# A PILOT STUDY INVOLVING THE EFFECT OF TWO DIFFERENT COMPLEX TRAINING PROTOCOLS ON LOWER BODY POWER

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#### ABSTRACT

**Purpose.** Complex training (CT) involves the coupling of two exercises ostensibly to enhance the effect of the second exercise. Typically, the first exercise is a strength exercise and the second exercise is a power exercise involving similar muscles. In most cases, CT is designed to enhance power. The purpose of this study was twofold. First, this study was designed to determine if lower body power could be enhanced using complex training protocols. Second, this study investigated whether the inclusion of a power exercise instead of a strength exercise as the first exercise in CT would produce differences in lower body power. **Methods.** Thirty-six recreationally-trained men and women aged 20 to 29 years attending a college physical education course were randomly assigned to one of three groups: squat and countermovement squat jumps (SSJ), kettlebell swings and countermovement squat jumps (KSJ), and a control (CON). Training involving CT lasted 6 weeks. All participants were pre- and posttested for vertical jump performance in order to assess lower body power. **Results.** Vertical jump scores improved for all groups (p < 0.01). The results also indicated that there were no statistically significant differences between group scores across time (p = 0.215). The statistical power for this analysis was low (0.312), most likely due to the small sample size. However, the results did reveal a trend suggesting that the training improvements were greater for both the SSJ and KSJ groups compared with the CON (by 171% and 107%, respectively) although significance was not reached. **Conclusions.** Due to the observed trend, a replication of this study with a greater number of participants over a longer period of time is warranted.

Key words: complex training, lower body power

#### Introduction

Athletes are always searching for training techniques to gain a competitive edge. New methods are continually being developed whereas old methods are recycled and modified. Unfortunately, many of these training methods, though having some merit, become transient trends that fail to yield quality results.

Among the new training methods offering some promise is complex training (CT). CT is still being considered as a viable approach for enhancing power [1, 2]. It involves performing a resistance or weight training exercise followed shortly by a biomechanically-similar plyometric exercise. This particular combination is referred to as a complex pair. Training of this nature has become popular in recently developed programs, with one of the most well-known of these programs being CrossFit. The rationale behind CT is based on the theory of postactivation potentiation (PAP), which describes the enhanced neuromuscular state observed immediately after a session of heavy resistance exercise [3]. If biomechanically similar explosive power exercises are performed while the muscles are in this potentiated state, an individual may see an increase in both acute and chronic performance [1, 2]. Therefore, CT provides a channel for eliciting PAP.

A common example of how this is accomplished is by performing a 2–6 repetition maximum (RM) squat, followed within a few minutes by a vertical jump or series of vertical jumps. The challenge, however, is finding the point at which PAP is at its highest [3]. Fatigue makes this difficult to achieve. It can coexist with PAP and may inhibit its exploitation [4, 5]. If fatigue is too great, such as immediately after the heavy resistance exercise is performed, then PAP cannot have optimal effects [3]. If too much time passes, fatigue is lessened but so are the effects of PAP. Another factor which may affect PAP that has not received much attention is the demands of the exercises in the complex pair.

The majority of the research on CT utilized a protocol involving a strength exercise followed by a power exercise [1, 3, 6–12]. However, few studies have been conducted using an initial power exercise instead of the more often used strength exercise in the complex pair [13–15]. Therefore, the purposes of this study were to examine the effects of CT on lower body power as measured by vertical jump performance and to investigate whether or not the nature of the first exercise, strength (e.g. squat) or power (e.g. kettlebell swing), affected PAP and performance.

## Material and methods

University IRB approval was obtained before proceeding with this study. Thirty-six recreationally trained (in-

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volved in 60 min of moderate-to-vigorous physical activity, 3–5 days a week for the last 3 months) men and women aged 20–29 years participated in the study. The participants were recruited from a physical education course held at a Southwestern United States college. Each participant provided both written and oral consent before engaging in the study.

The participants were required to complete a screening questionnaire. The first portion of the questionnaire included questions to determine the physical readiness of each individual to participate in the study (Physical Activity Readiness Questionnaire); the second portion included questions regarding nutrition and supplement intake. All participants needed to be free of injury in the preceding 3 months. Participants were excluded if they had taken ergogenic aids (e.g. anabolic steroids, growth hormone, or any performance-enhancing drugs). Participants were allowed to continue with the study if they were taking, or had previously taken, vitamins or mineral supplements.

The sample was randomly assigned to three groups (each with 12 participants): squat and countermovement squat jumps (SSJ), kettlebell swings and countermovement squat jumps (KSJ), and a control group (CON). Vertical jump performance was assessed using a Vertec measurement apparatus [16] and follows a similar model used by the National Strength and Conditioning Association [17]. Prior to testing, each participant conducted a dynamic warm-up consisting of the following exercises: walking superman stretch (posterior chain), lunge walk w/twist, lateral lunge walk, walking knee lift, quad stretch, leg swings, calves stretch, and arm swings. After performing the warm-up, the reach height of each participant was obtained by keeping the shoulders square and the reach arm (chosen by the participant being tested) was extended straight upward. Standing reach was subtracted from the highest of the participant's respective vertical jump attempts to determine vertical jump height. No approach steps were permitted but a countermovement jump was used prior to takeoff. Each of the participants completed a minimum of three jump attempts although the participants were not limited to three jumps if they continued to improve. Rest periods between jumps were determined by the participants' perceived readiness and lasted approximately 30 s to 2 min. Testing for each participant was completed within 15 min or less. The highest vertical jump measure of each participant was used for data analysis.

The study protocol involved one preliminary screening session, the intervention (6 weeks of complex training held three times per week for the SSJ and KSJ groups), and one post-test session. The preliminary screening included the previously mentioned questionnaires and a pre-test assessment of vertical jump performance (Figure 1).

Participants assigned to the SSJ group were tested for 1RM squat in order to ensure that at least 75–85% of







Figure 2. Squat depth

1RM is used as a preload for the complex sets [2, 18]. The participants were required to squat to a depth in which the top of the quadriceps were parallel with the floor (Figure 2). If during the 6 weeks of training a participant progressed and became capable of lifting 85% 1RM for more than six repetitions, the number of repetitions was then increased to eight. If lifting the weight at eight repetitions was found to be too easy, 5 kg were added and the repetitions dropped to four and six.

Participants assigned to the KSJ group were also tested if they were capable of swinging a kettlebell of at least 20 kg for four to six repetitions. Participants in this group were required to swing the kettlebell so that the handle reached at least the clavicle during the four to six repetitions (Figure 3). If during the 6 weeks of training a participant was capable of lifting a heavier weight, the load was increased by at least 4 kg (the maximum weight recorded in the study was 36 kg).

The 6 weeks of CT performed by the SSJ and KSJ groups involved 18 sessions that were held three times per week on non-consecutive days. Each session lasted approximately 30 min. All three groups (CON, SSJ, and KSJ) were required to maintain the same level of physical activity throughout the 6 week period as they



Figure 3. Approximate kettlebell swing height

had for the 3 months prior to the start of the study. Participants were allowed to miss no more than two nonconsecutive training days. Missing two consecutive training sessions or more than two nonconsecutive training sessions resulted in dismissal from the study.

The protocol for the training sessions involved a dynamic warm-up and three CT sets. The dynamic warm-up consisted of the following exercises: walking superman stretch (posterior chain), lunge walk w/twist, lateral lunge walk, walking knee lift, quad stretch, leg swings, calves stretch, and arm swings. Both groups were also allowed a warm-up set of their respective exercise, as needed, before beginning the three complex sets. Four to six squat repetitions were performed in the SSJ group followed by five consecutive countermovement squat jumps. In the KSJ group, four to six repetitions of kettlebell swings were performed followed by five consecutive countermovement squat jumps. A recovery period of 3 min between the resistance training exercise (squats/ kettlebell swings) and the plyometric exercise (countermovement squat jumps) was provided to allow for phosphocreatine resynthesis [7, 9, 19, 20] (Figure 4).

At the cessation of the 6-week training, all participants (CON, SSJ, and KSJ) were post-tested for vertical jump performance. Overall test results were utilized to determine if CT had potential as an effective training strategy for enhancing lower body power and also to determine if the nature of the first exercise within a complex set (strength vs. power) affects the efficacy of this training.

Statistical analysis for the collected data was conducted using SPSS software ver. 16.0 [21]. Repeated measures ANOVA ( $3 \times 2$  factorial design) was used to test differences in pre- and post-measures of vertical jump height. An alpha value of 0.05 was selected in the data analysis.



Figure 4. Complex Training sessions used in the SSJ and KSJ groups

## Results

Of the three groups in the study, only eight subjects completed the training session in the SSJ group, eleven in the KSJ, and nine in CON group. In the SSJ group, one participant sustained an injury outside of the study and was unable to complete the program. The remainder of the subjects were excluded from the study due to low participation.

A statistical analysis was run on the pre-test measures, confirming there were no statistically significant differences between groups. The results of this study revealed a statistically significant main effect difference in pre–post vertical jump measures (F = 26.19, p < .001, pre-test mean:  $53 \pm 11.2$ ; post-test mean:  $57.3 \pm 12.6$ ). As demonstrated in Table 1, participants in the SSJ, KSJ, and CON groups improved by a mean 5.72 cm, 4.62 cm, and 2.11 cm, respectively. However, the results also indicated there were no statistically significant differences between group vertical jump scores across time (p = 0.215) for all three groups. However, the results did suggest that the training improvements were practically significant between the SSJ and CON groups as

| Table 1. Descriptive statistics for pre- and post-mean | n |
|--|---|
| vertical jump heights, % improvement,                  |   |
| and vertical jump differences                          |   |

|     | Group Vertical jump pre-test Vertical jump<br>post-test % improvement Difference |                 |      |      |  |
|-----|--|-----------------|------|------|--|
|     | (cm)   | (cm)            | (cm) | (cm) |  |
| SSJ | 55.6 ± 13  | 61.5 ± 13       | 10.5 | 5.72 |  |
| KSJ | $50.3 \pm 12.2$  | $54.9 \pm 13.5$ | 9.2  | 4.62 |  |
| CON | $53.1 \pm 8.4$   | $55.4 \pm 11.4$ | 3.97 | 2.11 |  |



Figure 5. Complex training effects on vertical jump height

well as between the KSJ and CON groups ( $\eta_p^2 = 0.12$ , Figure 5). This fits within the criteria for practical significance as explained by Tolson [22]. Cohen's *f* statistic for the group × time analysis was 0.35 ( $\eta_p^2 = 0.12$ ). Further examination of the results revealed low power (0.312), most likely due to the low number of participants in the study.

### Discussion

The purpose of this study was twofold. First, the study was designed to determine if lower body power could be enhanced using CT protocols. Second, this study investigated whether the inclusion of a power exercise instead of a strength exercise as the first exercise in the complex set would produce differences in lower body power.

The results of this study revealed a statistically significant difference in pre–post vertical jump scores in all three groups. The improvement of the SSJ group as a result of 6 weeks CT is in agreement with previous research [1, 3, 6–9, 11, 12, 15, 23–25]. For instance, MacDonald, Lamont, and Garner [8] found a significant improvement in vertical jump measures after 6 weeks of complex training in recreationally-trained males. Mihalik et al. [23] reported similar results in male and female club volleyball players after only 4 weeks of training. To the authors' knowledge, no research had been previously conducted using kettlebell swings as part of a complex training method, and the improvements observed in the KSJ group warrant further study. Why the CON group saw significant improvements in pre–post vertical jump scores is not entirely clear. It is possible that the participants in the CON group were more familiar and comfortable during the post-test assessment and this testing effect had some influence on the final result.

While there was a significant difference for each group from pre-to-post testing, no statistically significant difference was found between the SSJ, KSJ, and CON groups' vertical jump scores across time. Due to this result, it remains unclear whether there is any difference if the first exercise in a complex set is a squat or kettlebell swing. It is likely that with a higher number of participants in each group (e.g. n = 18 per group), there may have been different results. Figure 5 also suggests a trend for establishing statistical significance between groups over time had the study been carried out for a longer period.

From a practical standpoint, it appears that the results of the SSJ and KSJ groups are more favorable than those of the CON group as they improved, on average, by 5.72 cm and 4.62 cm, respectively, when compared with the CON group (2.11 cm). Furthermore, the improvements of the SSJ group appear to be more favorable than those of the KSJ group. One explanation for this result may be found when comparing the squat and kettlebell movements, squats are biomechanically more similar to the vertical jump than the kettlebell swing. Kettlebell swings rely more on the muscles of the posterior chain while the squat exercise places greater reliance on the quadriceps group. Nevertheless, it is difficult to determine how much of a factor this played in the results particularly without having enough participants or statistical significance.

Experimental mortality appears to have influenced results of the study, where the study began with 36 participants and ended with 28. The SSJ group lost the largest number of subjects, and it is possible that the training was physically more challenging with this group as opposed to the KSJ and CON. However, it is unclear whether the degree of difficulty with the workouts played a role in participant attrition. The most common reason given by participants who were unable to complete the study was that they could not fit the workouts into their schedule.

There are limitations in this study with regard to the pre- and post-vertical jump testing. After conducting the warm-up, the participants were not given a ceiling on the number of jumps they could attempt, only that

they were required to complete a minimum of three. The rest period was not specifically defined and controlled, with approximate recovery time from 30 s to 2 min between attempts. In addition, some studies have suggested a rest period of 3 min between jumps in order to ensure phosphocreatine resynthesis. Future studies may benefit from using the same recovery time [10, 15]. Also of note was that each participant finished vertical jump testing within 15 min or less. This method of testing may be more applicable in real life situations where the rest period between jumps or jump attempts are not so closely scrutinized. However, due to the lack of research supporting this approach, controlling the number of jumps and rest interval length is recommended in future research. In addition to using a more standardized testing protocol, researchers may consider using other methods of assessing vertical jump besides the Vertec. Although this device is commonly used in research studies, it has its weaknesses as a testing instrument [26-29]. Future studies might benefit from using videography in addition to the Vertec, as well as providing a familiarization session for vertical jump testing [30].

# Conclusions

Although the study presented a relatively basic pilot study, it provides useful information on the design of future research. The results indicate that such a complex training protocol can potentially increase lower body power. In addition, the results reveal a trend suggesting that the training improvements were greater for both the SSJ and the KSJ groups compared with CON group. While significance was not reached in this regard, the SSJ and KSJ groups improved 171% and 107% more than the CON group, respectively. Due to the observed trend, a replication of this study with a greater number of participants over a longer period of time is warranted.

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