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The influence of muscular activities in a squat with hands on a table for “locomotion training”

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Abstract

[Purpose] We studied the muscular activities activated during standing-up exercises with subjects’ hands on a table from a sitting position on a stool and compared them with muscle activities activated during normal squat exercises from the standing position. [Subjects] Healthy female subjects were selected for this study. [Methods] Muscular activities were measured by EMG during a normal squat exercise from the standing position and exercise from the sitting position using a table positioned slightly in front of a stool. The muscular activities during the latter exercise condition were evaluated by changing the height of the table in two different positions. [Results] Statistically significant differences ($p < 0.05$) were found between the normal squat exercise and the low table exercise for the rectus femoris muscle, vastus medialis muscle, and semitendinosus muscle. The rectus femoris muscle also showed a significant difference ($p < 0.01$) between the muscular activities obtained from the normal squat and high table exercises. [Conclusion] Our results failed to show a significant difference in the muscular activities of the lower extremities between exercises in which tables with different heights were used. These results suggest that frail elderly people may strengthen their muscles reasonably and effectively by using height-adjusted tables.

Key words: locomotive syndrome, squat, muscular activities

INTRODUCTION

The Japanese Orthopaedic Association defines "locomotive syndrome" as a dysfunction of one or more motile organs, such as bones, joints, muscles, and peripheral nerves, that leads to or likely leads to long-term confinement in bed or conditions requiring long-term nursing care[1]. In an aging society, with the extension of life expectancy, it is considered important for elderly persons to be able to spend their daily lives in good health and without need for nursing care. Many studies have suggested that exercise training is effective in improving the motor functions of elderly persons. To prevent "locomotive syndrome", the Japanese Orthopaedic Association recommends a one-leg standing exercise with eyes open and a squat exercise for daily locomotive training[2].

If a standing exercise or squat is difficult to perform, a similar effect was reported to be achieved by rising halfway or just attempting to rise to a halfway position from sitting [3-4]. However, no report has shown the effect of such training on the muscular activities of the lower limbs in an English-language journal.

In the present study, we studied the muscular activities activated during standing-up exercises from a sitting position on a stool with the subject's hands on a table and compared them with muscular activities activated during normal squat exercises from the standing position. A similar study was done in Japan and published in a Japanese journal, however the effect of using a table still has room for consideration. This study is the first of its kind to be published in English.

SUBJECTS AND METHODS

Healthy female students (n = 22; age, 21.5 ± 2.7 years; height, 158.8 ± 4.3 cm; weight, 50.4 ± 4.5 kg) were selected for this study. This study was carried out following the principles of the Declaration of Helsinki. We explained the main points of this study to the subjects and their families, and obtained their informed consent in writing before conducting the experiments.

Electromyography was analyzed by using the MyoSystem (Telemyo 2400T V2; NORAXON U.S.A. Inc.). A FootSwitch (NORAXON) was used to confirm that the subjects raised their hips from the stool. The flexion angle of the knee joint was measured during exercise by using an electric goniometer (DKH Co., Ltd.). A table mounted with an electric lifting apparatus (Hamamoto Industry) and a height-adjustable stool was used.

Muscular activities were measured during the normal squat exercise from the standing position and exercise from sitting on a stool using a table. The muscular activities during the latter exercise were measured by changing the height of the table in 2 different positions. Muscular activities were measured after 10 seconds of exercise and enough intervals were allowed between the measurements.

The standard squat exercise was used for Condition 1 (NSE; Fig. 1). From the standing position with both feet spread apart to shoulder width and the feet externally rotated to an angle of about 30°, the subjects were asked to flex their knee joints to an angle of about 90°. For this exercise, the subjects were instructed to move their hips backwards and not allow their knees to move in front of their toes. To keep their balance, both arms were kept in a comfortably flexed position at the shoulder joints.

The low table exercise was used for Condition 2 (LTE; Fig. 1). The height of the upper surface of the table was adjusted to the height of the superior edge of the patellae. For the starting position, the subjects were asked to sit on the stool with the ischial tuberosities at the center of the stool, and the height of the stool was adjusted so that the knee joints flexed to a 90° angle when the subject's ankles touched the stool legs. The subjects' feet were abducted at an angle of 30°, and the table was placed one fist apart from the edge of the knees

The high table exercise was used for Condition 3 (HTE; Fig. 1). The height of the upper surface of the table was adjusted while the subject was sitting on the stool. and the elbow joints were flexed to a 90° angle .The other conditions were similar to those of Condition 2.

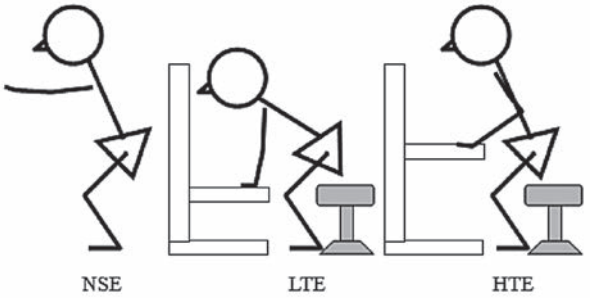

Fig 1 Experimental conditions

In Conditions 2 and 3, the subjects were asked to place their hands on the table at an angle that allowed them to stand up comfortably. Although the elbow angles were different for each subject, once the subject determined the angle, it could not be changed during the experiment. When the subjects raised their hips from the stool, they were instructed to confirm the rising of their hips by using a foot switch placed under the ischial tuberosities and to flex the knee joints to an angle of not less than 80°.

Muscular activities were measured by using surface electrodes attached to the rectus femoris, vastus medialis, semitendinosus, and gluteus medius muscles. The electrodes were placed on the skin surface of the right lower limbs about 15 mm apart from each other, and signals were detected at a sampling frequency of 1 kHz. Muscular activities were evaluated by using the rate of maximum voluntary contraction (% MVC) in the manual muscle test (MMT) of the right lower limb.

When the data obtained showed normal distribution, the muscular activities of the lower limbs were compared between the 3 conditions by using a one-way analysis of variance and multiple comparison of the Scheffé test. In case normal distribution was not found, results were analyzed by using the Kruskal-Wallis test.

RESULTS

Muscular activities of the 4 muscles were measured in the 3 exercise conditions. The results showed there were statistically significant differences ($p < 0.05$) between the normal squat exercise and the low table exercise for the rectus femoris, vastus medialis, and semitendinosus muscles. The rectus femoris muscle also showed a significant difference ($p < 0.01$) between the muscular activities obtained in the normal squat and high table conditions. The gluteus medius muscle showed no significant difference in the muscular activities obtained under the 3 conditions. All significant results indicated that the normal squat was a larger activity than another squat.

The % MVC of the 4 different muscles in the different exercise conditions are shown in Table 1.

Table 1 Comparison of normalized EMG in the three positions

Muscles	mean± SD (%MVC)		
	NSE	LTE	HTE
rectus femoris	29.4±11.2*, **	20.0±9.7*	19.2±8.8**
medial vastus	39.2±16.4*	28.2±12.7*	29.4±14.2
semitendinosus	4.3±2.2*	2.7±1.7*	2.9±1.8
gluteus medius	6.0±6.4	4.1±3.2	4.1±2.8

*: $p<0.05$, **: $p<0.01$

DISCUSSION

In the present study, we compared electromyograms and obtained muscular activities for several major muscles in 3 different conditions, namely a standard squat exercise, squat exercise with a low table, and squat exercise with a high table.

The results showed statistically significant differences in the muscular activities of the rectus femoris, vastus medialis, and semitendinosus muscles measured in the NSE and LTE conditions. In LTE, the upper surface of the table was adjusted to the height of the superior edge of the subjects' patellae to make it easy for the subject to place their hands on the table and rise halfway from sitting on a stool. Therefore, it was easier for the subjects to use their arm muscles than when the height of the table was adjusted with the subject sitting on the middle of the stool and the elbow joints flexed to 90°. This might explain the small variations observed in the effects of the exercise on the subjects. When the height of the table was adjusted to the same position as the arms (Condition 3), some subjects claimed that it was difficult to use their upper extremity muscles, which might have caused the scattering in the amount of load on the arms, and, consequently, resulted in the variation of the lower extremity muscular activities. A statistically significant difference was found between the muscular activities of the rectus femoris muscle measured during NSE and HTE. The rectus femoris muscle is the only biarticular muscle in the quadriceps muscle group; it originates at the inferior anterior iliac spine of the ilium and terminates on the tibial tuberosity[5]. Because in HTE the exercise included a smaller forward trunk flexion angle and therefore induced a smoother motion for the rectus femoris muscle than in LTE, a significant difference was demonstrated between NSE and HTE. Because the semitendinosus muscle originates on the ischial tuberosity and inserts on the medial tibial condyle[5], a significant difference in muscular activities were observed in LTE, in which the pelvis tilts to a more anterior position.

No significant differences in % MVCs were demonstrated in the muscular activities of the gluteus medius muscle measured under the different exercise conditions, and the mean values widely differed. The number of subjects was considered a main factor in this trend. As the exercise conditions studied in this report might have easily induced a wide distribution of results in the subjects, a larger sample size may show statistically significant differences. In addition, control of hip rotation during the exercise experiments may be necessary to reduce variations in movements during the exercise. Lee JH et al. suggested that side-lying hip abduction with medial rotation might be used as an effective method to increase the gluteus medius muscle activation[6]. Furthermore, Krause et al reported that the single limb stance places more demands on the gluteus medius muscle than double limb stance, whereas

single limb squats are more demanding than the single limb stance[7]. The results found by Krause et al. suggest that, if exercises are performed with the legs further apart or on a single limb, the gluteus medius muscle might obtain a larger muscular activation than those obtained in this study.

In LTE and HTE, the % MVCs of the 4 muscles were about two-thirds of those observed in NSE. In LTE and HTE, the exercises were performed with the subject's hands on the table, and, consequently, this placed a lighter load on the subject's lower extremities, but only resulting in slightly smaller muscular activities than in NSE. As no significant difference in muscular activities were observed between LTE and HTE, it was suggested that the muscular activities of the lower extremities were not affected by the height of the table on which the subject's hands were placed.

For all the four muscles studied under all the exercise conditions, the vastus medialis muscle showed the most muscular activation. The results suggest that the vastus medialis muscle was best activated by performing exercises in which the subject's hips were lifted up from the stool with the hands on the table, just as in a standard squat exercise. Gaston et al. reported that even when changing the projection of the center of gravity in the squat exercise, the activity of the quadriceps muscles is high compared to the hamstring and soleus muscles[8].

The levels of the muscular activities of the semitendinosus and gluteus medius muscles were less than 6.0% for the % MVC. From these results, it was suggested that the strengths of the semitendinosus and gluteus medius muscles cannot be appropriately reinforced by exercises in which the hips of the subject were raised up from the stool with the hands on the table. Ninos et al. demonstrated also that significant changes in muscle activity did not occur in the semimembranosus/semitendinosus muscles with changes in the knee flexion angles of the squat [9].

In this study, although our results failed to show a significant difference in muscular activities of the lower extremities between exercises that used tables with different heights, they may suggest that frail elderly people[10] may be able to strengthen their muscles safely and effectively by using height-adjusted tables. The muscular activities obtained in the exercises that used stools and tables were about two-thirds of that obtained in the standard squat exercise. Therefore, the standard squat exercise may be more effective for elderly persons who still retain certain levels of physical strength.

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テーブルを用いたスクワットによるロコモーショントレーニングが筋活動に与える影響

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抄　録

スクワットは運動療法として汎用性の高い運動である。本研究では健常女性を対象に，通常スクワット，および椅子と高さの異なる 2 つのテーブルを用いたスクワットの 3 条件で筋電図を測定し，各条件での筋活動量を比較した。この結果，測定したすべての筋で，通常スクワットの筋活動量が最も高く，他の 2 条件の筋活動量は通常スクワットの約 3 分の 2 の値となったが，高いテーブルでは四頭筋のみ有意差を確認できたが，低いテーブルでは大腿直筋，内側広筋，半腱様筋にて有意差を確認できた。これらの結果は，テーブルを用いることで下肢筋活動すべてが有意に減少するのではなことから，高齢者によっては効果的で安全なスクワットとして使用できる可能性を示唆できた。

キーワード：ロコモティブシンドローム，スクワット，筋活動