weightlifting actions are considered a desirable modality for developing velocity, force and power, as they incorporate moderate to high external loads, along with minimal, if any, deceleration during the propulsion phase (10-12, 14, 15). Such activities result in a combination of high forces and velocities both of which can be manipulated dependant on the external load used (13, 22, 26). In addition, there is considerable intermuscular coordination resulting in the potential for a greater transfer of training to athletic performance (26).

However, when compared to less complex resistance training tasks, there is a belief that the increased technical demands of such exercises may require extended periods of practice before improvements in muscle function and transfer to athletic performance is revealed, particularly in individuals who are weaker and possess a lower resistance training age. This can have implications in strength and conditioning settings where the time available to develop physical qualities and technical proficiency is often limited. As such, some may question the time-cost of incorporating weightlifting actions in those with limited strength or technical proficiency. Recently, Haug et al. (16) investigated this notion in a group of four elite athletes naive to weightlifting movements. It was revealed that considerable increases in power output derived from the countermovement jump (CMJ) and squat jump (SJ) resulted following the inclusion of the hang power clean to regular training over a four-week period. While this provides information on the transfer of weightlifting actions to performance in elite athletes, it is currently unknown the extent of athletic performance improvement experienced by non-athletes with low relative strength levels in weightlifting movements compared to stronger individuals with a greater resistance training age. This investigation seeks to compare the adaptability of individuals with lower versus higher relative maximal power clean (PC) performance in response to weightlifting-derivative based training. It was hypothesised that those with limited resistance training experience and a lower relative maximal (PC) performance would not only improve strength levels in this lift to a greater extent than individuals with superior PC results and greater training experience, but that these improvements will translate into similar gains in athletic performance (measures derived from the CMJ) after short-term (10 weeks) training. Furthermore, it was anticipated that a delayed training effect would be experienced by the weaker participants, resulting in a greater magnitude of improvement in athletic performance markers in the later stages of training. If the data support these hypotheses, then coaches can more confidently reject the notion that weightlifting actions are not a viable method for improving athletic performance amongst weaker, inexperienced lifters in a brief timeframe.

METHODS

Experimental design

Participants were divided into either a higher- or lower-performance (HP or LP) group on the basis of their relative one repetition maximum (1RM) PC, consequently training age differed between the groups also. A 10-week training program that emphasised the use of weightlifting derivatives for the lower body was completed by both groups. Training was arranged into two, five-week mesocycle blocks. Testing occurred prior to the onset of training (baseline), after the first five-week mesocycle (mid-test) and after completion of all training requirements (post-test). Familiarization for all testing and training techniques occurred across three one-hour sessions, prior to baseline testing. Measures of lower body CMJ performance were taken at each timepoint. To assess early stage changes in weightlifting based performance, the 1RM PC was performed at baseline and mid-test.

Participants

Twenty recreationally active males participated in the investigation. Subjects were ranked in accordance with their relative 1RM PC performance at baseline. To establish two groups, data from the participants with a relative 1RM PC between 0.8 and 1.0 kg·BM^{-1} were removed from the analysis. This resulted in an HP group ($N = 8$; BM = 78.1 ± 4.0 kg; height = 1.74 m; 1RM PC = 1.08 ± 0.09 kg·BM^{-1};1RM squat = 2.0 ± 0.2 kg·BM^{-1}) and LP group ($N = 8$; BM = 82.6±14.0 kg; height = 1.81 m; 1RM PC = 0.78 ± 0.1 kg·BM^{-1};1RM squat = 1.38 ± 0.32 kg·BM^{-}

^{1}) group. This stratification method also resulted in a considerable difference in resistance training age between the groups (HP: resistance training experience = 3.5 ± 1.2 years; LP: resistance training experience = 1.4 ± 1.5 years; $P < 0.01$, ES = 1.43). This allowed for comparison between groups of distinctly different resistance training experience and relative PC strength level. Written, informed consent was secured from all participants and the study was approved by the university's Human Research Ethics Committee.

Training program

Familiarization with all training and testing procedures occurred across three, one-hour sessions. The training plan included three supervised one-hour sessions each week over two, five-week mesocycles separated by one-microcycle of a week duration to allow for restitution and mid-testing. The objective of the first mesocycle was to determine the presence of early-stage changes in PC and athletic performance. The second mesocycle was introduced to explore any delayed training effect that might have been present. Training sessions were at least 24 hours apart and consisted primarily of weightlifting derivatives. To better replicate a common resistance training plan, ballistic tasks and plyometric exercises using a variety of loads were also included (Table 1). Weightlifting derivatives were encouraged to be performed with maximal intent, while ballistic and plyometric actions were executed with the goal of achieving the greatest vertical displacement. At the beginning of each session, participants performed a general dynamic warmup followed by multiple submaximal sets preceding the working sets of all exercises. A recovery period of three minutes was enforced between each set, and participants were required to refrain from any additional lower body training.

Table 1: Integrated ballistic training intervention

WEEKS 1- 5			**WEEKS 6 - 10**		
Exercise	*Sets/Reps*	*Loading*	*Exercise*	*Sets/Reps*	*Loading*
Day 1 and 3			**Day 1 and 3**		
Power clean	5 x 5	70% 1RM	Jump squat	5 x 5	0%1RM(D1) 30%1RM(D3)
Jump squat	5 x 5	40% 1RM (D1), 50% 1RM (D3)	Power clean	5 x 4	85%1RM
Day 2			Depth jump (5s between repetition recovery)	*	Unloaded
Hang power clean	4 x 5	55% 1RM (of the PC)			
Snatch grip pull	4 x 5	70% 1RM (of the PC)	**Day 2**		
			Hang power clean	5 x 4	70%1RM (of the PC)
			Snatch grip pull	5 x 4	85%1RM (of the PC)
			Plyometric split squat (rebound)	4 x 3ea	Unloaded

1RM: 1 repetition maximum; D1: day 1; D2; day 2; D3: day 3; PC: power clean
* Depth jump volume progressed in the following fashion (sets/reps): Week 6 – 3 x 3, Week 7 – 3 x 4, Week 8 - 4 x 4, Week 9 and 10 - 5 x 4

Testing overview

Participants completed a testing battery before commencement of training (baseline), after five weeks of training (mid-testing) and after ten weeks of training (post-testing). Mid-testing occurred three to five days after the final workout of week 5, while post-testing was conducted between seven and ten days after the last workout of week 10. Weightlifting performance was assessed via the PC one-repetition maximum (1RM). The unloaded CMJ was employed to determine a series of maximal neuromuscular related variables (e.g. peak and average velocity and power, force, rate of force development (RFD)). Simultaneous force plate readings were gathered during the session for the CMJ test.

1RM power clean

The PC 1RM was assessed two to seven days prior to the CMJ testing requirements. Participants performed a full body dynamic warmup followed by the PC at the following estimated loading conditions and repetition ranges: 30 and 50%1RM for three repetitions, 70 and 90% 1RM for a single repetition. Maximal attempts were then made until a 1RM was reached via an increasing load of ≥ 2.5 kg. Three to five minutes of passive recovery was enforced between 1RM attempts, and a second effort after a failed attempt was allowed. A trial was considered successful if the performer received the bar at an internal knee angle ≥ 90°, which was visually monitored by the primary researcher.

Countermovement jump

Participants performed a minimum of three non-continuous CMJ's for maximal height. The jump containing the highest peak velocity was used for analysis. Analog ground reaction force (GRF) signals (Bertec Corporation, USA) were collected at 2000 Hz (NI USB-6259 BNC, National Instruments) and processed using a custom interface (LabView, V.12.0f3, National Instruments). Secondary processing occurred offline using a custom program (The Mathworks, Inc., Natick, MA). Vertical ground reaction force (Fz) provided direct measures of force applied to the system. The onset of the countermovement was considered the sample at which Fz decreased by four times the SD of body weight attained from the preceding period of standing. A forward dynamics approach was used via the impulse-momentum relationship to assess velocity of the center of gravity, while the product of force and velocity at each time point represented power. Peak velocity, force, power and acceleration were defined as the greatest instantaneous sample of the respective variable during the action. The integral of force with respect to time for the values exceeding system weight during the jump represented impulse. Average power and velocity were calculated from the bottom of the countermovement (minimum velocity) to take-off, while RFD was calculated between the minimum and maximum force value throughout the movement. Force, impulse, power, and RFD were divided by body mass to be expressed in relative terms. The test-retest reliabilities for jump squat variables achieved an ICC = 0.92, and a CV = 4.7%.

Statistical analyses

All data were normally distributed (Shapiro-Wilks test) and homogeneity of variance was accepted (i.e. Levene's test return a non-significant result). This allowed for the execution of a 2 × 3 (group × time) repeated measures general linear model with a post-hoc Bonferroni adjustment to locate any differences in the absolute change between groups. This procedure was also used to identify any significant within group changes between time points using a 1 × 3 (group × time) structure. An Alpha level of $P \leq 0.05$ denoted statistical significance. Hedges' g effect size (ES) calculations were employed with thresholds set at <0.2, 0.21-0.5, 0.51-0.8 and >0.8 for trivial, small, moderate and large magnitudes of effect, respectively, to establish the practically relevant within group changes between means during baseline, mid- and post-test. Data are presented as mean ± standard deviation. Statistical Package for Social Sciences (Version 23.0, IBM Corporation, Somers, New York, USA) was utilized to analyse non-magnitude based data, while ES were calculated using a custom designed spreadsheet (Microsoft Excel 2013, Microsoft Corporation, Washington, USA).

RESULTS

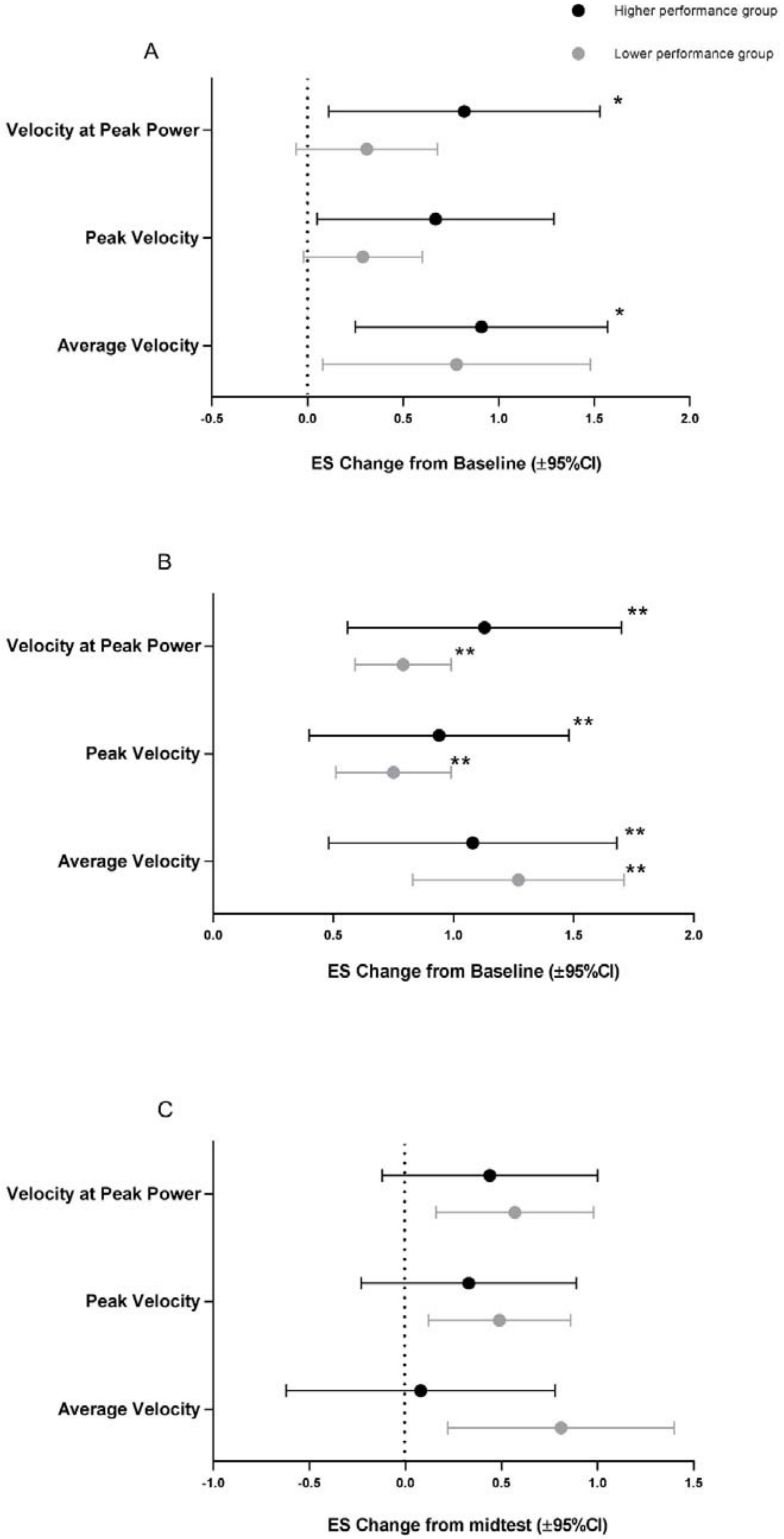
All participants completed 100% of the training sessions, and no adverse events were recorded. Both groups displayed significant improvements in PC 1RM across the two time-points in which it was measured (HP: $P = 0.02$; LP: $P < 0.01$; ES 95% CI = HP: 0.51 (0.23 to 0.83); LP:

1.05 (0.73 to 1.45)). There was a significantly greater magnitude of change in PC 1RM amongst the weaker participants ($P < 0.01$).

The degree of change between any time-points did not differ significantly between the two groups across the primary CMJ variables (peak velocity: baseline to mid-test $P = 0.53$, baseline to post-test $P = 0.69$, mid-test to post-test $P = 0.40$; average velocity: baseline to mid-test $P = 0.62$, baseline to post-test $P = 0.63$, mid-test to post-test $P = 0.18$, Net impulse: baseline to mid-test $P = 0.36$, baseline to post-test $P = 0.55$, mid-test to post-test $P = 0.12$) (Figures 1-3).

Both groups significantly improved across a number of outcome variables following training (Figures 1-3). Only the HP participants experienced significant changes at mid-test, while no significant changes were revealed between mid- and post-test in this group. In contrast to this, the LP participants displayed a significant improvement in relative impulse and RFD during this final period ($P < 0.01$).

Effect size comparisons revealed only decrements or trivial to small improvements during the second block of training in the HP group. In contrast to this, the LP participants experienced large and moderate improvements across a number of measures during the same period. From baseline to post-test, both groups experienced a large improvement over five measures. A moderate degree of improvement was displayed across a total of three and two variables in the LP and HP groups, respectively (Figures 1-3). The HP participants experienced a moderate decrease in force at peak power during this period, while no decrements in performance were present in the LP group.


Higher performance group
Lower performance group
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Velocity at Peak Power
Peak Velocity
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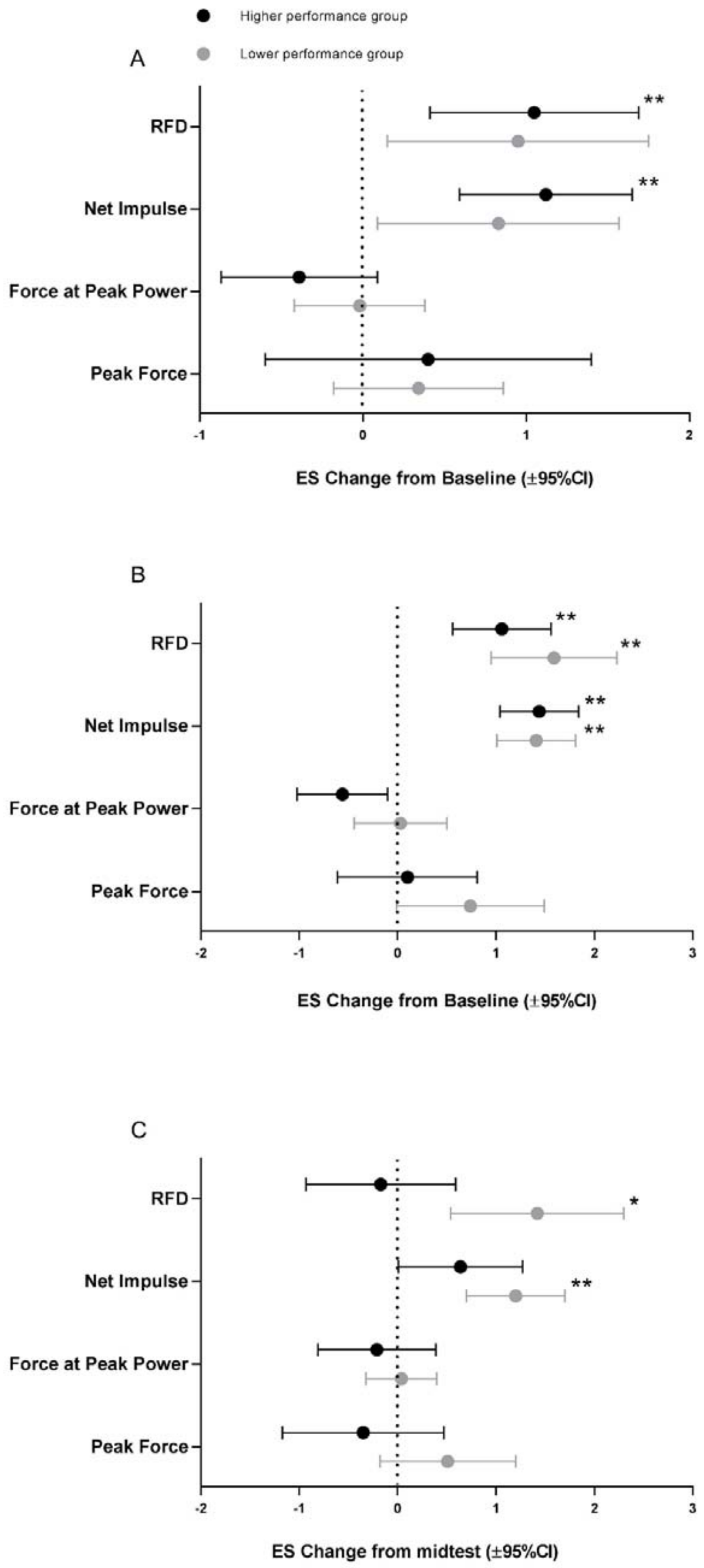
ES Change from midtest (±95%CI)

Figure 1. Magnitude of change (Hedges' *g*) from baseline to mid-test (A), baseline to post-test (B) and mid-test to post-test (C) across both groups in velocity variables. * Denotes statistically significant change at $P \leq 0.05$. **Denotes statistically significant change at $P \leq 0.01$. ES: Hedge's *g* effect size.


Higher performance group
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Force at Peak Power
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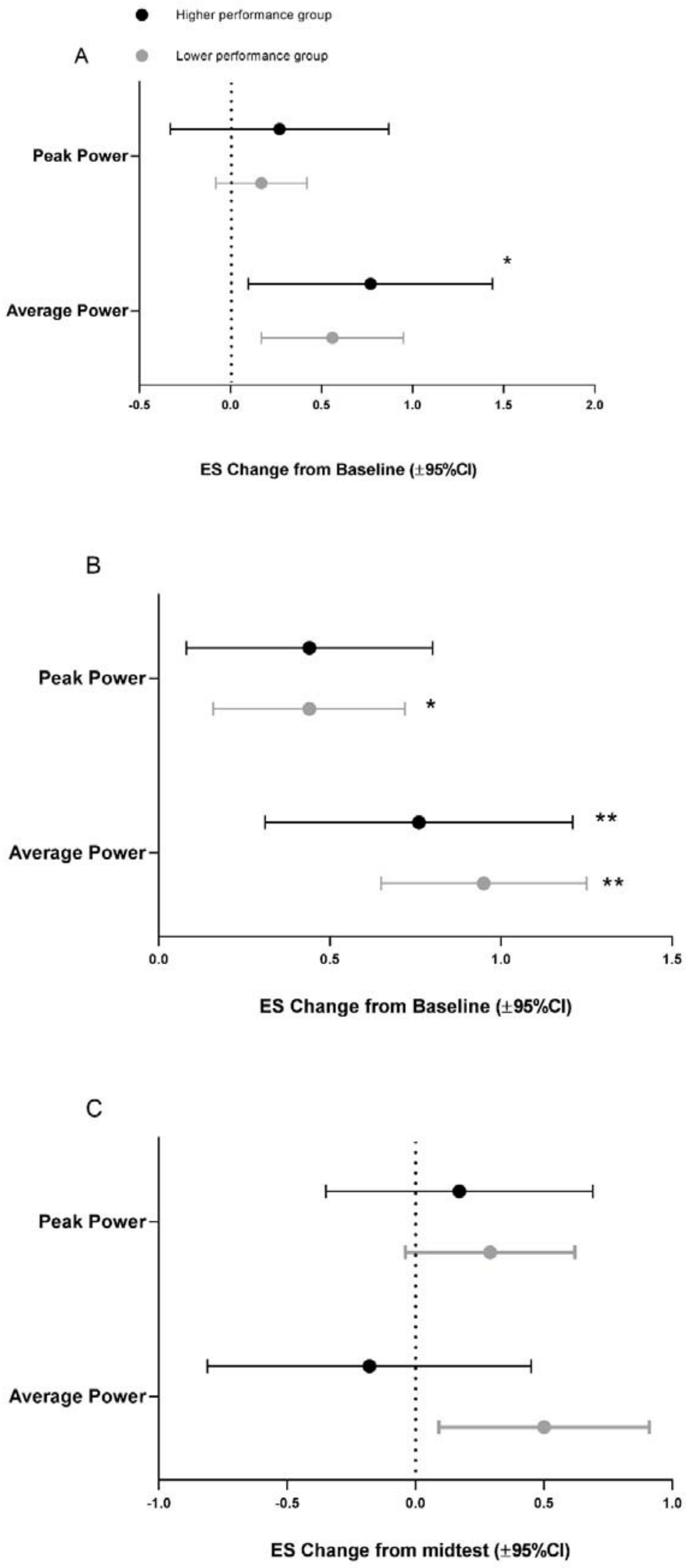
ES Change from midtest (±95%CI)

Figure 2. Magnitude of change (Hedges' *g*) from baseline to mid-test (A), baseline to post-test (B) and mid-test to post-test (C) across both groups in force variables. * Denotes statistically significant change at $P \leq 0.05$. **Denotes statistically significant change at $P \leq 0.01$. ES: Hedge's *g* effect size. RFD: rate of force development.


● Higher performance group
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C
Peak Power
Average Power
-1.0
-0.5
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1.0
ES Change from midtest (±95%CI)

Figure 3. Magnitude of change (Hedges' *g*) from baseline to mid-test (A), baseline to post-test (B) and mid-test to post-test (C) across both groups in power variables. * Denotes statistically significant change at $P \leq 0.05$. **Denotes statistically significant change at $P \leq 0.01$. ES: Hedge's *g* effect size.

DISCUSSION

The purpose of this study was to explore the extent and rate of adaptation experienced by weaker, lower training aged individuals, compared to those who are stronger, with a greater training age, in response to a 10-week weightlifting derivative-based training intervention. The main findings of this investigation were that both groups experienced significant improvements across a range of performance measures; however, the time course and nature of the adaptations were considerably different between groups. Firstly, a significantly greater change was experienced by the LP group in PC strength. While this is unsurprising considering the larger window of adaptation present, it does highlight that marked short-term improvements in weightlifting-based performance does occur in those with limited training experience and strength capabilities. As no adverse events were recorded either, taken together this supports the feasibility of implementing the weightlifting derivatives with inexperienced individuals under time constraints.

While changes in 1RM PC reflects the ability to improve the performance of weightlifting actions, inspection of the variables derived from the CMJ indicates the translation of this improvement to athletic performance. Perhaps the most interesting findings were the differing rates of adaptation between the two groups across the CMJ performance variables revealed by ES comparisons. When examined only between baseline and post-test, a similar or larger magnitude of increase in force and power variables were displayed by the LP group; however, comparisons between other time points (baseline to mid-test, mid-test to post-test) reveal notable ES differences. The magnitude of change between mid- and post-test across these particular mechanical functions was considerably greater in the LP group. This indicates the presence of a delayed training effect whereby timing must first be optimized to translate newfound strength into measures of athletic performance (3). In contrast to this, all velocity, power and most force variables had improved to a practically greater extent at mid-test amongst HP participants. This is in agreement with findings of markedly superior short-term improvements in jump performance variables following training in individuals with greater 1RM squat values (7). However, the stratification on the basis of 1RM PC performance in this present study indicates that this holds true for whole-body lifts with combined force-velocity demands also. As those who are stronger are in possession of increased CSA and maximal force capacity (which are considered the factors underpinning enhanced velocity performance) (31), it might be such that these allow for superior adaptation to training. However, the increased intermuscular coordination required for performance in the PC when compared to a more common measure of maximal strength (e.g. back squat) might alter this early adaptive response. This is because coordinative factors represent an additional function driving improved velocity-emphasised expressions (21, 22, 28). It is of note that McBride et al. (20) reported that despite no significant differences in 1RM squat strength, training age or body mass, competitive weightlifters displayed superior performance in the CMJ across a range of variables when compared to powerlifters. Such findings suggest that, when compared to less technical force-dominant actions, the mechanisms underpinning weightlifting performance might provide a superior foundation to develop high velocity expressions. This would also explain the significant performance improvements experienced by the LP group in the second block of training, after an increased PC 1RM was achieved (g = 1.26, 95% CI = 0.19 to 2.33). Another notable finding was that the HP group achieved marginal or negative further gains in performance measures across the final training block. It is possible that the training stimulus was not sufficient to counteract the cessation of their typical lifting behaviours, resulting in a degree of detraining during the last five weeks of the intervention.

In addition to the rate of adaptation, differences were present in the types of performance changes experienced between the groups. While the LP participants displayed more general improvements across force, velocity and power variables, the HP group produced more specific adaptations. This is represented by large increases in variables related to timing, such as net impulse, RFD and measures of velocity between baseline to mid-test and baseline to post-test in these participants. However, decrements or limited improvements in peak force and force at peak power were attained between any two time points. This suggests that while the HP group successfully improved the control of muscle function, maximal force capabilities were somewhat attenuated. Such a response is likely a consequence of reduced exposure to heavy strength training as a result of the training protocol. It would therefore be advisable to retain heavy strength training alongside weightlifting actions.

A limitation of this investigation is that the inclusion of other ballistic exercises may confound the ability to fully delineate the contribution of weightlifting actions to the observed adaptations. However, this study design better reflects those commonly found in high-performance settings by including a variety of modalities (8, 9, 24), while retaining an emphasis on weightlifting derivatives. As a consequence of this increased ecological validity, practitioners can be more confident in the applicability of these findings to their practice.

In conclusion, differing adaptations are experienced on the basis of weightlifting performance and training age when exposed to a weightlifting derivative-emphasised training plan. In particular, less experienced lifters with poorer PC performance experience large improvements in this lift in the short-term. However, while transfer to athletic performance does occur, it is somewhat delayed when compared to more experienced individuals with greater weightlifting ability.

PRACTICAL APPLICATIONS

As considerable short-term improvements in weightlifting performance are experienced by weaker, lower training aged individuals, strength and conditioning coaches should not consider training with weightlifting derivatives as technically prohibitive in this population. Furthermore, because a significant and relevant enhancement in maximal neuromuscular measures followed this group's improvement, practitioners can also expect a transfer to athletic performance (e.g. greater jump height as indicated by the increase in net impulse) in those with limited training experience. However, it is important for coaches to note that a delayed training effect might be present in less experienced individuals, and the nature of adaptation will differ from those with superior weightlifting ability.

Conflicts of interest

The authors have no conflicts of interest relevant to this investigation.

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FIGURE LEGENDS

Figure 1. Magnitude of change (Hedges' *g*) from baseline to mid-test (A), baseline to post-test (B) and mid-test to post-test (C) across both groups in velocity variables. * Denotes statistically significant change at $P \leq 0.05$. **Denotes statistically significant change at $P \leq 0.01$. ES: Hedge's *g* effect size.

Figure 2. Magnitude of change (Hedges' *g*) from baseline to mid-test (A), baseline to post-test (B) and mid-test to post-test (C) across both groups in force variables. * Denotes statistically significant change at $P \leq 0.05$. **Denotes statistically significant change at $P \leq 0.01$. ES: Hedge's *g* effect size. RFD: rate of force development.

Figure 3. Magnitude of change (Hedges' *g*) from baseline to mid-test (A), baseline to post-test (B) and mid-test to post-test (C) across both groups in power variables. * Denotes statistically significant change at $P \leq 0.05$. **Denotes statistically significant change at $P \leq 0.01$. ES: Hedge's *g* effect size.