EFFECTS OF FRONT SQUAT TRAINING METHODS ON FRONT SQUAT ONE REPETITION MAX AND CLEAN PULL FORCE PRODUCTION

Brian R. Budd II and Randall L. Jensen

School of Health & Human Performance, Northern Michigan University Marquette, Michigan, USA

This study examined effects of a six week front squat training program using a standard weight lifting technique (control) or a time under tension (TUT) technique on clean pull peak ground reaction force (pGRF) and front squat one rep maximum (1RM). Male collegiate subjects (n=9) with strength training experience performed a front squat 1RM. They also did a clean pull with their reported clean 1RM on force platforms pre and post training to determine pGRF. Front squat 1RM and pGRF for the clean didn't differ between groups ($p>0.05$) from pre to post-testing. Front squat 1RM increased 5.3% from pre to post in the TUT group, and 2.9% in the control group. Overall from pre to post training there was a significant increase in front squat 1RM and relative strength ($p<0.05$). Training used in this study caused significant strength improvements that may benefit an athlete.

KEY WORDS: time under tension, ground reaction force, weightlifting, resistance training

INTRODUCTION: Developing muscular strength and power are essential for increasing performance in many sports (Garhammer, 1993; Hedrick, 1993). Power, which is increased with an increase in force and/or velocity, has been shown to be beneficial to sport movements, as well as muscular strength. (Adams et al., 1993; Hoffman et al., 2004; Moffroid & Whipple, 1970). Considerations for modifying different variables when designing a resistance program such as sets, repetitions, frequency of training, and training methods are very important (Hedrick, 1993; Hedrick & Wada., 1993). Many training methods regarding strength training exist and there is much debate on which is the most effective (Cronin et al., 2004). Time under tension (TUT) during resistance exercise is defined as the cumulative time of tension that a muscle group undergoes during a training set or session (Tran et al., 2006). This type of training uses lighter loads compared to traditional training, but individuals perceive TUT training to be just as difficult due to the longer period of muscle tension (Egan et al., 2006). Slow lifting movements have been reported to produce greater increases in rate of muscle protein synthesis compared to rapid lifting movements (Burd et al., 2012). On the contrary, there is evidence that individuals performing normal or faster repetitions are able to produce significantly more force than those using slow training methods such as TUT (Keogh et al., 1999). Training at speeds that mimic the speed of performance (sport-specific) may benefit an athlete due to goals such as developing fast twitch muscle or developing high speed strength in sports that require a large amount of force and speed (Behm, 1991; Hedrick, 1993; Kaneko et al., 1983).
Weightlifting movements are of high force and velocity and are advantageous for power and strength development (Hoffman et al., 2004). Improving strength and force production are crucial in weightlifting to develop increased power (Garhammer, 1980). As previously mentioned, sport specific speed of training may be important to maintain or increase force and velocity (Burd et al., 2011). The purpose of this study was to use the same 6 week programming in two groups, TUT and control, each using a different weightlifting technique, and determining if these different resistance training methods alter force production (pGRF) and/or muscle strength (front squat 1RM).

METHODS: Nine collegiate males with resistance training experience were tested in this study (mean age = 21.5 ± 1.8 years, 77.8 ± 13.6 kg). Participants were currently resistance training for a minimum of one year and experienced with front squat and power clean weightlifting movements. They completed a Physical Activity Readiness Questionnaire and gave informed consent before the study began. Approval for the use of human subjects was obtained from the university's Institutional Review Board (HS17-893) prior to starting the study. Testing was on two separate days for both pre- and post-testing. Measures were taken the week before the program began and the week after it ended. In the first day of pre-testing, subjects performed a 1RM for the front squat starting with a general warm up, followed by 8-10 repetitions at 50% predicted 1RM (P1RM). After 3-4 minutes of rest, they performed 3 repetitions at 80% P1RM, followed by 3-7 attempts with 10-20% load increases with 3-4 minutes rest. Once 90% P1RM was reached, 5% load increases were done until 1RM was achieved. The 1RM was performed under supervision and subjects were told not to exercise within 24 hours of performing the 1RM. The second day of testing was conducted at least 48 hours after the 1RM with no exercise within 24 hours of the second test day. On this day, clean pulls on the force platforms were used to determine peak ground reaction force (pGRF). The clean pull was from the floor to full extension, with no countermovement to begin the pull, according to a competition weightlifting clean (IWF, 2018). The pGRF was defined as the sum of the maximum vertical values (from two force platforms). Body weight was measured and then the participants progressively warmed up as they desired to their reported maximum clean weight (mean=120 ± 36.4 kg). Participants then did two maximal pulls with two force platforms (OR6-7-2000; AMTI Watertown, MA USA) placed in the middle of a weightlifting platform, with one foot on each platform. Data were collected at 1000 Hz, displayed in real-time, saved, and analysed using AMTI Net Force Version 3.5.3 (Framingham, MA USA) along with Microsoft Excel to further analyse pGRF. The average pGRF for the two trials was used.

Following the pre-tests, subjects were randomly assigned to a control or experimental (TUT) squat group for a 6-week front squat program using an online random number generator (www.random.org). The post-testing procedures were the same as the pre-test and both the pre- and post-testing were done at the same time of day. For the TUT group, 85% of the tested front squat 1RM was used as the maximum for programming. Both groups followed a 6-week program (see Table 1). During 6 weeks of training, subjects were asked to follow their normal diet and workouts, but to limit intense aerobic and other leg resistance training. The control group in this study did a normal eccentric-concentric front squat technique with 2-3 minutes rest between sets. The TUT group performed front squats with a 3-4 eccentric phasefollowed by a 1 second pause in the isometric phase at the bottom of the squat and then a normal concentric phase (3/4-1-1-0). The TUT group rested for only 1-2 minutes between sets to elicit greater fatigue. The subjects could increase the intensity of the program, if desired, by reporting changes to the researchers. Subjects were required to complete at least 16 of the 18 total front squat workouts.

Table 1. Six week programming used for both control and TUT group with percentages based on pre-testing front squat 1RM.

	Monday	Wednesday	Friday
Week 1	2x10 @60%; 2x8 @70%	5x8 @70%	2x8 @75%; 2x6 @80%
Week 2	5x5 @75%	4x6 @75%	2x5 @70%; 3x6 @80%
Week 3	4x6 @75%	4x5 @75%	6x3 @82.5%
Week 4	3x2 @85%; 3x2 @90%	5x5 @75%	3x2 @95%
Week 5	4x2 @95%	3x3 @80%	3x5 @75%
Week 6	2x2 @100%*	3x3 @80%	4x2 @85%

*Subject should have an increased 1RM by week 6, therefore allowing for 2 repetitions of initial 1RM.

The pGRF during the clean pull and the front squat 1RM were recorded and used for comparison. Normalized pGRF (N/kg of body weight) was defined as the pGRF divided by body weight. Relative strength, was calculated as the weight lifted per kilogram of body weight (kg/kg of body mass). Statistical analysis was done with SPSS v. 24. A Two-Way Repeated Measures ANOVA was used to examine pre- and post-training measures for pGRF, front squat 1RM, and normalized PGRF. Alpha for all comparisons was set *a priori* at p=0.05.

Effect sizes using partial eta^2 (η_p^2) were also obtained for each dependent variable using the formula: η_p^2 = SS effect / (SS effect - SS error), where SS effect = effect variance and SS error = error variance. Interpretation of effect size was done using a scale for effect size classification based on F-values for effect size and were converted to η_p^2 using the formula: $F = (\eta_p^2 / (1 - \eta_p^2))^{0.5}$. Consequently, the scale for classification of η_p^2 was: 0.04 = trivial, 0.041 to 0.249 = small, 0.25 to 0.549 = medium, 0.55 to 0.799 = large, and 0.8 = very large (Comyns, Harrison, Hennessy, & Jensen, 2007).

RESULTS: Overall 8 of 9 participants finished the study, 3 in the control and 5 in the TUT group. One control subject did not finish the study. Mean values for pGRF (N) are displayed in Table 2 and mean values for normalized pGRF (N/kg) in Table 3. Two-way repeated measures ANOVA revealed no significant differences for pGRF (p=0.721) or normalized pGRF (p=0.617) from pre to post between the control and TUT group. The η_p^2 for pGRF was 0.023 and for the normalized pGRF was 0.044, indicating a trivial and small effect respectively.
The overall mean difference for normalized pGRF was 4.32 N/kg with a standard error of 1.85 (p=0.058; η_p^2 of 0.476), and the mean difference for pGRF was 288.6 N with a standard error of 150.9 (p=0.104; η_p^2 of 0.379). Both of these η_p^2 values indicate a medium effect.
Mean values for front squat 1RM are displayed in Table 3. Two-way repeated measures ANOVA indicated that there were no significant differences between groups for front squat max from pre to post (p=0.313). The η_p^2 for front squat max was 0.168 indicating a small effect. However, the overall η_p^2 of 0.611 demonstrated changes in front squat max from pre to post, which was also statistically different (p=0.022); i.e. a mean difference of 5.2 kg with a standard error of 1.69. The TUT group demonstrated a 5.3% increase in front squat 1RM compared to a 2.9% increase from pre to post in the control group.
Two-way repeated measured ANOVA also indicated that there were no significant differences between groups for relative strength from pre to post (p=0.935), but the overall η_p^2 of 0.668 reflected change in relative strength from pre to post that was statistically different (p=0.013); i.e. a mean difference of 0.082 ± 0.024 kg/body mass. The mean relative strength for pre- testing was 1.64 ± 0.40 kg/body mass and for post-testing was 1.72 ± 0.40 kg/body mass.

Table 2. Mean ± SD clean pull peak ground reaction force (pGRF) for each training method pre and post-training programming (n = 8).

	Peak GRF Pre (N)	Post GRF Post (N)	Percent Increase
Time under tension (n=5)	2959.2 ± 1312.3	3191.3 ± 915.9	7.8%
Control (n=3)	2170.5 ± 1025.2	2515.7 ± 965.5	15.9%

No statistically significant differences (p>0.05).

Table 3. Mean ± SD for normalized clean pull peak ground reaction force (pGRF) and front squat 1RM for each training method pre and post-training programming (n=8).

	Time under Tension (n=5)	Control (n=3)
Normalized Peak GRF Pre (N/kg)	34.4 ± 10.4	31.6 ± 14.2
Normalized Peak GRF Post (N/kg)	37.7 ± 5.3	36.9 ± 11.0
Normalized Peak GRF % Increase	9.6%	16.8%
Front Squat Max Pre (kg)	134.0 ± 26.3	116.3 ± 51.9
Front Squat Max Post (kg)	141.1 ± 26.8	119.7 ± 49.8
Front Squat Max % Increase	5.3%	2.9%

No statistically significant differences (p>0.05).

DISCUSSION: The results from the current study demonstrate that a 6-week strength program using TUT training techniques for the front squat does not significantly improve pGRF, normalized pGRF, or front squat 1RM. Overall the strength training program caused statistically significant improvements in both front squat 1RM and relative strength. However, TUT training did not alter strength or force production compared to normal training techniques, and produced a smaller increase in pGRF and more of a percentage increase in front squat 1RM compared to control. Studies regarding TUT have shown that prolonged muscle TUT with fatigue leads to full motor unit recruitment with a significantly increase in myofibrillar protein synthesis at 24-30 hours post exercise compared to normal resistance training techniques (Burd et al., 2011).

CONCLUSION: Results of this study indicate that 6-weeks of strength programming using TUT training does not improve strength or force production compared to traditional resistance training. Overall, the 6-week front squat strength training program used in the current study demonstrated improvements in strength (front squat 1RM) and relative strength (kg lifted/body mass) for both groups (TUT and control). Further studies using a longer period of training, larger sample size, and variations of the TUT tempo times need to be completed to further investigate TUT techniques and its effects on hypertrophy, strength, force production, and performance.

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