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Original Research

Effects of Trunk and Foot Positions on Electromyographic Activity and Co-contraction of Selected Lower Extremity Muscles During Leg-Press Resistance Training

Mojtaba Golparian [1*], Mehrdad Anbarian [1], Amir Golparian [2]

1. Department of Sport Biomechanics, Faculty of Sports Sciences, Bu Ali Sina University, Hamedan, Iran.
2. Department of Sports Biomechanics, Faculty of Sports Sciences, Shahid Bahonar University of Kerman, Kerman, Iran.

ABSTRACT

The purpose of this study was to determine the effects of trunk and foot positions on electromyographic activity and co-contraction of selected lower extremity muscles during leg-press resistance training. 12 male powerlifters performed leg-press movement while the backrest of leg-press machine was adjusted at 15°, 20°, 25°, and 30° angles relative to the horizon. The feet were placed in three different positions namely, top, middle, and bottom of the foot-plate. Electromyography activity of the rectus femoris (RF), vastus medialis (VM), vastus lateralis (VL), biceps femoris (BF), and semitendinosus (ST) muscles were recorded while performing leg-press task at different trunk-feet conditions. The muscle co-contraction at the knee joint was also calculated. When the feet were placed on top of the foot-plate, RF had greater activity at 15°, 20°, and 25° compared to 30° backrest position. VM showed greater activity at 20° and 25° compared to 30°. VL showed greater activity at 20° and 25° compared to 30°. It was also more active at 20° than at 25° of backrest position. The ST and BF were more active at 20° compared to other positions. There was a slight co-contraction ratio difference at 20°-tap degrees condition compared to other conditions. According to the results, it is recommended that, for the recruitment of more motor units when using the 45-degree leg-press machine, the backrest of the machine be adjusted at a 20° angle with the feet placed at the top of the foot-plate.

Keywords: Leg-Press, Electromyography, Co-contraction, Foot Position, Trunk Position

Corresponding Author: Mojtaba Golparian, Department of Sport Biomechanics, Bu Ali Sina University, Hamadan, Iran. Email: golparianarash@gmail.com, Tel: 00989188189820

INTRODUCTION

Recently, many studies have examined muscle activity during various resistance training (1-3). Surface electromyography is a method which is often used to determine the extent to which muscle groups are involved in performing various techniques in many sports trainings (4-8). Resistance training, known as strength training or weight training, is one of the most popular exercises for attaining physical fitness (9). In the bodybuilding programs, leg-press training is used to strengthen the largest and strongest muscles of the lower extremity. In addition, this training has many neuromuscular and biomechanical similarities with many athletic movements such as running and jumping (10). On the other hand, quadriceps and hamstrings muscles are among the muscles which are exposed to constant pressure and fatigue in most daily activities, especially in athletic skills which require bearing and moving loads (11). While athletes are more inclined to use free loads as a means of improving strength and power, beginners often prefer resistance machines because of their relative safety and ease of use (12). Closed kinetic-chain exercise machines are easier to use by beginners and those with injuries in the early to mid-stages of rehabilitation protocols, as they are easier to control, require less trainer supervision and expose the exerciser to lower overall injury risk (13).

Closed kinetic chain exercises are regarded as safe exercises which are widely used in rehabilitation since they are highly similar to daily activities, require high interaction between muscles in the joints especially in the knee joint, exert less pressure on the ligaments, and reduce the shear force applied to the joint (14-18). Since leg-press training belongs to the group of closed kinetic chain exercises (14), it is often used in clinical settings to rehabilitate various sports injuries such as knee rehabilitation after anterior cruciate ligament surgery (14,19).

Many coaches and athletes believe that, by changing the position of the feet and the trunk while performing leg-press training, one can focus on a specific muscle in the quadriceps and hamstrings group of muscles (20). Athletes and patients undergoing rehabilitation perform leg-press exercises through various techniques on the basis of their training and rehabilitation protocols (21). To perform leg-press exercises, they choose techniques based on personal taste or the effectiveness of the technique (21). Evans (2015) stated that when there is a 90° angle between the seat and the backrest of the leg-press machine, more pressure is applied to gluteus and hamstrings muscles (20). When the backrest of the machine is lowered backwards toward the ground, the trunk also leans back (20). This exerts more pressure on the quadriceps muscles (20). Escamila et al. (1998) examined the activity of quadriceps and hamstrings muscles in eight different foot positions. They did not include the trunk position in their study. However, since rectus femoris and hamstrings muscles are biarticular, it seems that trunk position will affect the activity of these muscles. It was shown that co-contraction between hamstrings and quadriceps muscles was an important factor in reducing the tension of ACL ligament (10). The co-contraction of agonist and antagonist muscles around the joint is of great biomechanical importance for maintaining the position and stability of the joint. In general, there are two types of co-contraction which include general co-contraction and directed co-contraction (22). Directed co-contraction, which is calculated by the ratio of the activity of antagonist to agonist muscles, is considered to be an important factor in joint stability and the reduction of pressure on the joint in static or dynamic positions such as walking and running (23). Since quadriceps muscles pass in front of the knee, and hamstrings and gastrocnemius muscles pass behind the knee, the co-contraction of this group of muscles plays a very important role in increasing the anterior-posterior stability of the knee joint (10).

Due to the length-tension relationship in muscles, moment arm, and biarticularity of hamstrings and rectus femoris muscles, a simultaneous change in the position of the trunk and the feet during the leg-press training could change the activity level and co-contraction of these muscles. Due to lack of research literature, there is uncertainty over the effect of change in trunk position on the activity and co-contraction of quadriceps and hamstrings muscles. Thus, research in this area would provide valuable insights for athletes and trainers regarding the trunk positions which trigger highest level of activity and co-contraction in quadriceps and hamstrings muscles. Furthermore, research in this area could provide useful information for the designers of sports machines to improve their safety. Therefore, the purpose of this study was to determine the effects of trunk and foot positions on electromyographic activity and co-contraction of selected lower extremity muscles during leg-press resistance training.

METHODOLOGY

Samples and data preparation

One week before the main test, subjects participated in a pilot test in which the experimental technique which they had to perform in their leg-press training sessions was examined. During the pilot test, subjects were asked to perform the leg-press movement in the position they preferred for the trunk and feet. For each participant, the distance between the feet (distance between the middle of the heels), the angle of the backrest of the machine to the horizon, the location of the feet relative to the top and bottom edge of the foot-plate, and one-repetition maximum (1RM) were recorded as his preferred method of performing the leg-press movement. During the main test, three positions were defined for the feet: 1) The feet near the top edge of the foot-plate [top]، 2) the feet in the middle of the foot-plate [middle]، 3) the feet near the bottom edge of the foot-plate [bottom]. For normalization purpose, the distance between the feet was measured in terms of the distance between each participant's anterior superior iliac spine (10). On the foot-plate, the forefeet were placed parallel to the sagittal plane. The angle of the backrest of the leg-press machine to the horizon was set at four positions which included 15° (the average of the measured angles between backrest of the leg-press machine and the horizon in the pilot test), 20°, 25°, and 30°.

Subjects

In this quasi-experimental study, 12 healthy male powerlifters (age mean and SD: 25.1 ± 0.6 years, height mean and SD: 176.5 ± 0.78 centimeters, weight mean and SD: 80.5 ± 8.54 kilograms) who were available to the authors of the study participated in the experiment. The sample size was calculated with G*power software, for statistical power of 0.95 and effect size of 0.25 with alpha level of 0.05. The participants did not have any musculoskeletal abnormalities or injuries in the lower extremities and, in terms of anthropometric characteristics, they had equal leg and thigh lengths, enough experience in performing leg-press exercise (at least 5 years), and regularly used this movement in their training programs. Institutional review board of Bu Ali Sina University verified the compliance of this study with Declaration of Helsinki.

Procedures

An Iranian-made 45-degree leg-press machine was used which could be loaded by circular plate-like loads that slid in a 45° path (Figures 1 and 2).

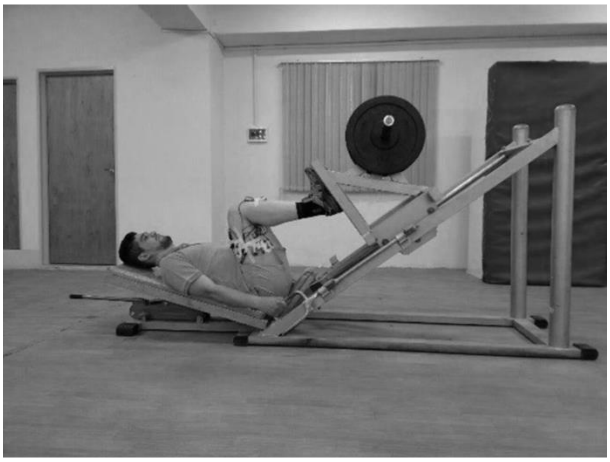

Fig. 1. Participant at the end of the flexion phase.

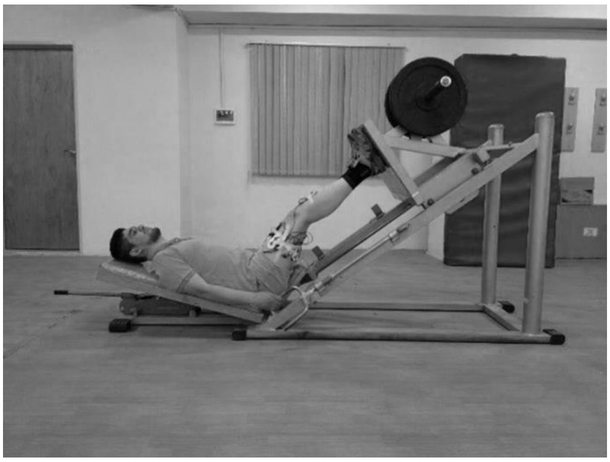

Fig. 2. Participant at the end of the extension phase.

Surface electromyography (EMG) signals were recorded by a 16-channel wireless EMG device made in Finland which had a sampling frequency of 2000 Hz and a signal-to-noise ratio of 90 decibels. Ag-AgCl disposable adhesive electrodes were used. After thoroughly shaving the thigh of the right leg, the skin was cleaned with cotton and rubbing alcohol to reduce the electrical resistance of the skin.

Electrodes were attached to the target muscles of the right leg: rectus femoris muscle (RF), the inner part of the vastus medialis (VM) muscle, vastus lateralis (VL) muscle, biceps femoris (BF) muscle, and semitendinosus (ST) muscle in line with European SENIAM protocol (24). Electrodes were placed between the nerve center of the muscle and the insertion tendon in the direction of the muscle fibers (21) (Figure 3).

Fig. 3. Electrode placement for the rectus femoris, the inner part of the vastus medialis, vastus lateralis, biceps femoris, and semitendinosus sites from the left to the right, respectively.

Ground electrode was placed on tibia bone. The distance between the centers of electrodes was 20 millimeters. Then, the cables were connected to the transmitter and the electrodes. The electrodes and cables were fixated on the skin so as not to interfere with the participants' movements. Then, maximum voluntary isometric contraction (MVIC) of the muscles was sampled by electromyography device. Repetitions of MVIC of rectus femoris, vastus medialis, and vastus lateralis muscles were recorded in the 90-degree flexion of the hip and knee joint while performing the knee extension movement sitting on the leg extension machine and in isometric contraction (10). Repetitions of MVIC of biceps femoris and semitendinosus muscles were recorded in the same position of the hip and knee joints while performing the flexion movement (10). In order to shorten the test period and prevent fatigue, the participants randomly performed two 3-second repetitions of MVIC for the muscle group and the participants had about three minutes of rest between each repetition (25). After completing the repetitions of MVIC of different muscles and after five minutes of rest, the participants performed the leg-press movement for each trunk-feet condition that was randomly selected three times with an intensity of 70% of one-repetition maximum (1RM) as the normalized load (10,14). Through sub-maximum load, low repetition number, participants' high level of readiness, and sufficient rest in between performing leg-press movements at different trunk-feet conditions, we tried to minimize the effect of fatigue. To analyze the raw data obtained from the surface electrodes, Mega Win 3.0.1 software package was used with a bandpass filter of 10 to 450 Hz. Then, the level of raw electromyographic activity of the muscles was calculated through the root mean square (RMS) method during knee extension movement (concentric phase of the movement). In order to normalize the activity level of each muscle, obtained values for the leg-press movement were divided by MVIC values for that muscle and the result was multiplied by 100. Then, directed co-contraction was calculated using the following equation (26):

If the mean electromyographic activity of the agonist muscles is greater than the mean electromyographic activity of the antagonist muscles; then we have: co-contraction = 1- (mean activity of agonist muscles / mean activity of antagonist muscles)

If the mean electromyographic activity of the antagonist muscles is greater than the mean electromyographic activity of the agonist muscles, then we have: co-contraction = (mean activity of antagonist muscles / mean activity of agonist muscles) - 1

In this equation, if agonist muscles are more active than antagonist muscles, co-contraction is above zero and vice versa. Maximum co-contraction occurs when the value of the equation is zero and co-contraction is at its lowest when the value of the equation is one or minus one (26).

Statistical analyses

Shapiro-Wilk test was used to check the normality of data distribution. Since co-contraction values were not normally distributed, a transforming [1 / (1 – co-contraction)] was used to normalize the data, and 0≤co-contraction≤1 was changed to 1≤co-contraction. For the analysis of the obtained data, generalized estimating equation (GEE) test was used to detect co-contraction and differences in the level of muscle activity at different trunk-feet conditions. The significance level was set to be 95%. SPSS software package (version 21; SPSS, Inc., Chicago, IL) was used to carry out GEE analyses.

RESULTS

Shapiro-Wilk test confirmed the normality of the data distribution for rectus femoris, vastus lateralis, vastus medialis, biceps femoris, and semitendinosus muscles in all feet positions (i.e. top, middle, and bottom) and all trunk positions (i.e. 15°, 20°, 25°, and 30° angles to the horizon).

When the feet were placed on top of the foot-plate, vastus medialis muscle was more active at backrest-to-horizon angle (henceforth simply referred to as trunk angle) of 20° compared to trunk angle of 30° (p= 0.001). Also, this muscle showed grater activity at trunk angle of 25° compared to trunk angle of 30° (p= 0.001). Vastus lateralis muscle was more active at trunk angle of 20° compared to trunk angle of 25° (p= 0.038). This muscle was more active at trunk angle of 25° compared to trunk angle of 30° (p= 0.001). Also, this muscle showed grater activity at trunk angle of 20° compared to trunk angle of 30° (p= 0.001). Rectus femoris muscle was more active at trunk angle of 15° compared to trunk angle of 30° (p= 0.033). This muscle displayed grater activity at trunk angle of 20° compared to trunk angle of 30° (p= 0.007). Also, it was more active at trunk angle of 25° compared to trunk angle of 30° (p= 0.001). When the feet were placed on the middle of the foot-plate, rectus femoris muscle was more active at trunk angle of 20° compared to trunk angle of 25° (p=0.033). Also, this muscle showed grater activity at trunk angle of 20° compared to trunk angle of 15° (p= 0.046) (Figure 4).

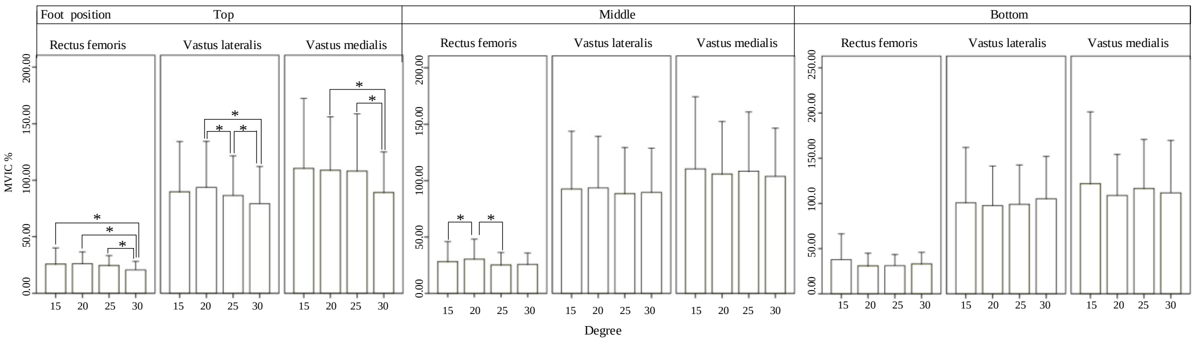

Fig. 4. Mean and standard deviation of electromyographic activity of quadriceps muscles at different trunk angles and feet positions near the top, middle, and bottom of the foot-plate in the concentric phase of the leg-press movement (*p<0.05).

When the feet were positioned at the top of the foot-plate, semitendinosus muscle was more active at trunk angle of 20° compared to trunk angle of 25° (p= 0.001). This muscle was more active at trunk angle of 20° compared to trunk angle of 15° angle (p= 0.001). Also, this muscle showed grater activity at trunk angle of 20° compared to trunk angle of 30° (p= 0.001). Biceps femoris muscle was more active at trunk angle of 20° compared to trunk angle of 25° (p= 0.001). This muscle was more active at trunk angle of 20° compared to trunk angle of 15° angle (p= 0.001). The activity of this muscle was more at trunk angle of 25° compared to trunk angle of 30° (p= 0.001). Also, this muscle showed grater activity at trunk angle of 20° compared to trunk angle of 30° (p= 0.001). When the feet were placed at the middle of the foot-plate, semitendinosus muscle was more active at trunk angle of 20° compared to trunk angle of 25° (p= 0.045). Also, the activity of this muscle at trunk angle of 20° was more than the trunk angle of 30° (p= 0.043). Biceps femoris muscle was more active when the trunk had a 20° angle to the horizon rather than a 15° angle (p= 0.017) (Figure 5).

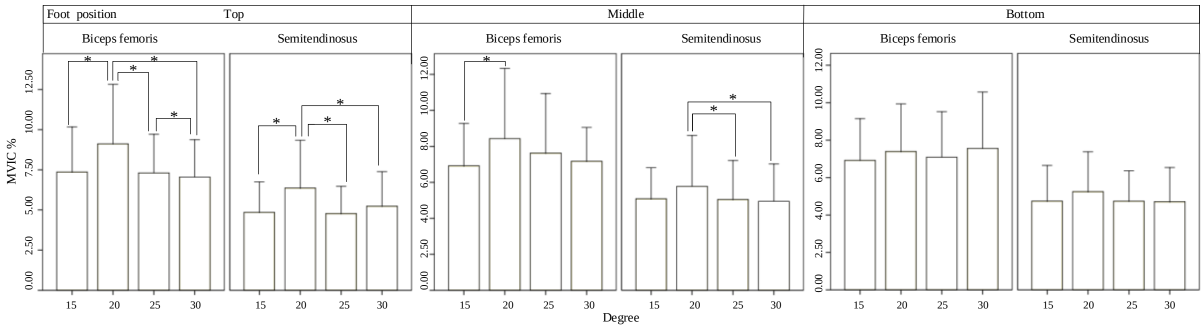

Fig. 5. Mean and standard deviation of electromyographic activity of hamstrings muscles at different trunk angles and feet positions near the top, middle, and bottom of the foot-plate in the concentric phase of the leg-press movement (*p<0.05).

Results for directed co-contraction of quadriceps and hamstrings muscles at four trunk angles (i.e. 15°, 20°, 25°, and 30°) and three feet positions (i.e. top, middle, and bottom of the foot-plate) showed that only when trunk had a 20° angle to the horizon and feet were positioned on top of the foot-plate a slight significant difference could be observed (Figure 6 and Table 1).

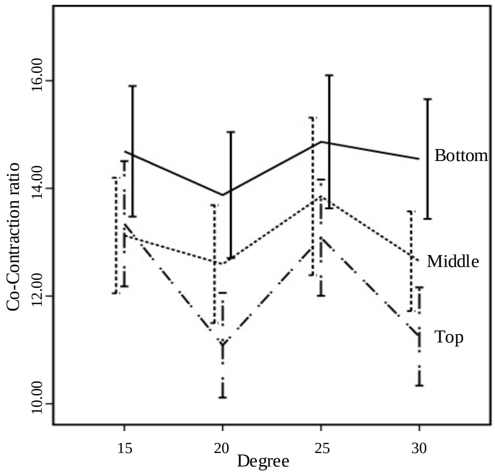

Fig. 6. Mean and standard deviation of the amount of directed co-contraction at different trunk angles and feet positions in the concentric phase of the leg-press movement.

Table 1. Mean difference and standard deviation of directed co-contraction at trunk-feet condition of 20°-top compared to other trunk-feet conditions.

(I) [Degree] & [Position]	(J) [Degree] & [Position]	Mean Difference (I-J)	Std. Error	Sig.
	[15°] & [top]	-2.2556[a]	2.51435	.004
	[15°] & [middle]	-2.0379[a]	2.41442	.004
	[15°] & [bottom]	-3.6021	2.59020	.099
	[20°] & [middle]	-1.5077[a]	2.41445	.025
	[20°] & [bottom]	-2.7901[a]	2.73492	.001
[20°] & [top]	[25°] & [top]	-1.9976[a]	2.38250	.016
	[25°] & [middle]	-2.7646[a]	2.91131	.013
	[25°] & [bottom]	-3.7777[a]	2.60867	.005
	[30°] & [top]	-.1621	2.18191	.052
	[30°] & [middle]	-1.5623[a]	2.16451	.017
	[30°] & [bottom]	-3.4591[a]	2.45352	.005

a. The mean difference is significant at the 0.05 level.

DISCUSSION

The purpose of this study was to determine the effects of trunk and foot positions on electromyographic activity and co-contraction of selected lower extremity muscles during leg-press resistance training. Concentric phase (knee extension) of the participants' performance was examined and muscle activity was measured for the surface muscles around the knee in the entire range of the knee extension movement. Any change in the angles of the joint caused a change in the moment arm of the muscles whose origin or insertion was located on the joint and thus, a change in the activity of those muscles (21). The position of the trunk relative to the knee and ankle joints significantly affected the muscular activity of the quadriceps and hamstrings muscles during closed kinetic chain exercise (27). Since the same relative load (70% 1RM) was used for the performance of each technique, muscle activity could be compared across different techniques (10). In the present study, the pattern and intensity of activity of quadriceps and hamstrings muscles, relative to each other, were similar to those in other studies (10,22). The large vastus group of muscles produces about 80% of the total extension torque at the knee, and the rectus femoris produces about 20% (28). In line with previous studies, during the leg-press movement the activity of vastus medialis and lateralis muscles was greater than that of rectus femoris muscle and this indicates that leg-press resistance training triggers more activity in vastus medialis and lateralis muscles compared to rectus femoris muscle (10,14). According to Figure 4, when the feet were placed near the top edge of the foot-plate and the trunk angle was increased, the activity of rectus femoris muscle was significantly reduced at trunk angle of 30° compared to trunk angles of 15°, 20°, and 25°. This decrease in muscle activity could be explained in terms of the length-tension relationship in the muscles. In fact, as the trunk angle increases, the pelvis adopts anterior tilt and the length of the rectus femoris muscle decreases. In this position, rectus femoris muscle is not at its desired length to increase force production and thus, its muscle activity is reduced (10,22,23,28,29). Also, the activity of vastus medialis and lateralis muscles had a significant decrease at trunk angle of 30° compared to trunk angles of 20° and 25°, but in comparison to trunk angle of 15°, there was no significant difference in muscle activity. Findings of the study confirmed that, compared to trunk angle of 30°, trunk angles of 20° and 25° were more effective in increasing the activity of vastus medialis, vastus lateralis, and rectus femoris muscles. The reason is that knee extensor torques are produced by maximal effort, with the hip held in extension (28). When the feet were placed on the middle of the foot-plate, rectus femoris muscle showed significantly more activity at trunk angle of 20° compared to trunk angles of 15° and 25°, but vastus medialis and lateralis muscles did not show a significant difference. This is due to the in accordance with the length-tension relationship in skeletal muscle, a constant length in the rectus femoris will allow it to be more effective in generating force throughout the entire concentric movement (10). As a biarticular muscle, the rectus femoris crosses both the knee and hip joints and thus changes in hip joint position during knee extension exercise would theoretically change sarcomere-length and epimuscular myofascial force transmission of the rectus femoris (31). When the feet were placed at the bottom of the foot-plate, vastus medialis, vastus lateralis, and rectus femoris muscles did not show significant differences in muscle activity at any of the trunk angles. As shown in Figure 5, in line with previous studies, during the leg-press movement a small amount of activity was observed in hamstrings muscles compared to quadriceps muscles (10,22). Due to the structure of the 45-degree leg-press machine, the motion range of the hip joint is limited during extension, and at the last 45° of the extension the hip joint extensors are not trained (32). Semitendinosus and biceps femoris muscles were significantly more active at trunk angle of 20° compared to trunk angles of 15°, 25°, and 30°. Since the origin of hamstrings muscles is located on ischial tuberosity, when trunk angle is increased, hamstrings muscles are lengthened. Since hamstrings muscles are biarticular, when trunk angle is 20 degrees and the feet are located near the top edge of the foot-plate, they are probably at their best length (10,22,23,28,29) and show more activity compared to other trunk angles. When the feet were placed in the middle of the foot-plate, biceps femoris muscle showed significantly more activity at trunk angle of 20° compared to trunk angle of 15° and also semitendinosus muscle was significantly more active at trunk angle of 20° relative to trunk angles of 25° and 30°. In pairwise comparisons of all possible conditions between the four trunk angles and the three feet positions, only a slight co-contraction was detected in trunk-feet condition of 20°-top compared to other conditions except for 15°-bottom and 30°-top conditions (Figure 6 and Table 1). As shown in Figures 3 and 4, due to the structure of the 45-degree leg-press machine, biceps femoris and semitendinosus muscles showed less activity than rectus femoris, vastus medialis, and vastus lateralis muscles. For this reason, very small co-contraction was observed in quadriceps and hamstrings muscles.

CONCLUSION

Co-contraction of quadriceps and hamstrings muscles has been confirmed as an important factor in increasing the anterior-posterior stability of the knee joint and reducing ACL tension. Based on the findings of the current study, a slight co-contraction was observed between these muscles during leg-press resistance training at different trunk-feet conditions. Thus, leg-press resistance training is not recommended for rehabilitation purposes after ACL surgery. The present study showed that rectus femoris, vastus medialis, vastus lateralis, biceps femoris, and semitendinosus muscles displayed significantly more muscle activity at trunk-feet condition of 20°-tap compared to other conditions. Thus, it is recommended that for the recruitment of more motor units while using the 45-degree leg-press machine for training purposes, the backrest of the machine be adjusted at an angle of 20° to the horizon and the feet be placed on top edge of the foot-plate.

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چکیده فارسی

تاثیر وضعیت قرارگیری تنه و پا بر فعالیت الکترومایوگرافی و هم انقباضی منتخبی از عضلات اندام تحتانی هنگام اجرای تمرین مقاومتی پرس پا

مجتبی گلپریان*[۱]، مهرداد عنبریان[۱]، امیر گلپریان[۲]

۱. گروه بیومکانیک ورزشی، دانشکده علوم ورزشی، دانشگاه بوعلی سینا، همدان، ایران

۲. گروه بیومکانیک ورزشی، دانشکده علوم ورزشی، دانشگاه شهید باهنر کرمان، کرمان، ایران

هدف از این تحقیق، تعیین اثرات وضعیت قرارگیری تنه و پا بر فعالیت الکترومایوگرافی و هم انقباضی منتخبی از عضلات اندام تحتانی هنگام اجرای تمرین مقاومتی پرس پا بود. دوازده پاورلیفتر مرد حرکت پرس پا را در حالی که پشتی دستگاه در زوایای ۱۵، ۲۰، ۲۵ و ۳۰ درجه نسبت به سطح افق تنظیم شده بود؛ اجرا کردند. پاها در سه وضعیت مختلف: بالا، وسط و پایین صفحه قرارگیری پا قرارگرفتند. فعالیت الکترومایوگرافی عضلات راست رانی، پهن داخلی، پهن خارجی، دوسر رانی و نیم وتری هنگام اجرای حرکت پرس پا در وضعیت های مختلف تنه و پاها ثبت شد. همچنین هم انقباضی عضلات مفصل زانو محاسبه شد. هنگامی که پاها در بالای صفحه قرارگیری پا قرارداشتند، عضله راست رانی در زوایای °۱۵ ، °۲۰ و °۲۵ فعالیت بیشتری نسبت به زاویه ۳۰ درجه پشتی دستگاه داشت. عضله پهن داخلی فعالیت بیشتری در زاویه °۲۰ و °۲۵ نسبت به °۳۰ نشان داد. عضله پهن خارجی فعالیت بیشتری در زاویه °۲۰ و °۲۵ نسبت به °۳۰ نشان داد. همچنین عضله پهن خارجی فعالیت بیشتری در زاویه °۲۰ نسبت به °۲۵ پشتی دستگاه داشت. عضلات نیم وتری و دوسر رانی در زاویه ۲۰ درجه فعالیت بیشتری نسبت به دیگر وضعیت ها داشتند. هم انقباضی ناچیزی در وضعیت °۲۰-بالا در مقایسه با سایر وضعیت ها مشاهده شد. با توجه به نتایج بدست آمده توصیه می شود برای فراخوانی واحدهای حرکتی بیشتر هنگام استفاده از دستگاه ۴۵ درجه پرس پا، پشتی دستگاه در زاویه ۲۰ درجه تنظیم گردد و پاها در بالا قرار گیرد.

واژه های کلیدی: پرس پا، الکترومایوگرافی، هم انقباضی، وضعیت پا، وضعیت تنه