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Effect of preload squatting on sprint performance in adolescent athletes

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ABSTRACT

Training methods and warm-up practices aimed at developing high levels of muscular power have recently received significant attention from researchers and applied practitioners. One such method utilises a combination of resistance training and sports–specific movement. The purpose of this study was to investigate the effects of different intensity resistance exercises (i.e., 65, 75 or 85% 1-repetition maximum back squat) conducted over multiple sets prior to a 50m sprint in highly trained adolescent track and field athletes. A secondary purpose was to investigate whether the athletes' 1-repetition maximum back squat has an impact on the responses observed. The results suggest that performing heavy load resistance exercises (HRE) prior to the sprint start has no significant effect on 50m sprint performance in highly trained adolescent track and field athletes, even when conducted over multiple sets. The results also suggest that practitioners may wish to consider improving a relative 1-repetition maximum back squat in already trained adolescent athletes in order to improve maximal sprinting speed. Our data also suggests that there might be at least positive time saving benefits in performing HRE prior to sprinting over multiple sets utilising the protocols provided.

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Introduction

Training methods and warm-up practices aimed at developing high levels of muscular power have recently received significant attention from researchers and applied practitioners. One such method utilises a combination of resistance training and sport–specific movement. Complex Training (CT) has been defined as the combination of a heavy loaded resistance exercise (HRE) followed by a biomechanically similar plyometric exercise performed in an alternating manner[1]. It has been suggested that after HRE (e.g. 3-5 repetition maximum [RM]), a post-activation potentiation (PAP) effect can occur. PAP has been defined as the change in the force-time and force-velocity characteristics of skeletal muscle whereby its contractile ability after a previous conditioning contraction results in an enhancement in the explosive capability[2]. PAP may lead to increased performance in an activity such as the vertical jump[1] or a sport-specific movement such as a sprint[3].

A number of recent studies in elite athletes or university-aged students have investigated the short-term effects of HRE such as a heavy load back squat on sprinting performance[3-9]. Studies have exhibited both inconsistent[3, 4, 7, 9] and positive responses[5, 6, 8] on performance (e.g. -1.12% in 100m sprint time[8]), based on variations in pre-sprint exercise volume and intensity, intra-complex recovery periods and athlete characteristics. Furthermore, most of these studies have utilised acute protocols over single sets with high intensities (≥85% 1-RM)[3, 4, 9] or 3 – 5- RM[5, 7-9] using the back squat as the stimulus to produce a PAP effect in subsequent sprint performance.

Maximal resistances have been suggested as necessary for full motor unit recruitment and thus necessary to create a PAP effect. Nevertheless, KHAMOUI et al.[10] recently suggested that an explanation for the failure to produce an enhancement in performance following their intervention may be the fact that, despite a potential beneficial PAP effect, a load of (≥)85% 1-RM may have evoked fatigue, masking, in turn, the possible PAP effect. This is further supported by KILDUFF et al.[11] who suggested that decreases in performance following a heavy resistance training (>80% 1-RM)[12-14] can be attributed to muscle fatigue associated with heavy resistance training (e.g. low intramuscular stores of phosphocreatine). BAKERr[15] also suggested that most studies that have not reported a significant effect have used in excess of 85% 1-RM or 5-RM for the "heavy stimulation set". Using lighter resistances in the range of 60-75% 1-RM may therefore be more effective when using CT[15,16]. Another explanation for the lack of inconsistencies among previous studies could be the subjects' maximal strength level. For instance, previous research has suggested that absolute back squat strength could influence subsequent performance following the 'heavy stimulation set" and that stronger subjects may exhibit a PAP effect whereas weaker subjects failed to potentiate[2].

The implication for applied practitioners working with adolescent athletes is prescribing the most appropriate intensity for the "heavy stimulation set". It appears that no study has investigated a range of intensities of HRE on subsequent sprint performance conducted over multiple sets in highly trained adolescent athletes. It appears also that no study has investigated whether stronger adolescent athletes possess a greater propensity to generate a PAP performance effect in sprint performance following a HRE than weaker adolescent athletes. Finally, this combination of training, if sprinting performance was at least not to be altered, would at least provide a potential time saving benefit during training.

Therefore, the purpose of this study was to investigate the effects different HRE intensity (i.e., 65, 75 or 85% 1-RM back squat) conducted over multiple sets in the form of CT prior to a 50m sprint in highly trained adolescent track and field athletes. A secondary purpose of this study was to investigate whether the athletes' 1-RM back squat has an impact on the responses observed.

Methods

Experimental Approach to the Problem

This investigation utilised a cross-over randomised design over three sessions in highly trained adolescent male athletes. With a minimum of seven days between sessions, athletes completed three different CT sequences (HRE + sprint), differing only by the pre-load HRE intensity (65, 75 and 85% 1-RM) (Figure 1). The choice of these three intensities was based on previous findings demonstrating enhanced performance following HRE[5, 6, 17]. The same time of day was used for reliability reasons and to control for circadian variation[7, 18]. Athletes completed all sprints on an indoor synthetic track in track shoes. Track temperature (24.3 ± 1.5º) and humidity (44.6 ± 3.2 %) were obtained during every session. Athletes 1-RM back squat was pre-determined in a testing session (Testing Session 1) no less than 7 days prior to the commencement of the study.

Subjects

Eight (n = 8) male adolescent athletes (sprinters, n = 7; and long jumper, n = 1) from an elite junior sports academy were recruited for the study ((mean ± SD: age 16.5 ± 1.3 y, mass 67.8 ± 6.2kg, height 175.6 ± 4.4cm, training 14 ± 2 hrs a week, maturity status estimated at 2.3 ± 1.0 year from peak height velocity (PHV)). PHV is an indicator of somatic maturity representing the time of maximum growth in stature during adolescence, and was defined from anthropometric variables according to Mirwald et al.[19]. Personal best times for the 100m sprint ranged between 10.61 and 12.2 sec. All athletes had a minimum of one year's experience in performing the back squat exercise and had been familiarised throughout the training year with various forms of CT including the back squat and sprint. Athletes were training within a specific preparation period prior to a summer competition schedule.

Written informed consent was obtained from the athletes and their parents. The study, which as approved by the local research ethics committee, conformed to the recommendations of the Decleration of Helsinki.

Procedures

Back Squat Testing Session - In testing session 1, each athlete's 3-RM back squat was determined and 1-RM was then estimated using the tables provided by BAECHLE & EARLE[20]. A warm-up protocol adapted from previous research was utilised for establishing each athlete's 3-RM back squat[11]. Participants performed three warm-up sets of eight repetitions at 50% of their previously known 1-RM, four repetitions at 70% 1-RM and two repetitions at 80% 1-RM. Following the final warm-up set, each participant attempted three repetitions of a chosen set load (3-RM). If the lift was successful, the lifting weight was increased until the weight could not be lifted through the full range of motion. All athletes were required to have their 3-RM determined within a maximum of three attempts. A five minute rest was imposed between all attempts to allow adequate time to recover, i.e. to replenish energy stores[11]. Lifts were deemed successful as described by the International Powerlifting Federation[21] rules for performing the back squat requiring the subject to descend to a point where the inguinal fold is lower than the patella and ascend to the standing position without assistance [22].

Treatment Testing Sessions - A timeline for each session is provided in Figure 1. During each session athletes performed one baseline sprint followed, ten minutes after, by four sets of the CT sequence (i.e., HRE + sprint). Each CT set consisted of five HRE repetitions of the back squat followed four minutes after by the 50m sprint. During the recovery period, they walked approximately 30m to the indoor track and changed to their running spikes in preparation for the 50m sprint. Athletes completed a four-minute active rest between sets during which time they were required to change in to their training shoes, walk back to the weight room in preparation for the next set of back squats.

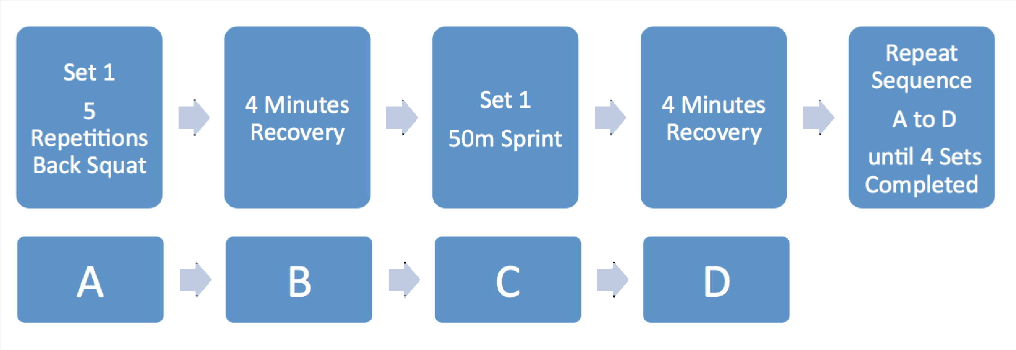

Figure 1: Timeline of Complex Training Protocol

Sprint Time Measurements

All 50m sprint trials were measured by the Laveg laser device (LAVEG, Jenoptik). A linear distance measurement at a sampling frequency of 100Hz was provided and connected to a laptop. The LAVEG was set at 2m behind the starting line and directed at the lower part of the athlete's back. Athletes were instructed to commence at a distance of 30cm behind the start line and followed the commands of "Set" and "Go" with the laser beam activated in the "Set" position. Data was recorded until the subject was a minimum of 2m past the finish line. Maximum sprinting speed, distance at which maximal sprinting speed is reached, 10m and 50m times were computed. Test-retest reliability of average running velocity measurements using the Laveg laser system within a 3m measurement zone has been estimated to present an intraclass correlation coefficient (ICC) of 0.96[23]. In our study, reliability of the Laveg laser system (calculated from the three baseline tests) for the following parameters were established: maximum sprinting speed: 1.9% (90%CL: 1.3;3.4), distance at which maximal sprinting speed is reached: 18.2% (12.5;35), 10m time: 3.1% (2.2;5.7) and 50m time: 1.9% (1.3;3.4).

Statistical Analysis

Data were analyzed using a 2-factor ANOVA for repeated measures with 'conditions' (65, 75 and 85% 1-RM) and 'sets' (Pre and the four sets) as factors. Analyses were carried out with SPSS Software 12.0 (SPSS Inc, Chicago, IL) and the level of significance was set at $P \leq 0.05$. Linear regressions with Pearson's coefficients were also used to establish the respective relationships between performance parameters and 1-RM back squat. In addition to statistical significance, especially because of the present small sample size, the following criteria were adopted for interpreting the magnitude of correlation (r (90% confidence limits, 90%CL)) between test measures: < 0.1, trivial; <0.1-0.3, small; <0.3-0.5, moderate; <0.5-0.7, large; <0.7-0.9, very large; and <0.9-1.0, almost perfect. If the 90% confidence limits overlapped small positive and negative values the magnitude was deemed unclear, otherwise that magnitude was deemed to be the observed magnitude 24. Data are presented as means ± SD.

Results

Times for 10m and 50m during the three conditions are illustrated in Figure 2. There was neither a condition (all P values > 0.41) nor a set (all P values > 0.32) effect on any of measured variables. Average values for maximal sprinting speed and distance at which maximal sprinting speed was reached were 9.0 ± 0.4 m.s-1 and 39.0 ± 0.4m, respectively.

We found no correlation between individual responses to each treatment and either absolute or relative 1-RM back squat (all correla-

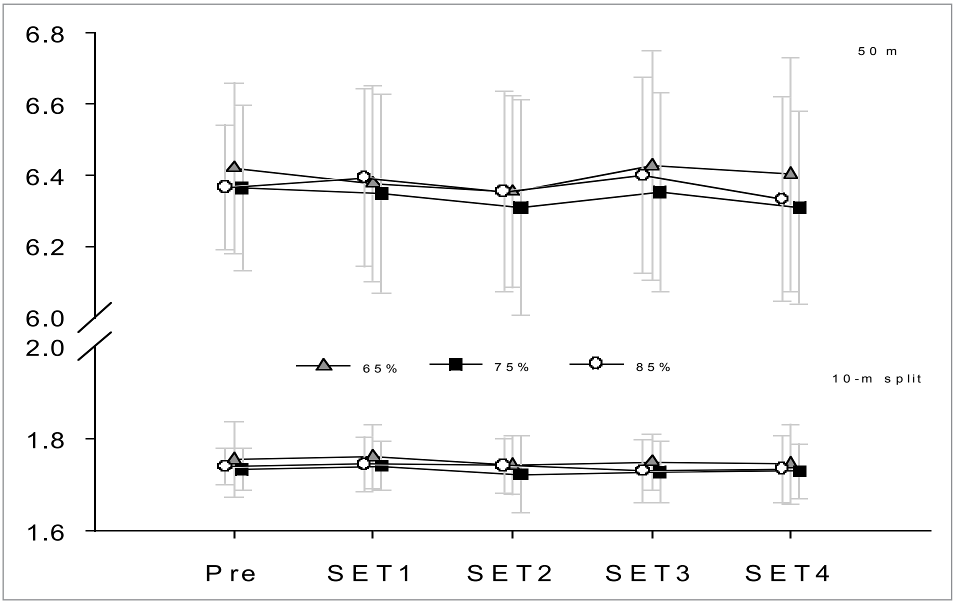

Figure 2: Changes in 10m split and 50m sprint times during the 65, 75 or 85% 1RM back squat pre-load conditions over the five repetitions (i.e., baseline (Pre) and four successive sets) (Data are mean values (SD)

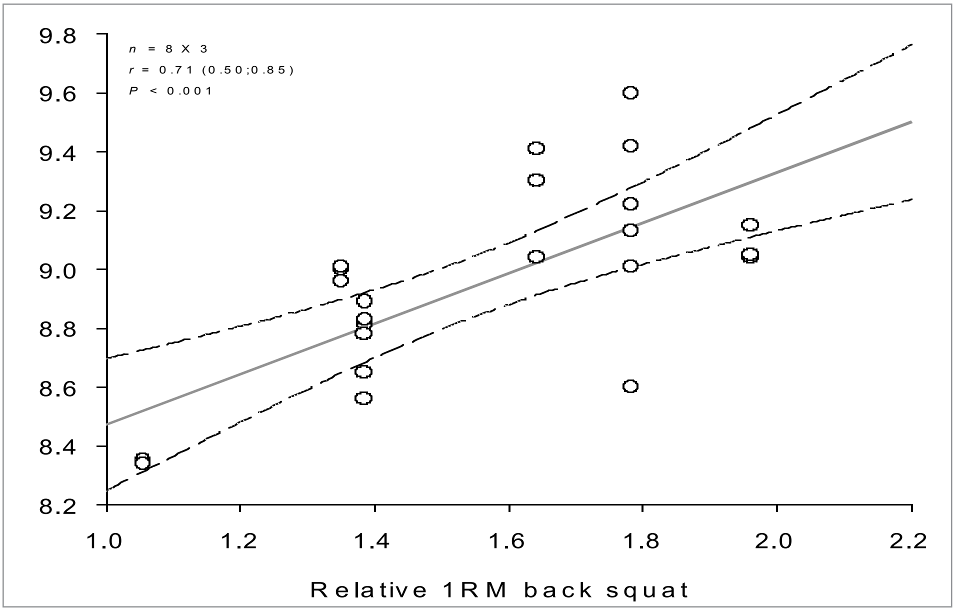

Figure 3: Correlation between maximal sprinting speed measured during each baseline measurement and relative 1RM back squat (Dotted lines are 95% confidence intervals.)

tions rated as unclear and all $P > 0.57$). There were however some large to very-large correlations between relative 1-RM back squat and 50m sprint times (r = 0.67 (0.42;0.82), $P < 0.001$) and maximal sprinting speed (r = 0.71 (0.5;0.85), $P < 0.001$) (Figure 3), but not with the distance at which maximal sprinting speed was reached (r = 0.20 (-0.15;0.51), P = 0.34). There was only a moderate correlation between relative 1-RM back squat and 10-m time (r = 0.35(0.01;0.62), P = 0.10).

Discussion

The main findings of this study were as follows: 1) the three intensities of HRE (65, 75 or 85% 1-RM) have similarly no impact on sprint performance; 2) there was no sprinting performance decrement over the four consecutive sets, irrespective of the intensity used during the HRE condition and 3) there were large to very-large correlations between relative 1-RM back squat and sprinting performance (i.e. 50m sprint time and maximal sprinting speed).

To our knowledge, this is the first study to investigate the effect of a range of intensities in the back squat prior to sprint performance conducted over multiple sets in highly trained adolescent athletes. We observed no effect of any of the heavy back squat loads on sprint performance (Figure 2). This is consistent with previous studies involving heavy loads and sprint performance[3, 4, 7]. However, these studies were conducted in amateur team sport players4, elite rugby players[7] and university-aged football players[3]. For example, Comyns et al.[7] found that over multiple exposures of a HRE + sprint sequence using a 4-minute intra-complex recovery period, there was no significant enhancement in 30m sprint performance. In contrast, McBride et al.3 found significant decreases (i.e., -0.87%) in 40m sprint times 4 minutes following HRE (90% 1-RM), despite no significant differences in 10m or 30m split times. Positive responses have also been found in other studies[5, 6, 8] (e.g., -8.0 ± 1.0% in 10m sprint time[9]) based on variations in pre-sprint exercise volume and intensity, intra-complex recovery periods and athlete characteristics.

No specific biomechanical and/or electromyography recordings were obtained in our study. Therefore, any effect of the heavy back squat protocol on any neuromuscular or stride parameters could not be examined. It may be speculated that if significant improvements in these variables occurred due to a number of mechanisms such as PAP, faster sprint times may have resulted. Alternatively, if a PAP effect has occurred, the lack of improvement in sprint times following either the 65, 75 or 85% 1-RM protocol may be masked by any number of confounding factors such as the balance between PAP and fatigue[2] intra-complex recovery period[25], variability of individual responses, as well as variations in individual squat and sprint technique[7].

This optimal balance between PAP and fatigue following HRE and the ensuing recovery period (i.e, namely the intra-complex recovery) prior to a performance such as a sprint, has implications for applied strength and conditioning coaches who wish to utilise any potential PAP effect through CT. In our study we utilised an intra-complex recovery period of 4 minutes, which is consistent with other studies that have demonstrated improvement in an acute subsequent sprint performance following HRE using intensities in excess of 80% 1-RM[3, 5, 7]. Given the fast neuromuscular performance recovery abilities of young individuals[26], it may be hypothesised that the intra-complex recovery period utilised in our study with young athletes was possibly not appropriate (i.e., too long) to allow any potential PAP effect to manifest during subsequent sprint performance. This intricate balance could be further confounded when one considers the differences between training status and/or differentiating between stronger and weaker athletes.

Training history and strength levels of individual athletes appear to be another common factor in PAP response throughout the literature[2, 9, 27-29]. GULLICH & SCHMIDTBLEICHER[27] reported that highly trained speed – strength athletes exhibited a significantly higher and longer lasting PAP effect compared with trained sports students while similar trends have been found in other studies that have distinguished between stronger and weaker subjects[30-32]. However, in contrast to these aforementioned studies, in the present study, we did not find any correlation between individual responses to each treatment and either absolute or relative 1-RM back squat. One possible reason for this lack of association could be related to methodological problems in the assessment of a 'true' 1-RM back squat with developing athletes, so that the actual relative load experienced by each athletes could have been different (i.e., not at a similar percentage of their 'true' 1-RM). While our subjects may be described as 'highly trained adolescent athletes', it may be that developing athletes are more exposed to a number of factors (e.g., poor motor control, lack of neuromuscular strength to accommodate the load being lifted[33], individual technique, hip flexor flexibility) than elite trained athletes during a technical movement such as the heavy load back squat. Such factors might confound the attainment of a 'true' 1-RM.

It is also possible that the difference in load intensities were not large enough to produce substantially different responses to each treatment in our adolescent athletes, i.e., the load difference between the 65 and 85% condition was no more than 13kg in one athlete. While previous research utilising lighter loads for the pre load intensity (30% 1-RM) failed to provide any improvement in 40m sprint times in university-aged football players[3], it is unknown whether greater contrasts in the conditioning 'stimulus' (e.g., 30-55% 1-RM) may have helped understand the greater effect these variations on subsequent sprinting performance. Nevertheless, as illustrated in Figure 3, we found a significant correlation between maximal sprinting speed and relative 1-RM back squat in our highly trained adolescent athletes. In contrast to what we hypothesized above, this tends to illustrate the validity of the 1-RM in our athletes. Such a relationship is in fact consistent with previous findings in elite soccer players ($r = 0.91$, 10-m sprint; $r = 0.71$, 30-m sprint)[34], elite rugby league athletes ($r = -0.66$)[35] and female 100m sprinters ($r = -0.88$)[36] demonstrating a strong correlation between maximal squat strength and sprint performance[34]. This association confirms the importance of maximal strength for sprinting performance, and that the squatting movement can be regarded as good predictor of sprinting performance. It incorporates some stretch-shortening cycle (SSC) and hip extensor activity typical of longer sprints and high concentric muscle contractions and knee extensor activity typical of shorter sprints and related to starting ability[37].

The practical application of our study prohibited the use of a control session involving four sets of the 50m sprint with a 4-minute recovery period and this limitation prevented any comparison to repeated bouts of the 50m sprint to determine if a PAP effect may have elicited any beneficial effect over the four sets. Future studies should also utilise a greater number of subjects to better quantify the physical capabilities of each subject so one may determine possible group characteristics (e.g. responders versus non-responders) or individual responses to CT in order to gain a better understanding of contributing factors influencing any PAP effect. Care must be taken in the interpretation of our findings as any number of confounding variables may be present to completely eliminate the concept of a PAP effect before sprint activities.

In conclusion, our results suggest that performing HRE at a range of intensities (65, 75 and 85% 1-RM) four minutes prior to a 50m sprint has no significant effect on sprinting performance in adolescent track and field athletes, even when conducted over four consecutive sets. While longitudinal studies are warranted to draw definitive conclusions, present data suggests that there might be at least positive time saving benefits in performing HRE prior sprinting over multiple sets utilising the protocols presently provided[38].

Practical Applications

While incorporating a series of heavy back squats prior to the sprint start is unlikely to provide immediate sprinting performance benefits in highly trained young track and field athletes, present results suggest however that coaches may wish to utilise the possible time saving benefits of the combination of HRE and sprints in during training utilising the protocols provided in this investigation. The time saving and practical benefits of being able to combine power- and speed-based activities as an alternative training content within a heavy resistance exercise training programme could be advantageous to athletes especially involved in heavy competition or training schedules[38]. Finally, our results confirm the significant relationship between maximal strength and sprint performance, which should encourage coaches to improve maximal back squat strength in order to improve MSS in trained adolescent athletes.

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