The Effect of Stance Width on the Electromyographical Activity of Eight Superficial Thigh Muscles During Back Squat With Different Bar Loads

Antonio Paoli,[1] Giuseppe Marcolin,[1] and Nicola Petrone[2]

[1]*Department of Human Anatomy and Physiology, Section of Physiology, and* [2]*Department of Mechanical Engineering, University of Padova, Padova, Italy*

Abstract

Paoli, A, Marcolin, G, and Petrone, N. The effect of stance width on the electromyographical activity of eight superficial thigh muscles during back squat with different bar loads. *J Strength Cond Res* 23(1): 246–250, 2009–Many strength trainers believe that varying the stance width during the back squat can target specific muscles of the thigh. The aim of the present work was to test this theory measuring the activation of 8 thigh muscles while performing back squats at 3 stance widths and with 3 different bar loads. Six experienced lifters performed 3 sets of 10 repetitions of squats, each one with a different stance width, using 3 resistances: no load, 30% of 1-repetition maximum (1RM), and 70% 1RM. Sets were separated by 6 minutes of rest. Electromyographic (EMG) surface electrodes were placed on the vastus medialis, vastus lateralis, rectus femoris, semitendinosus, biceps femoris, gluteus maximus, gluteus medium, and adductor maior. Analysis of variance and Scheffè post hoc tests indicated a significant difference in EMG activity only for the gluteus maximus; in particular, there was a higher electrical activity of this muscle when back squats were performed at the maximum stance widths at 0 and 70% 1RM. There were no significant differences concerning the EMG activity of the other analyzed muscles. These findings suggest that a large width is necessary for a greater activation of the gluteus maximus during back squats.

Key Words muscle activity, resistance training, submaximal loads

Introduction

The back squat is one of the most employed training exercises to develop lower-extremity muscles. Generally, it is included in a weight training program to develop not only the quadriceps (rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius) but also the hamstrings, triceps surae, and hip adductors and abductors. This closed-chain kinetic exercise is also chosen in knee rehabilitation because it reduces anterior cruciate ligament strain and tibial femoral shear, as reviewed by Schaub and Worrel (7). Recently, there also has been a growing interest in the effects of exercise technique variations on muscle pattern activity during back squat lifts. In these studies, electromyography (EMG) is the most employed method to identify muscle group contributions while comparing different body positions during the lifting.

Signorile et al. (11) compared the activation of thigh muscles in squats and leg extensions. The EMG data of the vastus lateralis and vastus medialis showed no significant variation of the root-mean-squared EMG activity in the 2 typologies of exercise. Another study conducted by Signorile et al. (10) investigated the effects of 3 foot positions (approximately 30° inside parallel, 0°, and approximately 80° outside parallel) on the levels of electrical activity of selected muscles of the quadriceps during parallel squat and leg extension exercises to find a possible correlation between foot placement and different muscular pattern activation. The EMG data of parallel squats showed no significant differences among any foot positions for any of the superficial quadriceps muscles. Boyden et al. (2) also investigated the influence of foot position on the quadriceps EMG activity using lower degree values of foot rotations (−10° inward, 0°, +10°, and +20° outward) than the values employed by Signorile et al. (10). Results and analysis of variance (ANOVA) showed that low foot rotations did not influence the EMG activity of quadriceps muscles. Caterisano et al. (3) measured the relative contributions of 4 hip and thigh muscles (vastus medialis, vastus lateralis, biceps femoris, and gluteus maximus) while performing squats at 3 depths.

Address correspondence to Antonio Paoli, antonio.paoli@unipd.it.

23(1)/246–250

Journal of Strength and Conditioning Research

Subjects' EMG data were expressed as percentages of the total electrical activity of the 4 muscles. Statistical analysis indicated a significant difference only in the activation of the gluteus maximus during the concentric phases among the 3 squat depths. McCaw and Melrose (6) compared the EMG activity of 6 muscles crossing the hip and/or the knee joint during the performance of parallel squats with different stance widths and bar loads. In particular, they used as a reference the shoulder width: 75 and 140% of shoulder width. Bar loads were, respectively, 60 and 70% of 1-repetition maximum (1RM). Results and statistical analysis indicated that stance width did not cause isolation within the quadriceps but did influence gluteus maximus and adductor longus.

Also, the choice of exercise intensity expressed as a percentage of 1RM is very important for understanding motor unit recruitment and muscular training adaptations: Shimano et al. (9) have shown that the muscle mass used during the exercise influenced the number of repetitions with respect to the 1RM. In particular, more repetitions at a given percentage of 1RM could be performed during the back squat than during other exercises such as the bench press or arm curl.

Considering these previous investigations and the variables analyzed, we decided to focus our attention only on the back squat and on one of the execution variations most used in fitness and sport training: the distance between the feet of the lifter. Then, we decided to employ submaximal bar loads for comparison with previous studies and also to avoid possible nonvoluntary technique changes during the last repetitions of each set attributable to fatigue from heavy load as reported by Duffey and Challis (4).

So, the purpose of our study was to investigate the effects of 3 stance widths at 3 different bar loads on the EMG activity of 8 thigh muscles during the weighted back squat.

Methods

Experimental Approach to the Problem

The change of stance width during the back squat is one of the most employed exercise variation in a fitness hall. Another variable that is manipulated in fitness programs is the bar load. In the present study, we chose 3 stance widths (100, 150, and 200% of great trochanter distance [GTd]) and 3 selected bar loads. The different bar loads were 0 and 30% 1RM, which are the loads most commonly employed by beginners and women, and 70% 1RM, which is often selected in training programs. The surface EMG activity of 8 thigh muscles was recorded while 6 testers performed back squats in the 3 stance width conditions with the 3 bar loads in a randomized order and with specific rest pauses. Because the repositioning of the EMG probes could cause a change in EMG raw signal output, all trials for each tester were performed in one day session. This experimental design allowed identification of the effect of the stance widths and of the bar loads on the EMG activity of the 8 thigh muscles selected.

Subjects

Six men with 3 years of lifting experience were involved in the study. Mean age was 25.8 ± 3.7 years, mean weight was 83.2 ± 5.8 kg, mean height was 182 ± 3.5 cm, and GTd was 44.3 ± 1 cm. Each participant was requested to read and sign an informed consent about the tests. Physical characteristics of each subject are presented in Table 1.

Lifting Protocol

The protocol was divided into 2 sessions. In the first session, each participant was familiarized with the kinds of exercises and individuated his own 1RM bar load. The 1RM was determined using each subject's preferred stance width, by increasing the weight at each lift until the subject could not perform the squat through the entire range of motion. The second session consisted in a standardized warm-up (squats without the bar over the shoulders, stretching, and light-weighted squats) and then in the following trials: 3 sets (0, 30, and 70% 1RM) of 10 repetitions with stance width equal to GTd, 3 sets of 10 repetitions with stance width equal to 150% of GTd, and, finally, 3 sets of 10 repetitions with stance width equal to 200% of GTd. The rest between trials was 6 minutes, with a further rest of 3 minutes between the sets. For each subject, all trials were randomized and performed in one day session.

Data Collection

The EMG activity of 8 muscles of the right thigh was recorded by means of a Muscle Lab 4100e (Europe Ergotest, Boscosystem srl, Italy). Muscles analyzed were the vastus medialis, vastus lateralis, rectus femoris, semitendinosus, biceps femoris, gluteus maximus, gluteus medium, and adductor maior. Bipolar surface electrodes were placed on the muscular bellies along the direction of the fibers: the distance between each couple of electrodes was 25 mm. The Muscle Lab converted the amplified EMG raw signal to an average root mean square signal via its built-in hardware circuit network (frequency response, 450 kHz; averaging constant, 100 milliseconds; total error, ±0.5%). Surface

Table 1. Subjects involved in the study.

Subjects	Height (cm)	Weight (kg)	Age (y)	GTd (cm)
1	183	92	28	45
2	183	77	23	45
3	180	80	26	43
4	180	85	23	45
5	178	78	23	43
6	188	87	32	45

GTd = distance between great trochanters.

electrodes were chosen because this system is noninvasive and painless. Furthermore, Basmajian and De Luca (1) specifically recommend surface electrodes when the level of EMG activity in large superficial muscles has to be examined. The skin over each muscle was shaved, scratched with abrasive paper, and, finally, cleaned with alcohol to reduce impedance values. An electrical goniometer was also fixed in the right leg: its signal and EMG signals were synchronously recorded. Each trial was finally recorded with a 6-camera stereophotogrammetric system (BTS, Padova, Italy) working at 60 Hz. All subjects had 28 reflective markers placed on preselected body anatomic landmarks: head (3), trunk (3), pelvis (2 at PSIS and 2 at ASIS), great trochanters (2), knees (8), ankles (4), and feet (4). Kinematic analysis was employed to verify the technical execution during each set of squats. For this reason, knee angles and vertical velocity of the 2 markers fixed on great trochanters were evaluated to check consistency among repetitions and among sets. Electromyographical analysis involved every set of lifts; for each one, the first and the last repetition were excluded from the study because kinematic evaluation showed differences from the other repetitions of the same set, particularly concerning the velocity and displacement of the markers stuck on the great trochanters. The root mean square of the amplitude of the EMG (rmsEMG) for all muscles was calculated, taking into consideration the entire range of motion of each lift, with no distinction between eccentric and concentric phase. In each set, the mean rmsEMG of each lift (excluding the first and the last one, as explained above) was made. Then, the mean of the means was calculated.

Statistical Analyses

One-way ANOVA for each independent variable (muscle, stance width, and bar load) was used to analyze differences in rmsEMG. Differences in levels of muscular activity were assessed for statistical significance ($p \leq 0.05$), and then, if appropriate, a Scheffè post hoc test was calculated.

Results

Overall mean values of EMG activity of the 8 muscles are presented in Table 2. As expected, the EMG signal for each muscle was greater with the increase of the bar load from 0 to 70% 1RM. For the vastus medialis, vastus lateralis, rectus femoris, semitendinosus, biceps femoris, gluteus medium, and adductor maior, no statistically significant differences were found ($p > 0.05$) in the levels of EMG activation with different stance widths at either 0, 30, or 70% 1RM. Gluteus maximus EMG activity turned out to differ significantly with different stance widths, as reported in Figure 1. In particular, with the bar load at 70% 1RM, the activation of this muscle recorded at 200% of GTd was greater than the one at 100% ($p < 0.05$), where the statistical power was 0.99, with an effect size of 1.34. Also, at 150% of GTd, the EMG activity of the gluteus maximus was higher than at 100% of GTd ($p < 0.05$; effect size = 0.5; statistical power = 0.55). With the light load

Table 2. Overall mean of electromyographic activity of the 8 thigh muscles for the 3 different stance widths (mean ± *SE*; mV).

	GT distance			1.5 GT distance			2 GT distance		
	0% 1RM	30% 1RM	70% 1RM	0% 1RM	30% 1RM	70% 1RM	0% 1RM	30% 1RM	70% 1RM
RF	0.0370 ± 0.0147	0.0428 ± 0.0156	0.0571 ± 0.0087	0.0309 ± 0.0131	0.0412 ± 0.0097	0.0504 ± 0.0081	0.0279 ± 0.0087	0.0397 ± 0.0110	0.0516 ± 0.001
VM	0.0453 ± 0.0097	0.0477 ± 0.0120	0.0573 ± 0.0072	0.0424 ± 0.0083	0.0476 ± 0.0084	0.0575 ± 0.0097	0.0411 ± 0.0051	0.0486 ± 0.0054	0.0532 ± 0.0154
VL	0.0441 ± 0.0054	0.0476 ± 0.0095	0.0605 ± 0.0077	0.0412 ± 0.0060	0.0487 ± 0.0072	0.0597 ± 0.0090	0.0422 ± 0.0055	0.0514 ± 0.0051	0.0660 ± 0.0117
SEM	0.0132 ± 0.0045	0.0164 ± 0.0057	0.0232 ± 0.0074	0.0147 ± 0.0050	0.0175 ± 0.0059	0.0238 ± 0.0107	0.0143 ± 0.0059	0.0208 ± 0.0114	0.0254 ± 0.0115
BF	0.0165 ± 0.0033	0.0184 ± 0.0043	0.0245 ± 0.0036	0.0158 ± 0.0029	0.0190 ± 0.0034	0.0256 ± 0.0065	0.0155 ± 0.0019	0.0207 ± 0.0028	0.0272 ± 0.0070
Gmax	0.0097 ± 0.0040	0.0156 ± 0.0051	0.0205 ± 0.0058	0.0131 ± 0.0070	0.0172 ± 0.0062	0.0241 ± 0.0092	0.0156 ± 0.0075	0.0216 ± 0.0068	0.0288 ± 0.0075
Gmed	0.0124 ± 0.0054	0.0176 ± 0.0047	0.0252 ± 0.0071	0.0158 ± 0.0092	0.0195 ± 0.0057	0.0265 ± 0.0074	0.0182 ± 0.0116	0.0239 ± 0.0094	0.0318 ± 0.0124
AM	0.0080 ± 0.0027	0.0110 ± 0.0056	0.0170 ± 0.0058	0.0074 ± 0.0023	0.0105 ± 0.0039	0.0166 ± 0.0079	0.0064 ± 0.0012	0.0107 ± 0.0035	0.0169 ± 0.0066

Stance width is expressed with reference to great trochanter (GT) distance. Lifted load is expressed with reference to maximal resistance (1RM).
RF = rectus femoris; VM = vastus medialis; VL = vastus lateralis; BF = biceps femoris; SEM = semitendinosus; Gmax = gluteus maximus; Gmed = gluteus medium; AM = adductor maior.

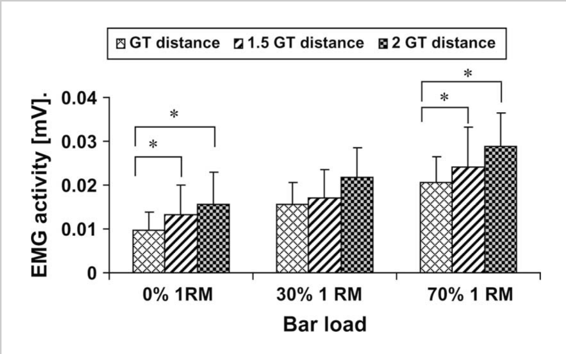

Figure 1. Gluteus maximus: overall mean of electromyographic (EMG) activity in the 3 experimental conditions with the 3 different bar loads. *Significant differences ($p < 0.05$). GT = great trochanter; 1RM = 1-repetition maximum.

(0% 1RM), the EMG activity of the gluteus maximus at 200% of GTd was greater than the one at 100% of GTd ($p < 0.05$), where the statistical power was 0.99, with an effect size of 1.07. Also, at 150% of GTd, the EMG activity was higher than at 100% of GTd ($p < 0.05$; effect size = 0.65; statistical power = 0.83).

Discussion

In the present study, the results and their statistical analysis indicate, first of all, that the EMG activity of each muscle was greater when increasing the loads; this is in agreement with the study of Boyden et al. (2), even when considering the overall mean EMG peak activity. This study also shows that, during a back squat, the modification of the stance width did not influence the EMG activity of thigh muscles, except for the gluteus maximus. This is in agreement with the study of McCaw and Melrose (6), where they identified greater gluteus maximus integrated EMG values during a squat at 75% 1RM with a foot distance equal to 140% of shoulder width compared with a squat with a foot distance equal to 75% of shoulder width. These findings disagree with some previous studies (5,8) with regard to the relationship between stance width and muscle activation. In particular, our observations are in contrast with the view that the use of a wide stance, with the feet rotated 45° outward, results in increased activation of the vastus medialis, and that the use of a narrow stance, with the feet pointed forward, results in greater activation of the vastus lateralis. The employment of light and moderate loads allowed us to obtain consistency among repetitions and among sets in such a way that EMG muscle variation could be attributed above all to foot position and not to possible technique changes attributable to fatigue as reported by Duffey and Challis (4) in bench press exercise.

In conclusion, because previous studies had demonstrated that changing the foot rotation or depth during the execution of a squat was not related to changes in muscle recruitment, in this study we demonstrated that different stance widths did not involve a change in thigh muscle EMG activity, except for the gluteus maximus. This is very important because it demonstrates that leg positions do not influence muscular activation; therefore, everyone–athlete or fitness amateur–can choose his or her best comfortable and safe position.

Further investigations comparing EMG data with kinematic data are needed to better understand the activity of each thigh muscle during the concentric and eccentric phases. In particular, it will be important to identify the knee angle at which the greatest EMG activity of some preselected muscles can be registered, and whether, in this situation, the variation of the same execution parameters such as stance width or foot rotation could increase the EMG activity of one muscle rather than another one.

Practical Applications

Although some fitness handbooks (5,8) report that a change in stance width and foot rotation could increase the activation of specific thigh muscles, the results of our study do not confirm these statements. In fact, only the gluteus maximus was shown to increase its EMG activity when stance width was increased, but only at 0 and 70% 1RM. These results indicate that choices of foot position and stance width are not strictly related to the level of muscular electrical activity, such that an athlete can freely select his or her most comfortable and safe position to perform back squats. Our results refer to submaximal bar loads; this is because the majority of lifters and recreational weight trainers usually employ submaximal loads for training. In further investigations with experienced lifters, and using maximal loads, we will compare maximal and submaximal EMG activity of the thigh muscles with different stance widths.

REFERENCES

1. Basmajian, JV and De Luca, CJ. *Muscle Alive*. Baltimore: Williams & Wilkins, 1985.
2. Boyden, G, Kingman, J, and Dyson, R. A comparison of quadriceps electromyographic activity with the position of the foot during the parallel squat. *J Strength Cond Res* 14: 379–382, 2000.
3. Caterisano, A, Moss, RF, Pellinger, TK, Woodruff, K, Lewis, VC, Booth, W, and Khadra, T. The effect of back squat depth on the EMG activity of 4 superficial hip and thigh muscles. *J Strength Cond Res* 16: 428–432, 2002.
4. Duffey, MJ and Challis, JH. Fatigue effects on bar kinematics during the bench press. *J Strength Cond Res* 21: 556–560, 2007.
5. Holman, S. *Home Gym Handbook: A Complete Guide to Training at Home*. Los Angeles: Homebody Productions, 1990.
6. McCaw, ST and Melrose, DR. Stance width and bar load effects on leg muscle activity during the parallel squat. *Med Sci Sports Exerc* 31: 428–436, 1999.

7. Schaub, TA and Worrel, TW. EMG activity of six muscles and VMO: VL ratio determination during a maximal squat exercise. *J Sports Rehabil* 4: 195–202, 1995.
8. Schwarzenegger, A and Dobbins, B. *The Arnold Schwarzenegger Encyclopedia of Modern Bodybuilding*. New York: Simon and Schuster, Inc., 1985
9. Shimano, T, Kraemer, WJ, Spiering, BA, Volek, JS, Hatfield, DL, Silvestre, R, Vingren, JL, Fragala, MS, Maresh, CM, Fleck, SJ, Newton, RU, Spreuwenberg, LP, and Häkkinen, K. Relationship between the number of repetitions and selected percentages of one repetition maximum in free weight exercises in trained and untrained men. *J Strength Cond Res* 20: 819–823, 2006.
10. Signorile, JF, Kwiatkowski, K, Caruso, JF, and Robertson, B. Effect of foot position on the electromyographical activity of the superficial quadriceps muscles during the parallel squat and knee extension. *J Strength Cond Res* 9: 182–187, 1995.
11. Signorile, JF, Weber, B, Roll, B, Caruso, JF, Lowensteyn, I, and Perry, AC. An electromyographical comparison of the squat and knee extension exercises. *J Strength Cond Res* 8: 178–183, 1994.