

Muscle Activation Analysis of Step and Jump Forward Lunge among Badminton Players

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Abstract: This study was conducted to determine and compare the muscle activity during step forward lunge (SFL) and jump forward lunge (JFL) in badminton. Fifteen university badminton players (mean age = 22.07 ± 1.39 years old) were recruited and were assigned to perform SFL and JFL while holding a badminton racquet using their preferred hand. Muscle activation of vastus lateralis (VL), vastus medialis (VM), rectus femoris (RF), biceps femoris (BF), gluteus maximus (GM), medial gastrocnemius (MG), and lateral gastrocnemius (LG) were analysed and compared between SFL and JFL and also between dominant and non-dominant lower limb in each lunge protocol. Results showed for both the dominant and non-dominant lower limb, all the muscle activation was greater during JFL compared to SFL except for the MG muscle. All the muscle activation was also found to be greater in the dominant compared to non-dominant lower limb for both lunge protocols. Overall, findings demonstrated the existence of differences in muscle activation across difference protocols of movement and different site of limbs. This should be taken into consideration for developing training program in order to enhance performance and reduce the risk of injuries.

Key words: *muscle activation, electromyographic, step forward lunge, jump forward lunge, dominant, training*

INTRODUCTION

One of the most performed lunges technique is the forward lunges. Forward lunge started with a front step followed by a backward push. In order to enhance its effectiveness, the forward lunge should be performed with the lead leg been brought as far as possible to the front as in descent phase, the knee should not exceed the toe.

Badminton is one of the sports that involved a lot of lunges movement in the game [1]. The important of lunges in a game could be seen when the player want to retrieve a drop shot where the player need to do a deep lunge to get to the shuttlecock. Sturgess and Newton [2] had highlighted the importance of the ability to accelerate from receiving stance to retrieving a drop shot.

Two of the most performed forward lunge in badminton are step in or jump [3]. Throughout the relevance of the

lunge pattern to sport, it is important to know the muscle activated during the movement. The knowledge on the muscle activation will enable a more specific resistance training program to be designed in order to enhance all the muscle needed to perform the movement successfully. Thus, the aim of this study were to determine and compare the muscle activation during step forward lunge (SFL) and jump forward lunge in both dominant and non-dominant lower limb.

METHODOLOGY

Participants

This study involved university male badminton players as study participants (n=15). Participants recruited were the currently active university representatives in any badminton tournament organized by Malaysian University Sports Council (MASUM). During this study, participants were required to perform two methods of badminton specific lunges (SFL and JFL).

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Participants performed all lunges exercises that had been randomized and counterbalanced between the participants in order to ensure results not affected by the order of tests. All the participants selected were males aged between 20-25 years old based on their year of birth. Participants had no medical problems. 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 Ethical Committee (CODE E 060/2559).

Step and jump forward badminton-specific lunges

Participants were instructed to stand with one of their hand (preferred) holding a badminton racquet, feet shoulder width apart. Participants lunged forward and must lower the thigh to be parallel with the ground, and then returned back to the starting position. As to simulate the movement used in real badminton game situation, participant bent their trunk to 45° forward. Jump forward lunges were performed similar to the step forward lunge except participants need to explosively (jump) lunged forward and then explosively (jump) returned back also by jumping to the starting position. Participants were required to perform all the SFL and JFL for three trials consisting of three repetitions for each trial for both dominant and non-dominant lower limb.

EMG Collection and Analysis

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 [4] using wireless electrodes (Trigno, Delsys, USA). The surface EMG for non-invasive assessment of muscles (SENIAM) were used as guidelines for muscle determination [5]. Maximum voluntary isometric contraction (MVIC) [5] were conducted before the lunge movement EMG testing. 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 [6]. For each muscle, the peak and mean EMG signals were analyzed and reported.

Data Collection

All participants involved in familiarization session in order to make sure all the participants were able to perform all the lunges movement correctly. Uniformed

testing protocols were applied to all the participants. Participants were tested in randomized order to minimise order effects. In order to ensure maximal performance, participants were instructed to “lunges as far as possible and as fast as possible”. Muscle activation of the stepping limb (dominant and non-dominant) was assessed during each test. Comparisons of the muscle activation were made between each lunges protocol and between dominant and non-dominant limbs. All sessions were conducted at the Sports Biomechanics Laboratory, Universiti Pendidikan Sultan Idris, Tanjong Malim.

Statistical analysis

Descriptive statistics were used to measure the mean and standard deviation of each physical characteristics and data scores. Repeated measure analysis of multivariates (MANOVA) was used to compare the difference of muscle activation. 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

<i>Physical Characteristics of Participants</i>	
Variables	Mean \pm SD
Age (years)	22.07 \pm 1.39
Body Mass (kg)	70.07 \pm 1.88
Body Weight (N)	687.41 \pm 13.53
Height (cm)	173.13 \pm 2.12
1RM (kg)	71.87 \pm 2.59
Relative 1RM (1RM/BM)	1.03 \pm 0.01

Dominant lower limb

Analysis of dominant lower limb showed significant main effects were found in the following muscle activity variables: i) vastus lateralis peak EMG (VL peak), $F(1,14) = 1095.512$; $p < 0.001$, ii) vastus lateralis mean EMG (VL mean), $F(1,14) = 240.283$; $p < 0.001$, iii) vastus medialis peak EMG (VM peak), $F(1,14) = 460.536$; $p < 0.001$, iv) vastus medialis mean EMG (VM mean), $F(1,14) = 373.270$; $p < 0.001$, v) rectus femoris peak EMG (RF peak), $F(1,14) = 686.644$; $p < 0.001$, vi) rectus femoris mean EMG (RF mean), $F(1,14) = 619.392$; $p < 0.001$, vii) biceps femoris peak EMG (BF peak), $F(1,14) = 363.265$; $p < 0.001$, viii) biceps femoris mean EMG (BF mean), $F(1,14) = 113.406$; $p < 0.001$, ix) lateral gastrocnemius peak EMG (LG peak), $F(1,14)$

= 102.690; $p < 0.001$, x) lateral gastrocnemius mean EMG (LG mean), $F(1,14) = 44.384$; $p < 0.001$, xi) gluteus maximus peak EMG (GM peak), $F(1,14) = 360.748$; $p < 0.001$ and xii) gluteus maximus mean EMG (GM mean), $F(1,14) = 104.8209$; $p < 0.001$.

No significant main effect was found for the: i) medial gastrocnemius peak EMG (MG peak), $F(1,14) = 78.791$; $p > 0.05$, and ii) medial gastrocnemius mean EMG (MG mean), $F(1,14) = 268.526$; $p > 0.05$.

Table 2
EMG Data of Dominant Lower Limb during SFL and JFL

EMG	SFL	JFL
VL peak (% MVIC)	81.60 ± 7.64 ^b	110.47 ± 10.49 ^a
VL mean (% MVIC)	35.27 ± 5.96 ^b	49.33 ± 9.29 ^a
VM peak (% MVIC)	93.60 ± 16.76 ^b	119.07 ± 12.75 ^a
VM mean (% MVIC)	42.87 ± 7.49 ^b	60.80 ± 10.01 ^a
RF peak (% MVIC)	87.73 ± 10.22 ^b	121.80 ± 14.51 ^a
RF mean (% MVIC)	44.33 ± 7.27 ^b	61.07 ± 9.32 ^a
BF peak (% MVIC)	35.87 ± 5.72 ^b	46.13 ± 6.44 ^a
BF mean (% MVIC)	18.80 ± 4.83 ^b	24.67 ± 6.36 ^a
MG peak (% MVIC)	29.40 ± 5.58	34.13 ± 9.80
MG mean (% MVIC)	15.40 ± 4.03	19.47 ± 4.27
LG peak (% MVIC)	24.67 ± 6.41 ^b	34.47 ± 9.85 ^a
LG mean (% MVIC)	17.87 ± 5.24 ^b	22.27 ± 7.43 ^a
GM peak (% MVIC)	40.15 ± 12.39 ^b	49.61 ± 10.93 ^a
GM mean (%MVIC)	24.78 ± 9.49 ^b	33.95 ± 9.81 ^a

^a = significantly difference from SFL, $p < 0.001$, $p < 0.01$, $p < 0.05$

^b = significantly difference from JFL, $p < 0.001$, $p < 0.01$, $p < 0.05$

Table 2 showed the EMG data during the two lunges protocols. Results showed that VL peak, VL mean, VM peak, VM mean, RF peak, RF mean, BF peak, BF mean, LG peak, LG mean, GM peak and GM mean during JFL were significantly higher compared to those recorded during SFL, $p < 0.001$. No significant differences were found for the MG peak and MG mean between both lunges protocols, $p > 0.05$.

Non-dominant lower limb

Analysis of the non-dominant lower limb showed significant main effects were found in the following muscle activity variables: i) vastus lateralis peak EMG (VL peak), $F(1,14) = 736.787$; $p < 0.001$, ii) vastus lateralis mean EMG (VL mean), $F(1,14) = 217.837$; $p < 0.001$, iii) vastus medialis peak EMG (VM peak), $F(1,14) = 474.811$; $p < 0.001$, iv) vastus medialis mean EMG (VM mean), $F(1,14) = 242.630$; $p < 0.001$, v) rectus femoris peak EMG (RF peak), $F(1,14) = 648.603$; $p < 0.001$, vi) rectus femoris mean EMG (RF mean), $F(1,14) = 586.285$; $p < 0.001$, vii) biceps

femoris peak EMG (BF peak), $F(1,14) = 360.526$; $p < 0.001$, viii) biceps femoris mean EMG (BF mean), $F(1,14) = 100.242$; $p < 0.001$, ix) lateral gastrocnemius

peak EMG (LG peak), $F(1,14) = 92.872$; $p < 0.001$, x) lateral gastrocnemius mean EMG (LG mean), $F(1,14)$

= 43.210; $p < 0.001$, xi) gluteus maximus peak EMG (GM peak), $F(1,14) = 367.802$; $p < 0.001$ and xii) gluteus maximus mean EMG (GM mean), $F(1,14) = 104.912$; $p < 0.001$.

As in the dominant limb, no significant main effect was found for the: i) medial gastrocnemius peak EMG (MG peak), $F(1,14) = 53.201$; $p > 0.05$, and ii) medial gastrocnemius mean EMG (MG mean), $F(1,14) = 125.23$; $p > 0.05$ in the non-dominant lower limb.

Table 3
EMG Data of Non-Dominant Lower Limb during SFL and JFL

EMG	SFL	JFL
VL peak (% MVIC)	77.60 ± 7.76 ^b	104.47 ± 10.57 ^a
VL mean (% MVIC)	32.27 ± 6.03 ^b	45.67 ± 9.35 ^a
VM peak (% MVIC)	87.60 ± 16.79 ^b	113.40 ± 12.74 ^a
VM mean (% MVIC)	39.20 ± 7.68 ^b	57.13 ± 10.07 ^a
RF peak (% MVIC)	82.57 ± 10.20 ^b	116.30 ± 14.61 ^a
RF mean (% MVIC)	40.67 ± 7.23 ^b	57.32 ± 9.42 ^a
BF peak (% MVIC)	32.87 ± 5.70 ^b	43.05 ± 6.45 ^a
BF mean (% MVIC)	16.80 ± 4.82 ^b	22.67 ± 6.35 ^a
MG peak (% MVIC)	20.57 ± 5.64	32.30 ± 9.80
MG mean (% MVIC)	13.40 ± 4.05	17.47 ± 4.25
LG peak (% MVIC)	22.83 ± 6.38 ^b	32.63 ± 9.89 ^a
LG mean (% MVIC)	15.87 ± 5.21 ^b	20.27 ± 7.47 ^a
GM peak (% MVIC)	36.23 ± 10.32 ^b	45.43 ± 9.59 ^a
GM mean (%MVIC)	23.57 ± 8.84 ^b	30.13 ± 7.89 ^a

^a = significantly difference from SFL, p < 0.001, p < 0.01, p < 0.05

^b = significantly difference from JFL, p < 0.001, p < 0.01, p < 0.05

Table 3 showed the EMG data during the two lunges protocols. Results showed that VL peak, VL mean, VM peak, VM mean, RF peak, RF mean, BF peak, BF mean, LG peak, LG mean, GM peak and GM mean during JFL were significantly higher compared to those recorded during SFL, p < 0.001. No significant differences were found for the MG peak and MG mean between both lunges protocols, p > 0.05.

Step forward lunge (Dominant versus non-dominant lower limb)

Analysis of the dominant and non-dominant lower limb during step forward lunge showed significant main effect was found for all the muscle activity variables: i) vastus lateralis peak EMG (VL peak), F(1,14) = 336.00; p < 0.001, ii) vastus lateralis mean EMG (VL mean), F(1,14) = 189.00; p < 0.001, iii) vastus medialis peak EMG (VM peak), F(1,14) = 756.00; p < 0.001, iv) vastus medialis mean EMG (VM mean), F(1,14) = 45.210; p < 0.001, v) rectus femoris peak EMG (RF peak), F(1,14) = 961.00; p < 0.001, vi) rectus femoris mean EMG (RF mean), F(1,14) = 211.750; p < 0.001, vii) biceps femoris peak EMG (BF peak), F(1,14) = 525.00; p < 0.001, viii) biceps femoris mean EMG (BF mean), F(1,14) = 264.502; p < 0.001, ix) medial gastrocnemius peak EMG (MG peak), F(1,14) = 108.72; p < 0.001, and x) medial gastrocnemius mean EMG (MG mean), F(1,14) = 336.00; p < 0.001, xi) lateral gastrocnemius peak EMG (LG peak), F(1,14) = 102.21; p < 0.001, xii) lateral

gastrocnemius mean EMG (LG mean), F(1,14) = 300.23; p < 0.001, xiii)

gluteus maximus peak EMG (GM peak), F(1,14) = 214.28; p < 0.001 and xiv) gluteus maximus mean EMG (GM mean), F(1,14) = 78.63; 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 SFL.

Jump forward lunge (Dominant versus non-dominant lower limb)

Analysis of the dominant and non-dominant lower limb during jump forward lunge Results showed a significant main effect in all the muscle activity variables: i) vastus lateralis peak EMG (VL peak), F(1,14) = 756.000; p < 0.001, ii) vastus lateralis mean EMG (VL mean), F(1,14) = 178.316; p < 0.001, iii) vastus medialis peak EMG (VM peak), F(1,14) = 289.000; p < 0.001, iv) vastus medialis mean EMG (VM mean), F(1,14) = 178.316; p < 0.001, v) rectus femoris peak EMG (RF peak), F(1,14) = 635.250; p < 0.001, vi) rectus femoris mean EMG (RF mean), F(1,14) = 278.698; p < 0.001, vii) biceps femoris peak EMG (BF peak), F(1,14) = 547.059; p < 0.001, viii) biceps femoris mean EMG (BF mean), F(1,14) = 336.000; p < 0.001, ix) medial gastrocnemius peak EMG (MG peak), F(1,14) = 121.000; p < 0.001, x) medial gastrocnemius mean EMG (MG mean), F(1,14) = 68.613; p < 0.001, xi) lateral gastrocnemius peak EMG (LG peak), F(1,14) =

121.000; $p < 0.001$, xii) lateral gastrocnemius mean EMG (LG mean), $F(1,14) = 336.000$; $p < 0.001$, xiii) gluteus maximus peak EMG (GM peak), $F(1,14) = 230.872$; $p < 0.001$ and xiv) gluteus maximus mean EMG (GM mean), $F(1,14) = 98.126$; $p < 0.001$. As during SFL, 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 JFL.

DISCUSSIONS

In this study, peak and mean electromyographic (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 SFL and JFL. Results showed VL peak, VL mean, VM peak, VM mean, RF peak, RF mean, BF peak, BF mean, LG peak, LG mean, GM peak and GM mean during JFL were significantly higher compared to those recorded during SFL, $p < 0.001$. No significant differences were found for the MG peak and MG mean between both lunges protocols, $p > 0.05$. These conditions applied to both dominant and non-dominant lower limb.

The EMG data in this study demonstrated that performing a movement in explosive manner will increase muscle activation. This might be due to the more force that needed to be performed by the performer as jumping movement need more muscle activation in order to produce greater force. Based on the EMG results, performing JFL over SFL 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 [7, 8]. Thus, it was more preferable to perform JFL over SFL 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 lunges had been shown by several previous studies before. For example, study by Farrokhi et al. [1] found that by erecting the trunk forward during lunges, there were increment of hip extensor impulse and EMG when compared to lunges with normal condition. It can be seen from this study that lunges with trunk forward erected would be a great choice to be performed if an athlete or individual want to improve their hip extensor strength. In contrast to the current study, Sorensen [9] did not find increasing of gluteus muscle activity during different variations of lunges performed in that study. Sorensen [9] results prevailed any significant increases of gluteus maximus peak EMG during any variations of the FL. Results on gluteus muscle activation that were

found to be increase as a result of jumping in this study was in line with findings by McCaw and Melrose [10] that found significant increase in gluteus maximus EMG activity as the result of protocol changes during exercise.

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 et al. [11] and Merletti et al. [12] that found the dominant side produced more muscle activation compared to the non-dominant side. Besides that, this current findings was also in contrast to what has been found by Niu et al. [13] 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. [13] might seldom be done by the participants thus the non-dominant site muscles activate greater muscle activation in order to effectively control the ankle motion. The present study involve participants to perform lunges 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 showed different levels of muscle activation during different protocols of movement and different site of limbs. These differences should be taken into consideration in developing training program to enhance performance and reduce the risk of injuries.

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