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Original Research

Influence of Trunk Position during Three Lunge Exercises on Muscular Activation in Trained Women

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ABSTRACT

International Journal of Exercise Science 14(1): 202-210, 2021. The present study aimed to compare the activation of the lower lumbar erector spinae, gluteus maximus, biceps femoris, and rectus femoris in two trunk positions (straight, and inclined) during three lunge exercises (static, step-forwarding, and walking) in trained young women in a randomized crossover design. Twelve women (24 ± 3 years) were selected and performed the lunge exercise with an overload of 30% of body weight in six conditions to analyze muscle activation via surface electromyography signals. Higher activation in the erector spinae (%MVIC) were observed ($p < 0.05$) when trunk position was inclined (straight = 20 ± 15, inclined = 40 ± 29) and during the walking lunge condition (static = 24 ± 16, forward = 26 ± 22, walking = 40 ± 33). Higher activation in the gluteus maximus was observed during step-forward and walking lunges conditions (static = 31 ± 12, forward = 54 ± 20, walking = 58 ± 30). All conditions displayed similar activations in the biceps femoris and rectus femoris ($p > 0.05$). Results indicate that positioning the trunk in a forward-inclined position induces greater lower lumbar erector spinae activation and dynamic lunge variations elicit greater muscular activation in the gluteus maximus than static lunges. Additionally, it seems that trunk and exercise variations do not influence the activation of tight muscles.

KEY WORDS: Split squat, electromyography, activity, female, exercise selection, resistance

INTRODUCTION

The lunge is a unilateral multi-joint leg exercise that involves knee and hip extensor muscles. This exercise is frequently performed in wellness and rehabilitation settings due to its closed-kinetic-chain characteristics and similarity to daily life activity movement patterns (10, 11, 13, 17). It is also used in sports programs to enhance the performance of jumpers (2) and sprinters (12), as well as in the recreational fitness schedule of healthy young practitioners.

There are many variations to execute the lunge, also known as the split squat. It can be done as a static, stepping, or walking movement, and it can be performed using bodyweight, barbells, elastic bands, or dumbbells as resistance. It can be carried out with the rear foot (or the front foot as well) on the ground or supported and elevated, as well as by doing the step laterally, diagonally, backward, or forward. How these different lunge forms influence joints and muscles actions have been investigated previously. For example, Riemann et al. noticed that forward lunges presented greater hip action, whereas lateral lunges prompted greater ankle and knee extensor contributions (18). Mausehund et al. recently observed similar activation of the primary movers (i.e., the gluteus maximus and vastus lateralis) when the lunge was done with both feet on the ground, with the back foot supported and elevated, or with the back foot descending from a box (13). However, during the latter two conditions, gluteus medius and hamstrings were activated at a higher level than during the standard lunge (13). This suggests that even small modifications to the lunge can change joint and muscle actions. Higher activation of secondary movers is observed when the lunge is performed with greater instability (6, 10, 20).

The performance of different lunges can also affect the movement of the upper body in the lateral and sagittal planes and, intricately, the action of the lower body as well (13, 18, 20). Although this has received less attention in the literature, trunk position during the lunge can influence exercise performance. Farrokhi et al. observed that during the step-forward lunge, positioning the trunk at a forward-inclined position increases the impulse and recruitment of hip extensor muscles compared to a straight-trunk position (6). It remains to be explored how trunk positioning conclusively affects movement during different lunge variations, as well as the kinematics and activation of muscles of the lower body. However, once investigations in these areas have been performed, this information may be applied to exercise selection for a variety of different uses.

Therefore, the present study aimed to compare the activation of the lower lumbar erector spinae (LLES), gluteus maximus (GM), biceps femoris (BF), and rectus femoris (RF) using surface electromyography activity (EMG) in two trunk positioning (straight and inclined) during three lunge exercises (static, step-forward, and walking) in young women. It was hypothesized that inclining the trunk during dynamic lunges would increase muscular activation.

METHODS

Participants

Participant recruitment was carried out via social media posts and home delivery of flyers in the university area. Inclusion criteria were as follows: females 20-30 years old, no lumbar, sacroiliac, or lower limb injury within the past year and free from orthopedic dysfunctions, and participation in regular resistance training for at least one year. Twenty healthy women volunteered and were individually interviewed. Eight women were dismissed, as they did not meet the inclusion criteria. Therefore, the remaining twelve women were included in the final analyses can be found in Table

1 below. The final sample size is considered satisfactory (n > 11) to achieve a power of 0.8 and an α of 0.05 for a 1:6 (groups:conditions) study, with an effect size of 0.25.

Table 1. Participant Demographics

Age (yrs)	Body Weight (kg)	Height (m)	Body Fat (%)	Training Experience (yrs)
24.4 ± 3.0	56.9 ± 5.6	1.62 ± 0.05	17.0 ± 5.9	2.5 ± 0.7

Protocol

The present study consisted of a cross-sectional design. Participants visited the laboratory two times. During the first visit, participants were given a detailed description of study procedures, signed informed consents, underwent anthropometric measurements (body weight, height, leg length, and skinfolds), and were familiarized with the exercises. During the second visit, data necessary to assess main outcomes were collected in the following conditions: static lunge (STAT), step-forwarding lunge (FORW), or walking lunge (WALK), with trunk positioned straight or inclined.

The STAT lunge consisted of the participant standing upright with the right foot in front of the left foot. The participant then lowers the left knee toward the ground, maximally flexing the right knee (~90° - 100°). The participant then returns to the initial standing position. The FORW consisted of the participant standing upright with feet together. The participant then takes a step forward, lowering the left knee (rear) toward the ground, while maximally flexing the right knee (front) (~90° - 100°). The participant returns to the initial position with feet together by pushing the right foot backward. The WALK consisted of the participant standing upright with feet together. The participant then takes a step forward, lowering the left knee (rear) toward the ground, while maximally flexing the right knee (front) (~90° - 100°). The participant then takes another step, pushing left foot forward to a standing position with their feet together. A detailed description can be found in Figure 1. The distance between feet for STAT condition and the step length for FORW and WALK conditions were normalized by individual leg length (79.4 ± 4.2 cm). Participants were instructed to maintain physiological spinal curves during the two trunk conditions. During the execution of the exercises, an instructor evaluated the technique and gave oral feedback for each movement.

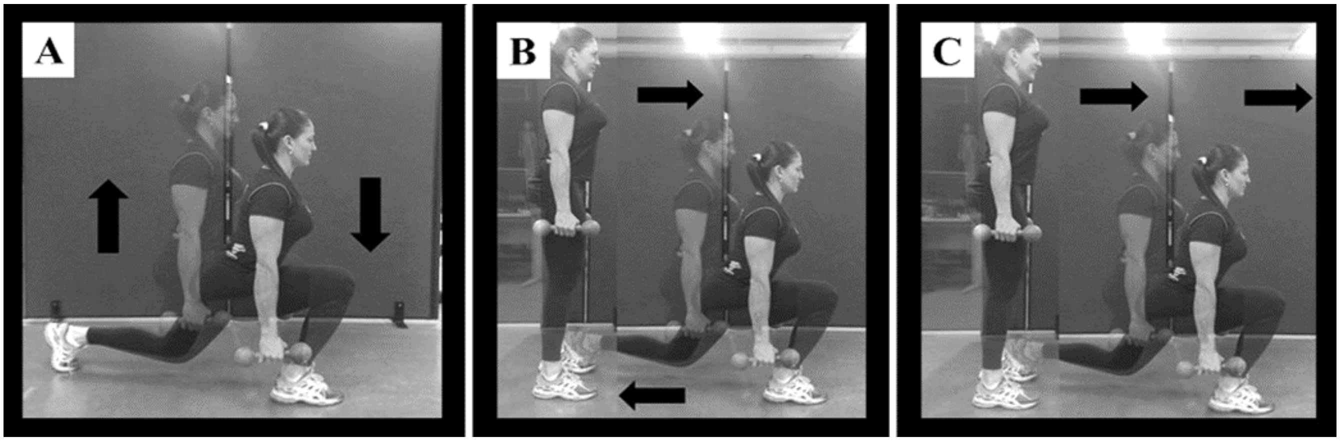

Figure 1. Lunge exercise variations for both trunk position: A: STAT (static lunge); B: FORW (step-forwarding lunge); C: WALK (walking lunge). Arrows indicate the displacement during the execution of the exercises.

During the second visit, participants performed a 10-min warm-up on a treadmill (moderate-velocity walking), followed by two 5-s maximum voluntary isometric contractions (MVIC) with a 60-s rest between MVICs. (9). After 10 min, participants executed the lunge exercises in a random sequence (with trunk straight or inclined; STAT, FORW, or WALK) with an additional load of 30% of bodyweight via two hand-held dumbbells. Exercises were performed in one set of six repetitions in a slow and controlled manner, using a 2:1:2 tempo (2 s for ascending/concentric phase, 1-s pause, 2 s for descending/eccentric phase). Participants were afforded with 5-min rest between exercises.

Kinematics of the lunge exercises were assessed to determine ascending/concentric and descending/eccentric phases accurately, then to synchronize the kinematic and EMG data and to obtain muscular activation on the exact phase of the repetitions. An eight-camera infrared system, operating at 100 Hz, was used to create a full-body model (model ViconMX T20-S, Denver, CO, USA). This system allowed for the collection of kinematic data from passive reflective spherical markers placed bilaterally on specific anatomical landmarks. For this model, markers were secured with medical, double-sided, adhesive tape on the head (helmet with 3 markers), trunk (acromion and spinous process of seventh cervical vertebra), arms (lateral and medial wrist epicondyle, ulnar and radial styloid process), hand (top of the third metacarpal bone), pelvis (anterior-superior iliac spine and posterior-superior iliac spine), thigh (great trochanter and lateral condyle), shank (fibula head), and foot (calcaneus and head of the fifth metatarsal). The beginning of the concentric phase of the repetitions was identified as when the virtual marker of the hip reached the lowest vertical value and ended when this marker showed the highest vertical value.

Superficial EMG data was collected using a Delsys Trigno Wireless EMG system and Trigno sensors (Delsys Inc., Natick, MA, USA) at a sampling rate of 2000 Hz. Upon arrival at the laboratory on measurement day, the participant's skin was shaved and cleaned with rubbing alcohol with a dermatographic pen at the electrode sites. electrodes were placed on the body right side, parallel to muscle fibers, following the recommendation of the Surface Electromyography for the Non-invasive Assessment of Muscles (8). For LLES, electrodes were placed 3 cm lateral to the spine and nearly level with the iliac crest between the L3 and L4 vertebrae. For GM, electrodes were placed halfway between the distance of the greater trochanter and second sacral vertebra in the belly of the muscle. For BF, electrodes were placed halfway between the distance of the ischial tuberosity and the lateral epicondyle of the tibia. For RF, electrodes were placed 1/3 proximal between the distance of the anterior superior iliac spine and the superior side of the patella. The raw sEMG signals were filtered using a fourth-order recursive band-pass Butterworth digital filter at 20–500 Hz and were processed into root mean square (RMS) values. Data of LLES, GM, BF, and RF muscles were normalized by the average RMS from both MVIC 1-s plateaus for each muscle. As mentioned above, EMG values were then synchronized with kinematic data to define the time-point of concentric muscle actions accurately. The mean RMS during the ascending phase was calculated for the third trial of each one of the six movements of exercise, and values obtained herein represented the muscular activation of each muscle and were expressed in %MVIC. For the analyses, appropriate mathematical routines were developed using Matlab 8.0 software (Math Works Inc., Natick, USA). This investigation was approved by the local University Ethics Committee. All procedures were conducted according to the Declaration of Helsinki and complied with the ethical standards of the International Journal of Exercise Science (15).

Statistical Analysis

Normality and homogeneity of variances were checked via Shapiro-Wilk's and Levene's tests. Two-way analysis of variance was used to compared results during the different trunk positions (straight vs. inclined) in three exercises (STAT vs. FORW vs. WALK). Tukey's post-hoc test was used to identify the mean differences when necessary. Effect size (ES) was calculated as mean difference divided by pooled standard deviation (4). An ES of 0.00–0.19 was considered as trivial, 0.20–0.49 as small, 0.50–0.79 as moderate, and ≥ 0.80 as large (4). A p value of < 0.05 was accepted as statistically significant. The data was expressed as mean, standard deviation, and 95% confidence intervals, and were stored and analyzed using SPSS software v. 21.0 (IBM Corp., Armonk, NY, USA).

RESULTS

For LLES activation, main effects of trunk position (straight = 20 ± 15, inclined = 40 ± 29; F = 14,554; p < 0.001; observed power [op] = 0.964), or exercise (STAT = 24 ± 16, FORW = 26 ± 22, WALK = 40 ± 33; F = 3,843; p = 0.026; op = 0.678) were observed. Positioning the trunk in a forward-inclined position elicited a largely higher activation (ES = 0.92) compared to the straight-trunk condition. During WALK lunge, a moderately higher activation was observed compared to STAT (p = 0.036; ES = 0.71), and FORW (p = 0.070; ES = 0.63) lunge conditions., However, similar results between STAT and FORW (p = 0.958; ES = 0.08) were observed. No trunk*exercise interaction effect was observed (F = 0.015; p = 0.985; op = 0.052). For GM, there were no observed main effects of trunk position (straight = 45 ± 26, inclined = 50 ± 23; F = 0,856; p = 0.358; op = 0.149).However, a main effect for exercise was observed (STAT = 31 ± 12, FORW = 54 ± 20, WALK = 58 ± 30; F = 10,544; p < 0.001; op = 0.986). A largely higher activation was observed for FORW (p < 0.001; ES = 1.13), and WALK (p < 0.001; ES = 1.31) lunge conditions compared to the STAT condition. Similar results were observed between FORW and WALK (p

= 0.825; ES = 0.18). No trunk*exercise interaction effect was observed (F = 0,388; *p* = 0.680; op = 0.110). For BF, no main effects of trunk position (straight = 23 ± 18, inclined = 24 ± 16; F = 0,130; *p* = 0.719; op = 0.065), or exercise (STAT = 21 ± 19, FORW = 26 ± 16, WALK = 24 ± 15; F = 0,361; *p* = 0.699; op = 0.106) were observed. Additionally, no trunk*exercise interaction (F = 1,874; *p* = 0.162; op = 0.377) was found. For RF, no main effects of trunk position (straight = 68 ± 30, inclined = 72 ± 28; F = 0,307; *p* = 0.581; op = 0.085), or exercise (STAT = 64 ± 32, FORW = 69 ± 26, WALK = 75 ± 29; F = 0,788; *p* = 0.459; op = 0.179) were observed., No trunk*exercise interaction (F = 0,273; *p* = 0.762; op = 0.091) was observed. The results of activation during the six conditions are displayed in Figure 2.

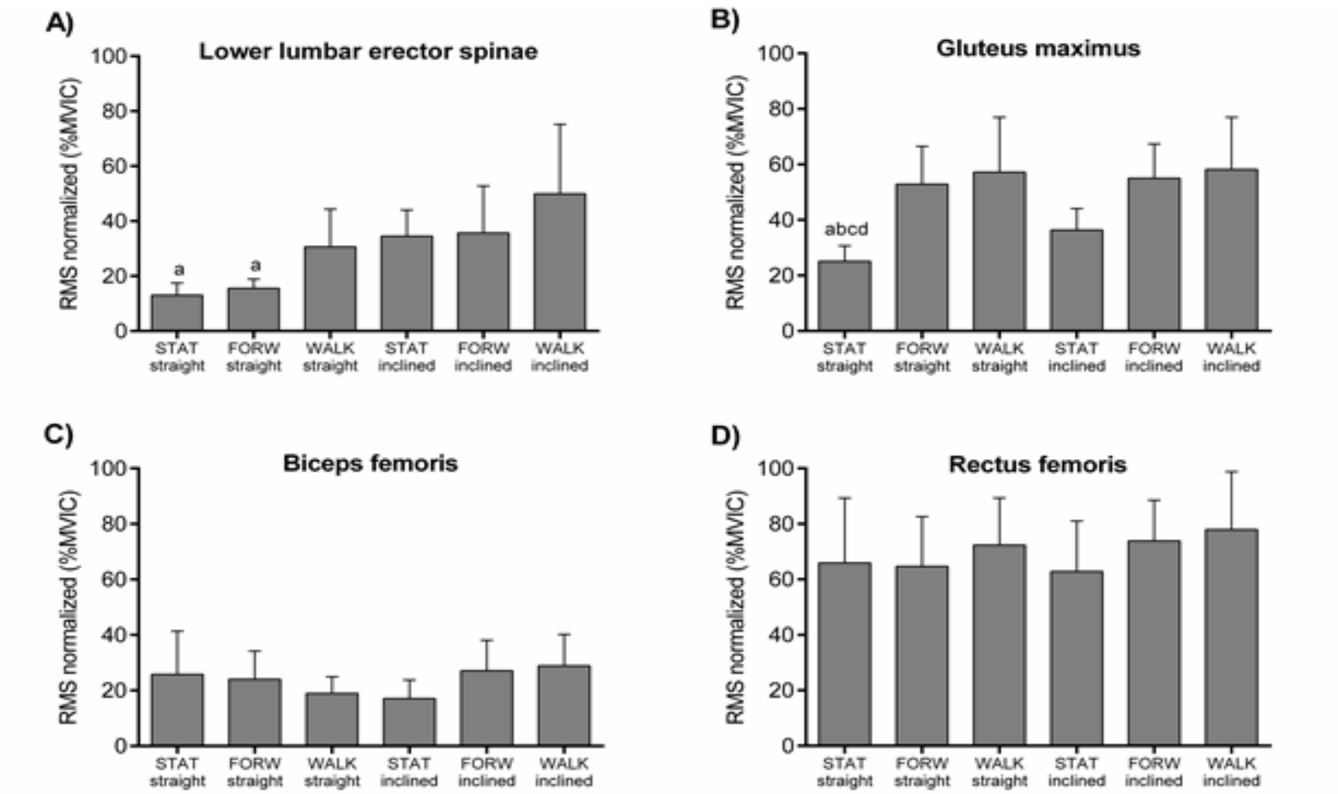

Figure 2. Values of muscular activation in lunge variations (n = 12). STAT = static lunge. FORW = step-forwarding lunge. WALK = walking lunge. aP < 0.05 vs. WALK inclined. bP < 0.05 vs. FORW inclined. cP < 0.05 vs. WALK straight. dP < 0.05 vs. FORW straight.

DISCUSSION

The main findings of the present study were that for the LLES, higher activations were observed when the trunk was positioned inclined and during WALK lunge. For GM, higher activations were observed during FORW and WALK lunges. Additionally, trunk and exercise variations do not influence the activation of BF and RF muscles. Therefore, the initial hypotheses that inclining the trunk and doing moving lunges would increase EMG activity were partially confirmed. The lack of main effect findings for trunk position and exercise makes the selection of exercises with a focus on BF or RF more flexible for this population, and therefore based on the practitioner's preference or aim. However, since some main effects were observed for LLES and GM, additional considerations need to be made.

No previous study has explored the influence of trunk position during lunges exercise in the activation of trunk muscles. This study observed that during STAT and FORW lunge conditions with trunk straightened muscular activation was lower in LLES compared to WALK inclined-trunk condition. Although not explored in this study, these results could be attributed to factors, such as the necessity to maintain anterior pelvic tilt and to stabilize the trunk position when participants were doing forward steps. For example, it has been previously observed that during a back squat, LLES was less activated when the exercise was done with partial depth (which requires less pelvic tilt maintenance) vs. full depth (16). In the same way, during hack and Smith machine squats, conditions that require minor stability, lower LLES activation was also observed compared to traditional bar squat (3, 7). Greater stability requirement seems to be a main factor that induces higher LLES since even when an exercise is done with a greater external load due to greater muscular action.

Considering the lower activation of LLES obtained in FORW straightened-trunk lunge, this variation may be preferable for the young women who suffer from chronic or acute low back pain. Although the LLES should be strengthened to ameliorate low back pain, training variations should focus on avoiding unnecessary pain and discomfort (19).

Given the relatively high activation of GM muscle (>50% of MVIC) during FORW and WALK lunges, individuals wanting to promote GM strengthening should include one of these exercises in their training protocol (1, 11). This rational can also be applied to the STAT lunge, although, if it is chosen, it should be performed with trunk inclined due to a largely higher GM recruitment (ES = 0.94). Farrokhi et al. also observed greater activation of GM when the trunk was inclined in comparison to straight/neutral position (6). This study suggests that STAT, FORW, or WALK lunges may induce relevant morphofunctional improvements in RF, but not in BF. However, variations in trunk position and exercise did not influence the activation of RF and BF muscles. It is important to note that the lunge variations specific to target muscles group should be included to create a complete training program for lower body (5, 10, 14, 17). This may be important mainly for women because they present higher GM:BF and RF:BF activation ratio compared to men (14, 21). In addition, considering the sex influence on EMG results, lack of trunk influence on tight activation in the present study as compared to previous studies, may be explained by the mixed sample they used (6). It is possible that men are influenced by trunk positioning in the lunge, while women are not, but this requires further comparative investigations.

Some concerns regarding the present study should be mentioned. A group of young trained women was selected for the present investigation. Thus, results here observed should be extrapolated with caution for untrained women. The same is valid for male and older counterparts. Also, the relatively small sample size might have affected the results. Moreover, electrodes were positioned in specific regions of trunk and lower-limb muscles. Therefore, the addition of more electrodes in different muscles or muscle regions would offer a better analysis of the outcomes and a greater application to exercise selection.

In summary, positioning the trunk forward-inclined induces, on average, a greater LLES activation, regardless of the variation of lunge exercise performed. Additionally, trunk and exercise variations do not influence the activation of BF and RF muscles, but greater GM activation is obtained when lunge exercise is performed in step-forwarding or walking ways. Coaches and practitioners should select lunge exercises for young women taking into account the participant's goal, particularly when attempting to place greater emphasis on a target muscle.

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