LOWER BODY MUSCLE ACTIVATION DURING LOW LOAD VERSUS HIGH LOAD FORWARD LUNGE AMONG UNTRAINED MEN

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ABSTRACT

This study was conducted to determine and compare the muscle activation during low load forward lunge (30% 1RM) and jump forward lunge (70% 1RM). Thirty recreationally active, untrained men (mean age = 21 ± 0.83 years old) were recruited and were assigned to perform forward lunge with 30% 1RM (30FL) and 70% 1RM (70FL) with both their dominant and non-dominant leg. Results showed the muscle activation of all muscles were significantly greater in the 70FL compared to 30FL. Besides that, all the muscle activation was also greater in dominant limb compared to non-dominant limb during both of the loading protocols. Due to the imbalances of muscle activation shown in this study, it was suggested that future studies to examine the long term effects of different loading protocols on the muscle adaptation.

Keywords: Forward lunge, Muscle, Loadings, Untrained

INTRODUCTION

Lunge had been shown to be one of major movement in several sports such as in racquet sports (Farrokhi et al., 2008). The important of lunge in sport (Nadzalan, Mohamad, Lee & Chinnasee, 2016) can be seen such as when a badminton player needs to do a deep lunge to get to the shuttlecock, tennis player try to reach the ball serve to the side, or a footballer try to steal the ball dribbled by the opponent.

Throughout the consistency of lunge used in sports, lunge exercises should be used widely as training exercises during strength training program. The inclusion of lunge as training exercises should be beneficial as it will allow athletes or individuals to train and improve their ability for the movement. As one of the way to overload the movement, individuals can carry weight during the training.

To know about the effectiveness of one movement, several measurements can be done. One of it is the measurement of muscle activation during the movement (Nadzalan et al., 2017). Muscle activation can be can be analysed through the electromyography (EMG) method. EMG is a method used to detect the level of neural drive or voluntary activation in a muscle (Nadzalan, Mohamad, Lee & Chinnasee, 2017). Voluntary activation is affected by both the motor unit frequency and the degree of muscle recruitment and is closely related unfatigued muscles' force production (Alkner, Tesch, & Berg, 2000; Lawrence & De Luca, 1983; Onishi et al., 2000; Perry & Bekey, 1981; Woods & Bigland-Ritchie, 1983). Muscles' EMG activity during an exercise has been shown to be associated with long-term improvement in muscle size in that part of muscle, when performing that exercise in a resistance training program (Wakahara, Fukutani, Kawakami, & Yanai, 2013; Wakahara et al., 2012).

It is the aim of this study to determine and compare the muscle activation of the lower limb during forward lunge with different loadings carried during the movement. It is currently unknown about the muscle activation during different loadings carried during lunge movement. The comparison also made between dominant and non-dominant site of limbs during both low and high loads forward lunge.

PARTICIPANTS

Thirty recreationally active men involved as study participants in this study. All the participants selected were males aged between 20-25 years old based on their year of birth. Participants were screened prior to testing using PAR Q. Each participant read and signed an informed consent for testing and training approved by the Thaksin University Ethics Committee (CODE E 060/2559)

PROCEDURES

30% 1RM and 70% 1RM forward lunge

Figure 1 showed the step for 30FL and 70FL that were performed in this study. Participants were instructed to stand with their hands holding a weight loaded barbell consisted of 30% or 70% 1RM placed on their shoulder, feet shoulder width apart. Participants lunged forward

with the dominant foot and lowered the thigh until be parallel with the ground, and then returned back to the starting position. The non-leading foot must not move from its starting position, and the head were constantly faced forward. The trunk was maintained straight. Participants were required to perform all the 30FL and 70FL for three trials consisting of three repetitions for each trial for both dominant and non-dominant lower limb.
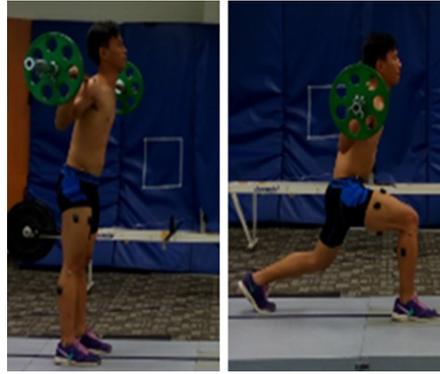
Fig.1. Forward lunge

EMG Collection and Analysis

Six infra-red cameras motion analysis system (Vicon T10s, Oxford Metrics, UK), sampled at 200 Hz was utilized to record the lunge movement.

EMG signals were recorded from vastus lateralis (VL), vastus medialis (VM), rectus femoris (RF), biceps femoris (BF), gluteus maximus (GM), medial gastrocnemius (MG), and lateral gastrocnemius (LG) as per SENIAM guidelines (Hermens & Freriks, 1997) using wireless electrodes (Trigno, Delsys, USA).

The surface EMG for non-invasive assessment of muscles (SENIAM) was used as guidelines for muscle determination. In order to get a good electrode-skin contact, participants were shaved if the skin surface at which the electrodes have to be placed is covered with hair. Participants' skins were then cleaned using alcohol swab and alcohol were allowed to vaporise so that the skin were dry before the electrodes were placed.

For the determination of vastus lateralis, vastus medialis and rectus femoris muscle electrode placement, participants were asked to sit on a table with the knees in slight flexion and the upper body slightly bend backward. The electrode at the vastus lateralis was placed at 2/3 on the line from the anterior spina iliaca superior to the lateral side of the patella. For vastus medialis, electrode was placed at 80% on the line between the anterior spina iliaca superior and the joint space in front of the anterior border of the medial ligament. For rectus femoris, the electrode was placed at 50% on the line from the anterior spina iliaca superior to the

superior part of the patella. In order to obtain the MVIC value for these three muscles, participants were asked to extend the knee without rotating the thigh while an assistant applied pressure against the leg above the ankle in the direction of flexion.

For the determination of biceps femoris muscle electrode placement, participants were asked to lying on the belly with the face down with the thigh down on the table and the knees flexed (to less than 90 degrees) with the thigh in slight lateral rotation and the leg in slight lateral rotation with respect to the thigh. The electrodes were placed at 50% on the line between the ischial tuberosity and the lateral epicondyle of the tibia. In order to obtain the MVIC value, participants were asked to press against the leg proximal to the ankle in the direction of knee extension resisted by an assistant.

To determine the medial and lateral gastrocnemius electrode placement, participants were required to lying on the belly with the face down, the knee extended and the foot projecting over the end of the table. For medial gastrocnemius, electrodes need to be placed on the most prominent bulge of the muscle. For lateral gastrocnemius, electrodes need to be placed at 1/3 of the line between the head of the fibula and the heel. The MVIC test for these two muscle were conducted by asking the participants to plantar flex the foot with emphasis on pulling the heel upward more than pushing the forefoot downward while given pressure by an assistant.

To determine the gluteus maximus electrode placement, participants were required to be in prone position, lying down on a table. The electrodes need to be placed at 50% on the line between the sacral vertebrae and the greater trochanter. This position corresponds with the greatest prominence of the middle of the buttocks well above the visible bulge of the greater trochanter. To obtain the MVIC value, participants were asked to lift the leg against l resistance by the assistant.

Raw EMG signals were recorded at an analogue-to-digital conversion rate of 2000 Hz and 16-bit resolution after being amplified (1000×). Recorded signals were full-wave rectified and filtered using a dual-pass, sixth-order, 10-500 Hz band-pass Butterworth filter, and then a linear envelope was created using a low-pass, second-order Butterworth filter with a cut-off frequency of 6 Hz (Earp, 2013).

For each muscle, the EMG signals collected from the start of the movement until the movement's completion were reported in two ways to describe muscle activity. Firstly, the greatest EMG value was reported as the peak muscle activity. Next the average of recorded muscle activity was used to show the mean of muscle activation during one single repetition.

DATA COLLECTION

All participants involved in familiarization session in order to make sure all the participants were able to perform all the forward lunge exercises correctly. After familiarization session, participants were tested for their forward lunge one repetition maximum (1RM).

To prevent risks of injury incidence during 1RM test, multiple-RM method were implemented as it was recommended to be safer (Baechle & Earle, 2008).

Muscle activities during the movement were assessed during each test. Comparisons of those variables were made between each loading protocols and between dominant and non-dominant site. All the familiarization and data collection sessions were supervised by the researcher with the assistance of appointed trained trainers.

All the lunge technique were closely monitored and controlled throughout all sessions. Participants were required to perform all exercises to a parallel depth as determined by the femoral line (line between the greater trochanter and the lateral epicondyle) being parallel to the ground. All the tests were conducted in randomized order to minimise order effects.

DATA ANALYSIS

Statistical analysis

Descriptive statistics were used to measure the mean and standard deviation of each physical characteristics and data scores. Repeated measure analysis of multivariances (MANOVA) was used to compare the difference of muscle activity during this study. Statistical significance was accepted at an α-level of $p \leq 0.05$. All statistical analyses were conducted using SPSS version 23 (IBM, New York, USA).

RESULTS

Table 1 showed the physical characteristics of participants involved in this study.

Table 1. Physical Characteristics of Participants

Variables	Mean ± SD
Age (years)	21 ± 0.83
Body Mass (kg)	71.00 ± 1.88
Body Weight (N)	696.57 ± 33.08
Height (cm)	171.41 ± 2.55
1RM (kg)	70.97 ± 6.57
Relative 1RM (1RM/BM)	1.00 ± 0.05

DOMINANT LOWER LIMB

Analysis on the dominant lower limb showed significant main effect for all the kinetics variables: i) vastus lateralis peak EMG (VL peak), $F(1,29) = 2156.951$; $p < 0.001$, ii) vastus lateralis mean EMG (VL mean), $F(1,29) = 993.546$; $p < 0.001$, iii) vastus medialis peak EMG (VM peak), $F(1,29) = 10139.288$; $p < 0.001$, iv) vastus medialis mean EMG (VM mean), $F(1,29) = 813.221$; $p < 0.001$, v) rectus femoris peak EMG (RF peak), $F(1,29) = 10069.444$; $p < 0.001$, vi) rectus femoris mean EMG (RF mean), $F(1,29) = 3351.648$; $p < 0.001$, vii) biceps femoris peak EMG (BF peak), $F(1,29) = 25919.095$; $p < 0.001$, viii) biceps femoris mean EMG (BF mean), $F(1,29) = 1530.652$; $p < 0.001$, ix) medial gastrocnemius peak EMG (MG peak), $F(1,29) = 141.285$; $p < 0.001$, x) medial gastrocnemius mean EMG (MG mean), $F(1,29) = 778.451$; $p < 0.001$, xi) lateral gastrocnemius peak EMG (LG peak), $F(1,14) = 7359.095$; $p < 0.001$, xii) lateral gastrocnemius mean EMG (LG mean), $F(1,29) = 248.122$; $p < 0.001$, xiii) gluteus maximus peak EMG (GM peak), $F(1,14) = 8237.762$; $p < 0.001$ and xiv) gluteus maximus mean EMG (GM mean), $F(1,14) = 236.586$; $p < 0.001$.

Table 2. EMG Data of Dominant Lower Limb during 30FL and 70FL

EMG	30FL	70FL
VL peak (% MVIC)	120.60 ± 17.39^b	154.40 ± 13.69^a
VL mean (% MVIC)	45.10 ± 6.57^b	64.30 ± 9.87^a
VM peak (% MVIC)	124.90 ± 15.93^b	164.30 ± 14.20^a
VM mean (% MVIC)	52.30 ± 9.63^b	66.20 ± 11.65^a
RF peak (% MVIC)	133.20 ± 12.44^b	158.20 ± 11.62^a
RF mean (% MVIC)	52.00 ± 10.39^b	67.80 ± 11.14^a
BF peak (% MVIC)	44.10 ± 9.34^b	71.50 ± 9.47^a
BF mean (% MVIC)	24.60 ± 7.56^b	34.90 ± 6.46^a

MG peak (% MVIC)	35.00 ± 6.09^b	42.40 ± 9.13^a
MG mean (% MVIC)	20.70 ± 4.94^b	28.10 ± 5.65^a
LG peak (% MVIC)	36.20 ± 7.80^b	50.80 ± 7.98^a
LG mean (% MVIC)	25.70 ± 5.42^b	35.90 ± 8.88^a
GM peak (% MVIC)	58.84 ± 15.90^b	70.75 ± 13.09^a
GM mean (%MVIC)	40.91 ± 10.04^b	49.67 ± 8.93^a

[a] = significantly difference from 30FL, $p < 0.05$

[b] = significantly difference from 70FL, $p < 0.05$

Table 2 showed the EMG data during the two lunge protocols. Pairwise comparison test showed that all EMG data (VL peak, VL mean, VM peak, VM mean, RF peak, RF mean, BF peak, BF mean, MG peak, MG mean, LG peak and LG mean) during 70FL were significantly higher compared to those recorded during 30FL, $p < 0.001$.

NON-DOMINANT LOWER LIMB

Analysis on the non-dominant lower limb showed a significant main effect for all the kinetics variables: i) vastus lateralis peak EMG (VL peak), $F(1,29) = 2032.23$; $p < 0.001$, ii) vastus lateralis mean EMG (VL mean), $F(1,29) = 873.24$; $p < 0.001$, iii) vastus medialis peak EMG (VM peak), $F(1,29) = 8834.56$; $p < 0.001$, iv) vastus medialis mean EMG (VM mean), $F(1,29) = 682.24$; $p < 0.001$, v) rectus femoris peak EMG (RF peak), $F(1,29) = 9768.24$; $p < 0.001$, vi) rectus femoris mean EMG (RF mean), $F(1,29) = 3843.24$; $p < 0.001$, vii) biceps femoris peak EMG (BF peak), $F(1,29) = 22803.176$; $p < 0.001$, viii) biceps femoris mean EMG (BF mean), $F(1,29) = 1320.92$; $p < 0.001$, ix) medial gastrocnemius peak EMG (MG peak), $F(1,29) = 89.24$; $p < 0.001$, x) medial gastrocnemius mean EMG (MG mean), $F(1,29) = 544.23$; $p < 0.001$, xi) lateral gastrocnemius peak EMG (LG peak), $F(1,14) = 5622.15$; $p < 0.001$, xii) lateral gastrocnemius mean EMG (LG mean), $F(1,29) = 198.24$; $p < 0.001$, xiii) gluteus maximus peak EMG (GM peak), $F(1,14) = 6723.97$; $p < 0.001$ and xiv) gluteus maximus mean EMG (GM mean), $F(1,14) = 189.02$; $p < 0.001$.

Table 3. EMG Data of Non-dominant Lower Limb during 30FL and 70FL

EMG	30FL	70FL
VL peak (% MVIC)	115.60 ± 17.47[b]	149.40 ± 13.79[a]
VL mean (% MVIC)	41.60 ± 6.18[b]	60.80 ± 9.4)[a]
VM peak (% MVIC)	117.97 ± 15.90[b]	157.37 ± 14.17[a]
VM mean (% MVIC)	48.93 ± 9.75[b]	62.83 ± 11.77[a]
RF peak (% MVIC)	125.23 ± 12.57[b]	150.23 ± 11.77[a]
RF mean (% MVIC)	47.67 ± 10.40[b]	63.47 ± 11.15[a]
BF peak (% MVIC)	40.50 ± 9.26[b]	67.90 ± 9.38[a]
BF mean (% MVIC)	23.10 ± 7.43[b]	32.73 ± 6.35[a]
MG peak (% MVIC)	32.83 ± 5.98[b]	40.23 ± 9.02[a]
MG mean (% MVIC)	19.07 ± 5.02[b]	26.47 ± 5.73[a]
LG peak (% MVIC)	34.30 ± 7.84[b]	48.90 ± 8.04[a]
LG mean (% MVIC)	24.27 ± 5.32[b]	34.47 ± 8.7[a]
GM peak (% MVIC)	55.23 ± 16.66[b]	66.45 ± 12.06[a]
GM mean (%MVIC)	37.60 ± 12.19[b]	45.10 ± 9.76[a]

[a] = significantly difference from 30FL, $p < 0.05$

[b] = significantly difference from 70FL, $p < 0.05$

Table 3 showed the EMG data during the two lunge protocols. Pairwise comparison showed that all EMG data (VL peak, VL mean, VM peak, VM mean, RF peak, RF mean, BF peak, BF mean, MG peak, MG mean, LG peak and LG mean) during 70FL were significantly higher compared to those recorded during 30FL, $p < 0.001$.

30% 1RM Forward Lunge (Dominant versus non-dominant lower limb)

Analysis on the dominant and non-dominant lower limb during 30FL showed a significant main effect for all the kinetics variables: i) vastus lateralis peak EMG (VL peak), $F_{(1,29)} = 271.875$; $p < 0.001$, ii) vastus lateralis mean EMG (VL mean), $F_{(1,29)} = 387.545$; $p < 0.001$, iii) vastus medialis peak EMG (VM peak), $F_{(1,29)} = 551.255$; $p < 0.001$, iv) vastus medialis mean EMG (VM mean), $F_{(1,29)} = 219.295$; $p < 0.001$, v) rectus femoris peak EMG (RF peak), $F_{(1,29)} = 403.142$; $p < 0.001$, vi) rectus femoris mean EMG (RF mean), $F_{(1,29)} = 2450.500$; $p < 0.001$, vii) biceps femoris peak EMG (BF peak), $F_{(1,29)} = 1566.00$; $p < 0.001$, viii) biceps femoris mean EMG (BF mean), $F_{(1,29)} = 261.00$; $p < 0.001$, ix) medial gastrocnemius peak EMG (MG peak), $F_{(1,29)} = 288.294$; $p < 0.001$, x) medial gastrocnemius mean EMG (MG mean), $F_{(1,29)} = 211.638$; $p < 0.001$, xi) lateral gastrocnemius peak EMG (LG peak), $F_{(1,14)} = 213.653$; $p < 0.001$, xii) lateral gastrocnemius mean EMG (LG mean), $F_{(1,29)} = 242.629$; $p < 0.001$, xiii) gluteus maximus peak EMG (GM peak), $F_{(1,14)} = 3451.980$; $p < 0.001$ and xiv) gluteus maximus mean EMG (GM mean), $F_{(1,14)} = 120.348$; $p < 0.001$.

Pairwise comparison test showed all the peak and mean EMG data of the dominant limb were significantly greater compared to the non-dominant limb during 30FL.

70% 1RM Forward Lunge (Dominant versus non-dominant lower limb)

Analysis on the dominant and non-dominant lower limb during 70FL showed significant main effect for all the kinetics variables: i) vastus lateralis peak EMG (VL peak), $F_{(1,29)} = 271.875$; $p < 0.001$, ii) vastus lateralis mean EMG (VL mean), $F_{(1,29)} = 387.545$; $p < 0.001$, iii) vastus medialis peak EMG (VM peak), $F_{(1,29)} = 551.255$; $p < 0.001$, iv) vastus medialis mean EMG (VM mean), $F_{(1,29)} = 219.295$; $p < 0.001$, v) rectus femoris peak EMG (RF peak), $F_{(1,29)} = 403.142$; $p < 0.001$, vi) rectus femoris mean EMG (RF mean), $F_{(1,29)} = 2450.500$; $p < 0.001$, vii) biceps femoris peak EMG (BF peak), $F_{(1,29)} = 1566..000$; $p < 0.001$, viii) biceps femoris mean EMG (BF mean), $F_{(1,29)} = 288.294$; $p < 0.001$, ix) medial gastrocnemius peak EMG (MG peak), $F_{(1,29)} = 288.294$; $p < 0.001$, x) medial gastrocnemius mean EMG (MG mean), $F_{(1,29)} = 211.638$; $p < 0.001$, xi) lateral gastrocnemius peak EMG

(LG peak), $F_{(1,14)} = 213.653$; $p < 0.001$, xii) lateral gastrocnemius mean EMG (LG mean), $F_{(1,29)} = 242.629$; $p < 0.001$, xiii) gluteus maximus peak EMG (GM peak), $F_{(1,14)} = 5428.12$; $p < 0.001$ and xiv) gluteus maximus mean EMG (GM mean), $F_{(1,14)} = 341.92$; $p < 0.001$.

As during 30FL, pairwise comparison test also showed all the peak and mean EMG data of the dominant limb were significantly greater compared to the non-dominant limb during 70FL.

DISCUSSIONS

In this study, peak and mean EMG data of vastus lateralis (VL), vastus medialis (VM), rectus femoris (RF), biceps femoris (BF), medial gastrocnemius (MG), lateral gastrocnemius (LG) and gluteus maximus (GM) were determined and compared between loadings lifted during forward lunge exercise.

Results showed that all EMG data (VL peak, VL mean, VM peak, VM mean, RF peak, RF mean, BF peak, BF mean, MG peak, MG mean, LG peak, LG mean, GM peak and GM mean) during 70FL were significantly higher compared to those recorded during 30FL, $p < 0.001$. These conditions were also applied to both dominant and non-dominant lower limb.

The EMG data in this study demonstrated that performing a movement with greater loadings will induce more muscle activation compared to lighter loads. Greater force production need more muscle activation.

Based on the EMG results, performing 70FL over 30FL as training routine would be more preferable as muscles' EMG activity during an exercise has been shown to be associated with long-term improvement in muscle size in that part of muscle (Wakahara et al., 2013; Wakahara et al., 2012). Thus, it was more preferable to perform 70FL over 30FL in training program due to their greater muscles' recruitment that will likely lead to increases in strength and size in the muscles investigated.

The different of muscle activation caused by different protocols of lunge had been shown by several previous studies before. For example, study by Farrokhi et al. (2008) found that by erecting the trunk forward during lunge, there were increment of hip extensor impulse and EMG when compared to lunge with normal condition.

In contrast to the current study, Sorensen (2009) did not find increasing of gluteus muscle activity during different variations of lunge performed in that study. The contrast in findings is suggested by the authors could be due to participants that were asked to make a 30° angle

from the anterior axis of their front foot, which might cause the participants not performed an enough wide step to cause changes in gluteus maximus length.

Results on gluteus muscle activation that were found to be increase as a result of increasing load in this study was in line with findings by McCaw and Melrose (1999) that found significant increase in gluteus maximus EMG activity as the result of protocol changes during exercise. In that study, gluteus maximus EMG activity increase during the squat as a result of increasing the stance width to 140% of their shoulder width and increasing the external load by 60% to 75% of the subjects' 1 repetition maximum. The increment of the gluteus maximus EMG activity could be the result of gluteus maximus being placed in a less optimal position on the force-length curve causing it to have to recruit more motor units as a way to achieve the necessary hip extension to complete the movement. 30° angle step during Sorensen (2009) study may not be enough to increase medio-lateral distance between the subject's feet to induce gluteus maximus EMG activity. The 70% 1RM load used in this study was shown to be enough to produce greater gluteus maximus muscle activity compared to 30% 1RM. Loadings used by Sorensen study might be not high enough to the subjects ability to cause more activation of gluteus maximus activity like that seen in this current study. Inducing more loads based on subjects maximal ability might cause muscles EMG activity to be increased.

Comparing dominant and non-dominant side, it was found that all the muscle activations of the dominant site were found to be greater compared to the non-dominant site. Not much study has been conducted on comparing dominant and non-dominant lower limb muscle activation. The current findings were in line with those found by De Luca, Sabbahi, and Roy (1986) and Merletti, De Luca, and Sathyan (1994) that found the dominant side produced more muscle activation compared to the non-dominant side. However, Williams, Sharma, and Bilodeau (2002) found no significant differences between the dominant and non-dominant side with regard to the changes in the EMG median frequency during fatigue conditions.

Besides that, This current findings was also in contrast to what has been found by Niu, Wang, He, Fan, and Zhao (2011) that found the non-dominant lower-extremity produced greater ankle flexor activities during drop landing. The differences might be influenced by the different exercise performed. The drop landing conducted by Niu et al. (2011) might seldom be done by the participants thus the non-dominant site muscles activate grater muscle activation in order to effectively control the ankle motion. The present study involve participants to perform lunge in which participants has adapted to it and the aim for this study was to perform the movement the best as they can thus cause the muscle activation to be greater in the dominant site that was stronger and faster.

CONCLUSIONS

Findings of this study demonstrated the more muscle activation during greater loadings lifted and in the dominant compared to non-dominant loadings. The imbalances existed in this study stressed the need for future studies to be conducted on examining the chronic effects in term of muscular adaptation to different loadings used during lunge exercise.

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