Neither Stretching nor Postactivation Potentiation Affect Maximal Force and Rate of Force Production during Seven One-Minute Trials

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ABSTRACT

Warm-up involves different factors and is implemented in multiple fields and applications. In athletics, it is an essential aspect of preparation. Four specific different warm-ups were randomly investigated in this study. PURPOSE: The purpose of this investigation was to compare the effects of stretching versus a heavy squat (potentiation) versus a loaded jump squat (potentiation) on subsequent maximal force and rate of force development capabilities in an isometric squat. METHODS: Ten male collegiate football and track & field athletes (9 & 1 respectively) participated as subjects in this study. Subjects were tested during four separate sessions that involved seven isometric squat trials on a force plate at one-minute intervals to determine maximal force (MF) and rate of force development (RFD) values. The sessions included a five-minute bike warm-up followed by nothing (control), a heavy squat set (3 reps at 90% 1RM), a loaded jump squat set (9 reps at 30%), or a stretching protocol (3 reps of 30 seconds on each leg; quadriceps and gluteals). RESULTS: MF and RFD in the isometric squat was not significantly different following any of the four conditions (C=3160.7+205.0 N, S=3092.2+188.2, JS=3268.9±207.6, HS=3172.7+190.3; C=167.1+19.3 N/s, S=153.1+20.9, 164.6+19.9, HS=172.0+20.9). CONCLUSION: Some insignificant results show that the loaded jump squat protocol may increase maximal force and that stretching may decrease this variable, with a larger sample size. Future experiments investigating the possibility of potentiation should involve loaded jump squats. Stretching seems to be detrimental to performance in athletic activities that require maximal force production.

Key Words: strength, power, flexibility, range of motion, force plate, athletic performance

INTRODUCTION

A warm-up using stretching has been a traditional practice for exercise or athletic event preparation. It is a common belief that stretching is effective in improving performance and this has been shown through scientific research. However, an increasing amount of research has recently studied the effects that stretching has on strength, power, neuromuscular activity, and other muscle properties in humans (Kokkonen, Nelson, and Cornwell, 1998; Nelson et al., 2001; Nelson and Kokkonen, 2001; Knudson et al., 2001; Young and Elliot, 2001; Cramer et al., 2004).

Many of these studies have shown that stretching prior to an activity can actually inhibit maximal performance (Kokkonen, Nelson, and Cornwell, 1998; Nelson and Kokkonen, 2001; Young and Elliot, 2001; Cramer et al., 2004). One study (Kokkonen, Nelson, and Cornwell, 1998) looked at flexibility (ROM) through the sit and reach, and strength through one repetition maximum (1RM) knee extension and flexion after an extensive static stretching routine. While they found that flexibility was increased in the experimental group when compared to the control group, strength significantly reduced in the experimental group for both the 1RM performances. Kokkonen and Nelson (2001) investigated the effects of ballistic stretching, or bouncing type stretching, using the same protocols as their previous study. Tests resulted in an increase in flexibility (less of an increase than that found in 1998) but a decrease in 1RM (less of a decrease than that found in 1998). The researchers concluded that prior to an event that requires maximal strength output, stretching intensely should not be implemented but they reiterate that more mechanistic information needs to be done to determine the exact mechanism or mechanisms of relationship. Young and Elliot (2001) studied the effects of static stretching, PNF stretching, and maximal voluntary contraction (MVC) on static VJ and drop jump performances. A significant decrease was only observed after the static stretching protocol in the drop jump. Young and Elliot (2001) suggested that for activities such as sprinting or jumping, static stretching may have a negative effect on performance. Cramer et al. (2004) investigated how static stretching affects peak isokinetic torque in women. They found that peak torque is decreased not only in the quadriceps muscle that was stretched but also in the ipsilateral limb. They advise professionals to consider these effects before incorporating static stretching into preperformance activities, but reiterate that future studies need to identify the underlying mechanisms of this.

Postactivation potentiation (PAP) is defined by Sale (2002) as a mechanism which by some "conditioning" activity allows for subsequent increases in contraction activity. This physiological occurrence most likely involves an increased sensitivity to calcium causing concurrent increased muscle performance. The PAP mechanism may also be attributed to an improved neuromuscular activation, measured by H-reflex amplitude (Gullich and Schmidtbleicher, 1996). Bruton et al. (1996) showed that a preceding bout of activity increases force output in a single muscle fiber. Potentiation activity refers to activity such as heavy squatting before a 100-meter sprint. Elite athletes commonly use this technique. Although the mechanisms of potentiation have been studied in the past, recent interest has been given to its effects on performance such as in the bench press and vertical jump (Gullich and Schmidtbleicher, 1996; Young, Jenner, and Griffiths, 1998). It is anticipated that through this research, PAP will become an effective and accepted warm-up protocol.

The purpose of this proposed research is to both increase the understanding concerning the effects of stretching on muscle performance properties and to obtain further information on postactivation potentiation. It is hypothesized that the stretching inhibits peak force and rate of force development output whereas potentiation enhances it. This information will help aid in an increased understanding of the effects of warm-up procedures in athletics and therefore promote the enhancement of athletic performance.

METHODS

Fifteen male subjects (age: 20.2 $\pm$ 1.2 years; weight: 97.5 $\pm$ 18.3 kg; height: 1.83 $\pm$ .08 m), who were all power athletes (football, track & field), participated in this investigation. Each subject completed an isometric MVC (squat) on the force plate following each of the protocols through a random selection: stretching (experimental), squat potentiation (experimental), jump potentiation (experimental), or nothing (control). All subjects performed five minutes of biking at 85 rpm prior to all protocols. A one repetition maximum (1RM) squat was completed the week before testing began to determine the load to be used during the potentiation protocols. The Institutional Review Board approved this study and all subjects signed informed consent forms.

The stretching routine included stretches for the gluteal and quadriceps muscles bilaterally, done three times for 30 seconds on each leg, alternating legs. These stretches are similar to the ones done by Bazett-Jones, McBride, and Winchester (2003). This protocol was used to ensure that the muscles were thoroughly stretched. Bandy and Irion (1996) found that 30 seconds was sufficient to elicit changes in flexibility. The primary researcher performed all passive static stretches on the subjects. Stretches were taken to the point of mild discomfort, without pain, as acknowledged by the subject. The potentiation protocol used two different treatments to attempt to elicit a response, squat and jump. Squat potentiation was performed through a barbell squat at 90% of the subjects' 1RM for 1 set of 3 repetitions. Subjects completed a repetition when their thighs became parallel with the floor and they returned to a fully upright position. The jump potentiation protocol included a jump squat on a Smith machine at 30% of the subjects' 1RM for 1 set of 9 repetitions. A repetition was considered full if the subject squatted to a 90-degree hip and knee angle and then jumped upwards. No resetting occurred (the jumps were continuous) and no warm-up sets were done for either squat or jump. For the control protocol, subjects performed only the bike warm-up. The testing measure used an isometric MVC (squat) and was done immediately after the treatment and every minute thereafter for six minutes. A force plate (Quattro Jump, Kistler) was used; measuring muscle performance in a standing position with legs and hips each positioned at approximately 90 degree angles. The force plate measured the MF output and the RFD (90 degrees of flexion).

A 2-Way Repeated Measures ANOVA (treatment x trials) design was used to analyze the differences between each treatment and between the seven trials (time 0 – 6 minutes). An alpha of $p \leq 0.05$ was considered statistically significant for all comparisons. Bonferroni post-hoc analysis was used for multiple comparisons when appropriate.

RESULTS

Table 1 contains the MF (N) and RFD (N/s) means $\pm$ standard deviations (SD) for treatments and trials. No significant differences were found between the control and the treatment groups. A post-hoc analysis found that the jump potentiation and stretching groups were marginally significantly ($p<0.05$) different from each other.

Difference in MF and RFD can be seen in Graphs 1 and 2, respectively. A larger sample size may have elicited a significant difference at the 0.05 alpha level. Significant differences were found between trials ($p<0.05$). Trials 1 and 2 were different from 3, 5, and 7, but not different from one another. These results are outlined in Table 2. No significant differences were found for the treatments or the trials. No significant interactions were found for either variable.

Table 1: MF (N) and RFD (N/s) means and SD

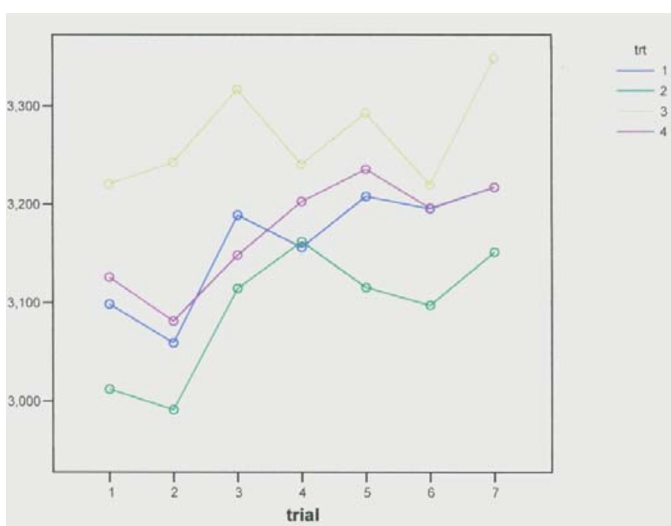
Treatments	MF Mean ± SD	RFD Mean ± SD
Control	3161 ± 205	16198 ± 1348
Stretching	3092 ± 188	18550 ± 3088
Jump PAP	3269 ± 208	16196 ± 1589
Squat PAP	3173 ± 190	18136 ± 2293
Trials		
0 min	3115 + 184	16250 ± 1243
1 min	3094 ± 170	16138 ± 1631
2 min	3192 ± 182	16225 ± 1427
3 min	3191 ± 198	17520 ± 2185
4 min	3213 ± 194	15538 ± 1732
5 min	3177 ± 199	21175 ± 2975
6 min	3234 ± 215	18043 ± 2112

Table 2: MF (N) Trial Differences

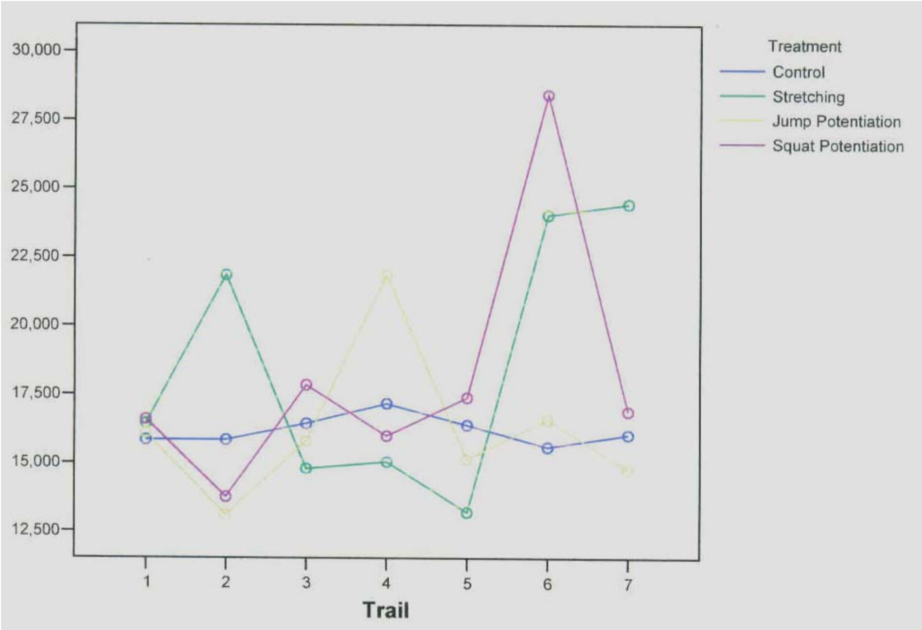
Trials	Difference*	P-value
1 & 3	-77.8	0.036
1 & 5	-98.6	0.015
1 & 7	-119.3	0.043
2 & 3	-98.5	0.012
2 & 5	-119.3	0.017
2 & 7	-139.9	0.039

*Differences are shown in Newtons as the first group listed minus the second group

Graph 1: Maximal Force (N)



Graph 2: Rate of Force Development (N/s)



DISCUSSION

The results of this study were inconsistent with previous studies (Kokkonen, Nelson, and Cornwell, 1998; Nelson and Kokkonen, 2001; Young and Elliot, 2001; Cramer et al., 2004) but did see that same results as a few studies (Bazett-Jones, McBride, and Winchester, 2003; Knudson et al., 2001) that reported no negative effect of stretching on MF or RFD. Also, the results showed no improved performance due to PAP. It is obvious, through this study and others showing inconsistent results, that much more investigating needs to be done to find the best protocols.

Much of the research done on stretching's negative effects have used movements that utilize the stretch-shortening cycle (SSC). The present study used an isometric squat to examine these effects. Bazett-Jones, McBride, and Winchester (2003) also used an almost exactly the same (isometric squat) test protocol as the current study, seeing no effect. It could be assumed that stretching most aptly effects those movements which utilize the SSC. Therefore, the isometric squat may be an inadequate testing movement. This should be investigated in future research.

The lack of results from the PAP protocol may be due, in part, to a couple different things. Again, the testing protocol (isometric squat) may not be adequate to test the effects that PAP has. More than likely, the squat PAP protocol was not intense enough to elicit an improvement. While the jump PAP protocol seemed to have had some positive effects, the recovery period probably did not allow for proper rest.

There was a significant effect for the trials on maximal force. The data shows that trials 1 and 2 are about the same and they are both different that trials 3, 5 and 7. It seems that changes occurred in two-minute intervals. This time frame may allow for better recover from fatigue. The one-minute testing times could be a factor in the lack of significant results because of a reduced recovery period. A testing protocol completed at times zero, two, four, and six minutes might allow for more rest and hence, an improved measure.

Although the subjects used in this study were trained athletes, they may not have had enough strength to see changes from the potentiation protocol. Young, Jenner, and Griffiths (1998) found that there was a positive correlation between the load used in the potentiation protocol and the performance enhancement in a squat, suggesting that stronger individuals may receive a greater potentiation benefit. Future studies should look at this to see if preexisting strength affects the results of a potentiation protocol.

Statistically, the sample size was too small. A larger sample may have shown significant results at a 0.05 alpha level. This is evident by the marginally significant difference between the jump potentiation and stretching protocols. More subjects need to be utilized in this type of statistical design.

CONCLUSIONS

Although it was not significantly evident in this study, stretching seems to have a negative effect on performances that require maximal force when the stretching is done prior to the activity. Also, potentiation may have a positive effect on force. The proper protocol for optimal performance needs to be found. The mechanisms behind both stretching and potentiation need to be investigated to better understand their effects. Future applications of this study can be directed towards coaches, athletic trainers, and strength and conditioning professionals as they prepare athletes for optimal performance.

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REFERENCES

BANDY, W.D. AND J.M. IRION. The effect of time on static stretch on the flexibility of the hamstring muscles. Phys. Ther. 74(9):845-852. 1994.

CRAMER ET AL. Acute effects of static stretching on peak torque in women. J. Strength Cond. Res. 18(2):236-241. 2004.

GROSSEN, E.R. AND D.G. SALE. Effect of postactivation potentiation on dynamic knee extension performance. Eur. J. Appl. Physiol. 83:524-530. 2000.

GÜLLICH, A., D. SCHMIDTBLEICHER. MVC-induced short-term potentiation of explosive force. New Studies in Athletics. 4:67-81. 1996.

KOKKONEN, J., A.G. NELSON, AND A. CORNWELL. Acute muscle stretching inhibits maximal strength performance. Res. Q. Exerc. Sport. 69(4):411-415. 1998.

NELSON, A.G., J.D. ALLEN, A. CORNWELL, AND J. KOKKONEN. Inhibition of maximal voluntary isometric torque production by acute stretching is joint-angle specific. Res. Q. Exerc. Sport. 72(1):68-70. 2001.

NELSON, A.G., J. KOKKONEN. Acute ballistic muscle stretching inhibits maximal strength performance. Res. Q. Exerc. Sport. 72(4):415-419.

SALE, D.G. Postactivation potentiation: role in human performance. Exerc. Sports Sci. Rev. 30(3):138-143. 2002.

YOUNG, W. AND S. ELLIOT. Acute effects of static stretching, proprioceptive neuromuscular facilitation stretching and maximal voluntary contractions on explosive force production and jumping performance. Res. Q. Exerc. Sport. 72(3):273-279. 2001.

YOUNG, W.B., A. JENNER, AND K. GRIFFITHS. Acute enhancement of power performance from heavy load squats. J. Strength Cond. Res. 12(2):82-84. 1998.