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Peak Power Output in Loaded Jump Squat Exercise is Affected by Set Structure

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ABSTRACT

International Journal of Exercise Science 11(1): 776-784, 2018. A priority in strength and power exercise might be to train with as high quality as possible for the shortest possible duration. In this context, peak power output could reflect quality. Designing an exercise session as a cluster set structure, as compared to a traditional set structure, may be a way to obtain higher peak power output in the session. But it is unknown whether that is obtainable for non-elite individuals performing loaded jump squat exercise. The aim of the present study was therefore to test the hypothesis that peak power output would be highest in a jump squat exercise session, which was structured with cluster sets, as compared to traditional sets. Ten individuals (2 women, 8 men; 26.5 ± 4.8 years, 1.81 ± 0.08 m, 90.9 ± 13.2 kg) performed two loaded jump squat exercise sessions structured with cluster sets and traditional sets, respectively. The sessions were performed on two separate days, in counterbalanced order. The position of the barbell was used to calculate derived values including peak power output. Values calculated as averages across the entire exercise sessions showed peak power output to be 178 ± 181 W, corresponding to 4.1% ± 4.9%, higher in the session with cluster set structure, as compared to the session with traditional set structure (p = 0.005). It was concluded that for non-elite individuals, peak power output was approximately 4% higher in a loaded jump squat exercise session structured with cluster sets as compared to an exercise session structured with traditional sets.

KEY WORDS: Ballistic exercise, resistance training, set configuration, weight training

INTRODUCTION

Preparation for sport performance includes training a number of skills or capacities, which can be grouped into: physical, psychological, technical, and tactical capacities (7). Discipline-specialized training of a particular sport of interest constitutes a part of the training. In addition, separate training sessions with focus on fundamental physical characteristics are often included as a part of the complete training regimen to enhance the athletes' performance. Such separate training sessions often aim at creating an overload, which is followed by recovery, adaptation, and improvement. One particular physical characteristic, which athletes and coaches often seek to improve, is peak power output. Lorenz *et al*. reviewed relevant literature and suggested that for anaerobic field and court sport athletes, peak power output is most predictive of elite athletes' performance (9).

One particular exercise that is used to improve peak power output is the loaded jump squat. The exercise includes knee and hip extension and involves the quadriceps and the gluteal muscles (12). Consequently, that particular training exercise is relevant for numerous sport disciplines, such as rugby, basketball, as well as disciplines within track and field (8). It has been reported that 6 weeks of loaded jump squat training performed with various loads could increase peak power output by approximately 12% in a counter movement jump (14).

Considering a single strength and power exercise session, a number of variables may be modified in an attempt to affect acute responses within the session such as for example force and power output. Examples of variables are duration, load, number of repetitions and sets, number and duration of rest periods, and set structure (12). The available time for a strength and power exercise session may be limited for the athletes. This may particularly be true when the strength and power exercise session is considered a supplement to improve performance in a specific sport. For athletes, a priority may become to train with as high quality as possible for the shortest possible time. In the present context, quality could be reflected by an overall high peak power output.

Strength and power training sessions are often organized as a certain number of sets that each contain the same number of repetitions. Further, each set is followed by a specified rest period with the purpose of counteracting fatigue. That organization could be termed a traditional set structure (16). As an alternative to the traditional set structure, a cluster set structure can be applied (16). A cluster set structure divides each set into clusters of repetitions (e.g. 2 clusters of each 2 repetitions) with a short rest period (e.g. 15 s) included between each cluster (5). Consequently, the total rest time within a set is longer during cluster set structure than during traditional set structure. A cluster set structure thus enables better recovery (e.g. adenosine triphosphate (ATP) resynthesis and metabolic byproduct removal) within each set (16).

Hansen *et al.* reported that peak power output during loaded jump squat was reduced less (indicating less fatigue) across a cluster set as compared to across a traditionally structured set (6). The difference amounted to on average 7.2% (p = 0.01). However, the study included elite rugby union players, and the results are therefore limited to this population. It is unknown if results would have been similar if non-elite individuals, for example recreationally active individuals, were studied. It is unknown if results would have been similar if non-elite individuals, for example recreationally active individuals, were studied.

The purpose of the present study was to compare peak power output in two different loaded jump squat exercise sessions structured with traditional sets and cluster sets, respectively. For the present study, non-elite individuals were tested. It was hypothesized that peak power output would be highest in the exercise session that was structured with cluster sets.

METHODS

Participants

A total of 10 individuals (2 women and 8 men) volunteered for the present study. They were 26.5 ± 4.8 years old, had a height of 1.81 ± 0.08 m, and had a body mass of 90.9 ± 13.2 kg. All participants were recreationally active, had at least one (on average 6.6 ± 4.5) year of experience with resistance training, but were all non-elite. None of the participants were trained in jump squats. Written informed consent was obtained from all participants. The present study was carried out in accordance with the recommendations of the North Denmark Region Committee on Health Research Ethics and the study conformed to the standards set by the Declaration of Helsinki.

Protocol

A group of participants performed two jump squat exercise sessions in a counterbalanced crossover design. This enabled a comparison of acute responses in the two exercise sessions. The exercise sessions simulated common practice consisting of warm up followed by a number of sets of repetitions of loaded barbell jump squats. The only difference between the two different exercise sessions was the set structure. In one of the exercise sessions, a traditional set structure was applied. In the other exercise session, a cluster set structure was applied. Details of the set structures are explained below. The two exercise sessions were separated by at least 7 (on average 8.7 ± 3.3) days.

The participants were instructed to abstain from exercise 24 h before both exercise sessions. At the beginning of the first exercise session, the participant filled out a questionnaire regarding his or her training background. In addition, age, height, and body mass were determined. Then, a warm up regimen was completed. The warm up regimen was initiated by approximately 7 min of diverse dynamic stretching exercises for the lower body. The stretching exercise are known as Supine Scorpion, Prone Scorpion, Spiderman Complex, Russian Baby-makers, Cossack Squat, and Rollovers into V-Sits. These stretching exercises targeted the back muscles as well as the hip and knee extensor muscles. The stretching exercises were followed by a set of 6 repetitions of jump squats. During these, the hands were gripping a broom stick that was placed across the shoulders, behind the neck. With regard to the jump squat technique in the present study, the following applied. The amount of knee flexion at the lowest position during the squatting movement, the movement tempo, as well as the duration of pause held at the lowest position, were freely chosen by the participant. The intention was to allow the participant to perform maximally. Subsequently, a set of 6 repetitions of jump squats were performed with a barbell (instead of the broom stick) loaded to a total mass (i.e. including the mass of the barbell and rounded to the nearest 1 kg) of 20% of the body mass. These two warm up sets were separated by 180 s of rest. After the two warm up sets, the participant had 180 s of rest before initiation of the key part of the exercise session.

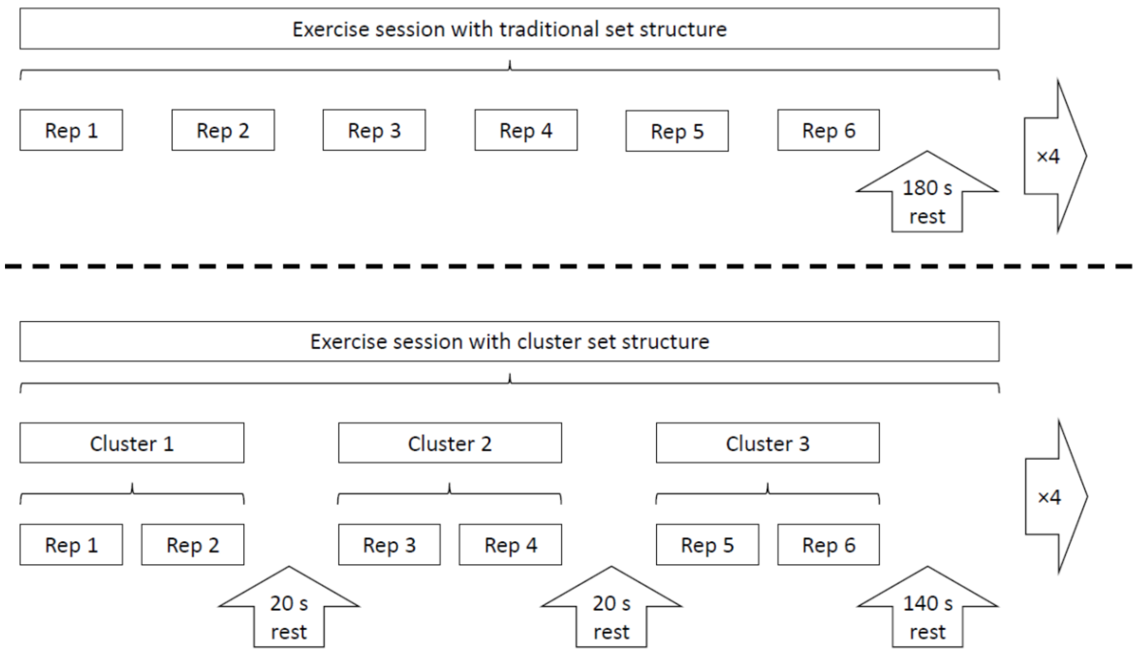

Figure 1. Illustration of the set structures in the two performed separate exercise sessions with traditional sets and cluster sets, respectively.

The exercise session with traditional set structure consisted of 4 sets of 6 repetitions of loaded jump squat. Within each set, the jump squats were performed in a consecutive way without rest. With regard to loading, the total mass (sum of barbell and weight plates) corresponded to 40% of the participant's body mass (rounded to the nearest 1 kg). After each set, the participant rested for 180 s. During rest, the barbell was placed in a squat rack. When the participant lifted the barbell from the squat rack, a start position was taken, on a drawn line on the floor. Then, the jump squats were performed. Verbal encouragement was given throughout the exercise session in order to encourage the participant to perform at a maximal effort in each jump squat. The cluster set structure also consisted of 4 sets. But each set was split into 3 clusters of 2 repetitions. The repetitions within each cluster were performed in a consecutive way without rest. Between the clusters, the participant rested for 20 s. After each set, the participant rested for 140 s. Otherwise, the exercise session with cluster set structure was performed as the exercise session with traditional set structure. Both the traditional and the cluster set structures resulted in a total of 720 s of rest. Figure 1 illustrates the two different set structures.

A version 5 Gymaware Powertool (Kinetics Performance, Mitchell, Australia) was used for data collection. This device was placed on the floor, to the right of the participant, under the barbell sleeve. A wire from the Gymaware Powertool was attached to the middle of the barbell sleeve. The Gymaware Powertool measured time as well as the position of the wire (i.e. how far the wire was pulled out of, or back into, the Gymaware Powertool device). The device uses a variable rate sampling with level crossing detection to capture data points. Subsequently, it limits (down samples) this to 50 points per s. From these data, variables of peak velocity, peak acceleration, peak force, and peak power output are calculated by differentiation.

The validity of peak power output calculated by a previous version (version 2) of the Gymaware Powertool has previously been assessed for the smith machine bench press throw exercise (2). The validation showed that peak power output determined from the Gymaware Powertool and from video analysis strongly correlated ($r = 0.99$, $p < 0.01$). In another validation study, kinematic and kinetic measures from the Gymaware Powertool were compared to data from a force platform in the loaded jump squat exercise performed at various external loadings of 20, 40, 60, and 80 kg (1). The results from Crewther *et al.* showed that for peak force ($r = 0.59 – 0.87$, $p < 0.05$) and peak power output ($r = 0.62 – 0.82$, $p < 0.05$), there were moderate to very strong correlations between data from the two recording systems (1).

The jump height was calculated from the position data as follows. For each jump squat repetition, a baseline vertical position was calculated for the participant in a standing position before beginning the jump squat. This baseline position was calculated as the average of 25 time points, corresponding to at least 0.5 s. Then, the baseline vertical position height was subtracted from the maximal vertical position obtained in each repetition, to achieve the squat jump height for each repetition. For each participant, and each calculated variable, an average value was calculated across the 24 repetitions performed within an exercise session. That average value was used for further analyses.

Statistical Analysis
All statistical analyses in the present study were performed with SPSS version 24 (IBM®, Armonk, New York, USA). First, data were tested for normal distribution using the Shapiro-Wilk test of normality. Only the difference in peak velocity was found to be normally distributed. Consequently, a paired samples two-tailed t-test was used to evaluate differences in this variable. For peak force, peak power, and jump height, the nonparametric related samples Wilcoxon signed rank test was applied to evaluate differences between set structures. Data are presented as average ± standard deviation, unless otherwise indicated. $p < 0.05$ was considered statistically significant.

RESULTS

Peak velocity, peak force, peak power output, and jump height for the two separate exercise sessions are presented in Figure 2. The peak force was 141 ± 263 N, corresponding to 5.2% ± 8.3%, higher in the session with cluster set structure as compared to the session with traditional set structure ($p = 0.047$). The peak power output was 178 ± 181 W, corresponding to 4.1% ± 4.9%, higher in the session with cluster set structure as compared to the session with traditional set structure ($p = 0.005$). The differences between the two exercise sessions for peak velocity ($p = 0.307$) and jump height ($p = 0.074$) did not reach statistical significance.

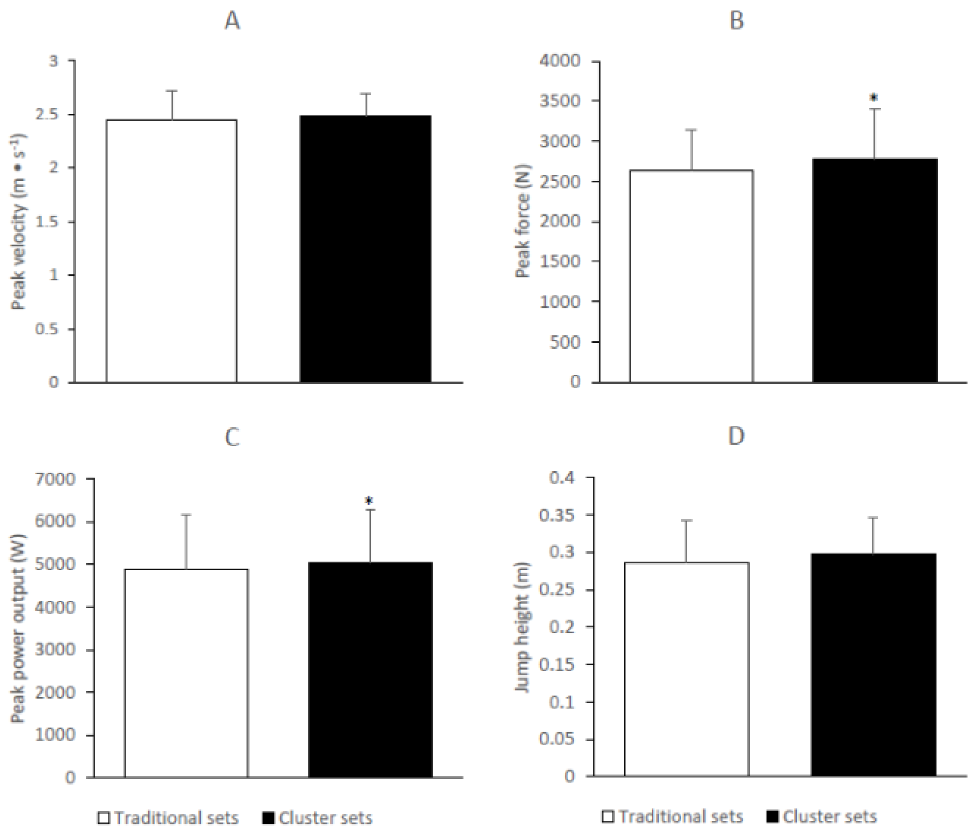

Figure 2. Illustration of peak velocity (A), peak force (B), peak power output (C), and jump height (D) from the two performed separate exercise sessions with traditional set structure and cluster set structure, respectively. The bars illustrate average values (+SD) for the entire group of participants. *Different from the exercise session with traditional set structure, $p < 0.05$.

DISCUSSION

The result of the present study showed that peak power output was approximately 4% higher in the exercise session with cluster set structure as compared to the session with traditional set structure. This result corresponds with a comparable previously reported result of 3% to 9% found by applying the same exercise, although in elite rugby union players (6). Yet another study that involved strength trained men who performed sessions of back squat exercise resulted in a finding of 9% to 16% higher peak power output for exercise sessions with cluster set structures as compared to a session with traditional set structure (16).

A possible mechanism for the higher peak power output during exercise with cluster set structure could be better conditions for regeneration of intramuscular phosphocreatine (PCr) and adenosine triphosphate (ATP). This has been reviewed recently (15). Briefly, ATP regeneration from PCr breakdown takes place during the rest periods and is important for production of power output during short term (< 30 s) maximal efforts. Phosphocreatine depletion starts almost immediately at the onset of muscle contractions, and depletion continues as the contractions are continued (10). During repeated contractions, as in dynamic resistance exercise, PCr is depleted more the further the set is continued. It has been reported that PCr in the vastus lateralis muscle was depleted significantly less after 5 repetitions than after 10 repetitions with the same load in the bilateral leg press exercise (4). Furthermore, Miller *et al.* showed that regeneration of PCr stores was initiated almost immediately following the cessation of exercise (10). When applying a cluster set structure, fewer repetitions are performed before rest is allowed. In addition, rest is allowed more frequently. Thus within each set, small windows of ATP and PCr regeneration is allowed, which eventually may allow higher peak power output to be performed.

Another possible mechanism relates to accumulation of metabolic byproducts, which has been suggested to attenuate the regeneration of ATP and PCr (13). A negative relationship between peak power output and muscle lactate concentration has been reported (4). Furthermore, blood lactate concentration has been reported to be significantly lower after exercise with a cluster set structure as compared to exercise with traditional set structure (3). In addition to lower blood lactate concentrations immediately after the cluster set structured exercise, subjects were able to perform better in counter movement and standing long jumps, again, as compared to the traditionally structured exercise. It is possible that the organization of rest periods in the cluster set structured exercise allows accumulated metabolic byproducts to be cleared more effectively and thus not influence the ATP and PCr regeneration and eventually peak power output production negatively.

In the present study, the peak force was approximately 5% higher when performing the exercise session with a cluster set structure. For comparison, Hansen *et al.* also investigated the jump squat exercise and found no difference in peak force between traditional set and cluster set structured exercise sessions when averaging all repetitions in a session (6). Tufano *et al*. found no difference in peak force in the back squat exercise when comparing sessions performed with traditional and cluster set structures (17, 18). Oliver *et al*. found that for back squat (performed as 4 sets of 10 repetitions), 5 out of the 10 repetitions (averaged across the 4 sets) were performed at a higher peak force, when using a cluster set as compared to a traditional set structure (11). Thus, with regard to the effect of set structure on peak force, the literature seems divided.

The present study found that by using a cluster set structure in a loaded jump squat exercise session, the peak power output in the jumps was higher than if a traditional set structure was applied. The two different exercise sessions applied in the present study were of equal duration, which is often relevant when planning exercise sessions. If the highest possible peak power output in an exercise session of loaded jump squats is wanted, it can best be achieved by applying a cluster set structure. In the future, longitudinal studies must be performed to elucidate any differences in long term training adaptations of applying cluster set structure in contrast to traditional set structure for loaded jump squats.

In conclusion, the present study showed that peak power output was approximately 4% higher in a loaded jump squat exercise session structured with cluster sets as compared to an exercise session structured with traditional sets. This result was obtained in non-elite individuals.

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