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Kinematics analysis of High Load Forward Lunge Exercise among Untrained Men

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ABSTRACT

This study was conducted to determine the kinematics during high loads forward lunge (70% and 85% 1RM). Thirty recreationally active, untrained men (mean age = 22.04 ± 0.81 years old) were recruited and were assigned to perform forward lunge with 70% 1RM (70FL) and 85% 1RM (85FL) with both their dominant and non-dominant leg. No significant differences were found on all the joint angles (ankle, knee, hip and trunk) between 70FL and 85FL. Ascend time, descend time and time taken were found to be significantly shorter during 75FL while step length was found to be significantly greater during 75FL. Besides that, ascend time, descend time and time taken were significantly faster and the step distance was significantly greater in the dominant limb compared to the non-dominant limb during both loading. To conclude, kinematics during movement are affected by the loading lifted and the dominant and non-dominant sides of limb used.

Keywords: loading, forward lunge, untrained men, kinematics

INTRODUCTION

One of the most important principles of training is the principle of specificity (Fleck & Kremer, 2014). Specificity is the principle of training that states that any training should be relevant and appropriate to the sport for which the individual is training in order to produce a training effect (Haff & Triplet 2015). Thus, it is important to analyse the movements been performed in a specific sport as the more similar the training activity is to the actual sport movement (Nadzalan et al., 2018; Nadzalan et al.,2018), the greater the likelihood of positive carryover to performance (Fleck & Kremer, 2014; Nadzalan et al 2017; Nadzalan et al., 2018).

One of the major movements performed in sports is the forward lunge. 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, to the extent that in the descend phase, the knee should not exceed the toe.

Lunge was performed during reaching the ball in racquet sports (tennis and squash), defending or attempting to steal the ball in football and many more. 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 a way to overload the exercise, weight carried during the exercise can be manipulated (Baechle & Earle 2008).

This study aimed to determine and compare the kinematics of dominant and non-dominant lower limb during forward lunge exercise with low load and high load. As kinematics is the description of motion, knowledge on the movement performed while performing lunge with high loading will enhance the knowledge on how the body response as an effect of the loading.

METHODOLOGY

Sampling

This study involved recreationally active, resistance-untrained men as study participants (n=30). 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.

Procedure and Instrumentation

All participants involved in familiarization session in order to make sure all the participants were able to perform the test correctly. After familiarization session, participants were tested for their forward lunge one repetition maximum (1RM). The 1RM test score were used as a part of loading determinant in the test. Uniformed testing protocols were applied to all the participants. The test consisted of; (i) 70% 1RM forward lunge and ii) 85% 1RM forward lunge conducted in randomized order to minimise order effects.

Movement kinematics of the stepping limb (dominant and non-dominant) was assessed during each test. Comparisons of those variables were made between each lunge protocols and between dominant and non-dominant limbs. All the lunge technique were closely monitored and controlled throughout all sessions.

70% 1RM and 85% 1RM forward lunge

Participants were instructed to stand with their hands holding a weight loaded barbell consisted of 70% or 85% 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 to be straight. Participants were required to perform all the 70FL and 85FL for three trials consisting of three repetitions for each trial for both dominant and non-dominant lower limb.

Movement Kinematics

Six infra-red cameras motion analysis system (Vicon T10s, Oxford Metrics, UK) was utilized to collect kinematics data, sampled at 200 Hz. The kinematics data were smoothed using a Butterworth, low-pass filter with 6 Hz cutoff frequency for the marker trajectories. A 15-component link-segment model, consisting of 29 reflective markers, was used to quantify the motions of the lower limb. Those markers were attached to the following anatomical landmarks of the lower limbs and trunk based on the Plug-in-Gait Marker Set, specifically on the bilaterally on anterior superior iliac spine, lateral thigh, lateral femoral epicondyle, lateral shank, calcaneus, lateral malleolus and second metatarsal. The kinematic model of the lower body consisted of the pelvis, thigh, and shank of the front leg. The angles of the trunk, hip, knee and ankle were examined.

Joint angle of the ankle, knee, hip and trunk during maximum descend phase were analysed. Besides that, the ascend phase, descend phase and time taken to complete one complete repetition of lunge were also analysed. The descend phase were defined as the time taken from the starting of descend phase (when the participant start to move from starting position) to the ending of descend phase (when the participant has stop moved in the downward position). The ascend phase was defined as the time taken from the starting of ascend phase (when participant start to move upward from the ending of descend phase) to the starting position of lunge. Time taken for one complete repetition of lunge refers to the time taken for the participant to perform the lunge from the starting position (beginning of descend phase) until the movement completion (ending of ascend phase).

Data Analysis

All statistical analyses were conducted using SPSS version 23 (IBM, New York, USA). Descriptive statistics were used to measure the mean and standard deviation of the data scores. Repeated measure analysis of variances (ANOVA) was used to compare the difference of movement kinematics. 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).

Statistical Analysis

Repeated measure analysis of variances (ANOVA) was used to compare the difference of movement kinematics. 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 age between 21 years old, body mass (kg) average 71.93 kg, body weight (N) mean average 696.57 N, height 171.41 cm, 1RM (kg) 70.97 kg and relative 1RM/BM mean average 1.00.

Dominant lower limb

Analysis of dominant lower limb showed non-significant main effect for the; i) ankle angle, $F(1,29) = 230.31$; $p > 0.05$, ii) knee angle, $F(1,29) = 812.79$; $p > 0.05$, iii) hip angle, $F(1,29) = 99.91$; $p > 0.05$, and iv) trunk angle, $F(1,29) = 82.01$; $p > 0.05$.

Significant main effect were found for the; i) ascend time $F(1,29) = 245.91$; $p < 0.05$, ii) descend time, $F(1,29) = 513.29$ $p < 0.001$, iii) time taken, $F(1,29) = 246.12$; $p < 0.001$ and iv) step distance, $F(1,29) = 782.21$; $p < 0.001$.

Table 2 showed the kinematics data during the two lunge protocols. Pairwise comparison test showed no significant differences were found on all the joint angles (ankle, knee, hip and trunk) between 70FL and 85FL, $p > 0.05$. Ascend time, descend time and time taken were found to be significantly shorter during 70FL, $p < 0.001$. Lastly, step length was found to be significantly greater during 70FL, $p < 0.001$.

Non-dominant lower limb

Analysis on the non-dominant lower limb showed non-significant main effect for the; i) ankle angle, $F(1,29) = 11.29$; $p > 0.05$, ii) knee angle, $F(1,29) = 11.28$; $p > 0.05$, iii) hip angle, $F(1,29) = 15.29$; $p > 0.05$, and iv) trunk angle, $F(1,29) = 211.29$; $p > 0.05$.
Significant main effect were found for the; i) ascend time $F(1,29) = 310.29$; $p < 0.05$, ii) descend time, $F(1,29) = 233.01$; $p < 0.001$, iii) time taken, $F(1,29) = 1501.12$; $p < 0.001$ and iv) step distance, $F(1,29) = 411.91$; $p < 0.001$.

Table 3 showed the kinematics data during the two lunge protocols. As in dominant limb, results showed no significant differences were found on all the joint angles (ankle, knee, hip and trunk) between 70FL and 80FL, $p > 0.05$. Ascend time, descend time and time taken were found to be significantly shorter during 70FL, $p < 0.001$, and step length was found to be significantly greater during 70FL, $p < 0.001$.

70% 1RM Forward Lunge (Dominant versus non-dominant lower limb)
Analysis on the dominant and non-dominant lower limb during 30FL showed non-significant main effect for the; i) ankle angle, F (1,29) = 5.19; $p > 0.05$, ii) knee angle, F(1,29) = 2.92; $p > 0.05$, iii) hip angle, F(1,29) = 6.29; $p > 0.05$, and iv) trunk angle, F(1,29) = 8.24; $p > 0.05$.
Significant main effect were found for the; i) ascend time F (1,29) = 192.23; $p < 0.05$, ii) descend time, F(1,29) = 492.71; $p < 0.001$, iii) time taken, F(1,29) = 283.03; $p < 0.001$ and iv) step distance, F(1,29) = 559.231; $p < 0.001$.

Pairwise comparison showed that the ascend time, descend time and time taken were significantly faster and the step distance was significantly greater in the dominant limb compared to the non-dominant limb.

85% 1RM Forward Lunge (Dominant versus non-dominant lower limb)
Analysis on the dominant and non-dominant lower limb during 70FL showed a non-significant main effect for the; i) ankle angle, F (1,29) = 9.32; $p > 0.05$, ii) knee angle, F(1,29) = 1.45; $p > 0.05$, iii) hip angle, F(1,29) = 8.32; $p > 0.05$, and iv) trunk angle, F(1,29) = 9.23; $p > 0.05$.
Significant main effect were found for the; i) ascend time F (1,29) = 751.83; $p < 0.05$, ii) descend time, F(1,29) = 542.21; $p < 0.001$, iii) time taken, F(1,29) = 609.26; $p < 0.001$ and iv) step distance, F(1,29) = 553.50; $p < 0.001$.

As in the 70FL, pairwise comparison test showed that ascend time, descend time and time taken were significantly faster and the step distance was significantly greater in the dominant limb compared to the non-dominant limb during 85FL.

Table 1. Kinematics data of dominant lower limb during 70FL and 850FL

Kinematics	70FL	85FL
Ankle angle (˚)	64.69 ± 4.49	65.29 ± 4.12
Knee angle (˚)	82.91 ± 3.73	83.28 ± 2.51
Hip angle (˚)	83.97 ± 3.51	80.53 ± 3.93
Trunk angle (˚)	42.70 ± 2.32	40.23 ± 3.33
Ascend time (s)	0.96 ± 0.03[b]	1.07 ± 0.03[a]
Descend time (s)	0.99 ± 0.05[b]	1.10 ± 0.05[a]
Time taken (s)	1.95 ± 0.10[b]	2.17 ± 0.08[a]
Step length (m)	0.84 ± 0.04[b]	0.80 ± 0.03[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. Kinematics data of non-dominant lower limb during 70FL and 85FL

Kinematics	70FL	85FL
Ankle angle (˚)	65.03 ± 4.60	66.01 ± 3.60
Knee angle (˚)	83.31 ± 3.68	84.31 ± 3.19
Hip angle (˚)	84.35 ± 3.27	85.35 ± 2.99
Trunk angle (˚)	43.27 ± 2.35	44.29 ± 3.01
Ascend time (s)	0.99 ± 0.04[b]	1.10 ± 0.04[a]
Descend time (s)	1.05 ± 0.05[b]	1.14 ± 0.05[a]
Time taken (s)	2.04 ± 0.09[b]	2.24 ± 0.09[a]
Step length (m)	0.82 ± 0.03[b]	0.78 ± 0.03[a]

[a] = significantly difference from SFL, $p < 0.001$, $p < 0.01$, $p < 0.05$
[b] = significantly difference from JFL, $p < 0.001$, $p < 0.01$, $p < 0.05$

DISCUSSIONS

In this study, participants (untrained men) were asked to performed lunge with 70% 1RM (70FL) and 85% 1RM (85FL) loading with normal (straight) trunk position, fast movement and the step should be as far as possible. Participants in this study were familiar with lunge exercises causing the need to accomplish the movement required were not difficult to be attained.

Ankle angle, knee angle, hip angle, trunk angle, ascend time, descend time, time taken for one complete lunge and step length of both dominant and non- dominant lower limb were assessed as the kinematics data. These data were compared between lunge protocols and between the dominant and non-dominant limb.

Results in this study showed no significant differences were found in all the joint angles (ankle, knee, hip and trunk) between 70FL and 85FL. However, ascend time, descend time and time taken were found to be significantly shorter during 70FL. Step length was found to be significantly greater during 85FL. These conditions were seen on both the dominant and non-dominant lower limb.

Results demonstrated that participants able to perform lunge with greater loads (i.e. 85FL) to the same range of motion as with lighter loads (i.e. 70FL). However, participants were shown to be affected by the loading they lifted. With greater loading, the time for them to complete ascend and descend phase were increased thus also increased the time for one complete lunge repetition. Of the interesting finding, although was not found to be significantly different, the time for the ascend phase was found to be faster compared to the descend phase. This demonstrated that participants controlled their descend movement by performing braking especially at the end of descend phase as the participants were getting ready to perform ascend time in a fast manner. As expected, step length was found to be shorter during 85FL. The possible explanation of this condition might be due to the participants' inability to move further or due to the participants become aware of their inability to perform ascend phase in smooth manner if further step length was taken.

Besides the comparison between lunge protocols, this study also compared the kinematics responses of dominant and non-dominant lower limb. This is the first known study that had compared the kinematics differences of dominant and non- dominant lower limb during lunge movement.

No significant differences were found for all joint angles between dominant and non-dominant lower limb. However, dominant lower limb was found to achieve faster ascend phase, descend phase and time to complete one repetition of lunge. Dominant limb was also showed to achieve greater step length. These conditions were applied to both lunge protocols conducted. These findings thus showed that imbalances existed between dominant and non-dominant limb during lunge movement.

Study on comparing dominant and non-dominant lower limb had been conducted among football players (Daneshjoo et al.,2013; Fousekis et al., 2010), martial artists (Hsieh et al., 2012; Falco et al., 2009; Harun & Xiong 2010), badminton players (Nadzalan et al 2017; Nadzalan et al 2017) and healthy populations (Jacob et al., 2005; Niu et al., 2011; Van der Harst et al 2007). The findings of this this current study were in contrast to those found by study conducted among martial artists that found no significant difference of dominant and non-dominant lower limb kinematics when performing kicks (Niu et al., 2011; Van der Harst et al 2007; Tang et al.,2007).

The slower movement in the non-dominant side reflect the lack of strength compared to the dominant side. Strength imbalances between dominant and non- dominant side need to be reduced as it has been shown that these imbalances could increase the risk of injuries to the weaker and even stronger sides (Niu et al., 2011; Wang & Cochrane 2001; Zifchock et al., 2008; Sadeghi et al., 2000).The faster dominant side will be more preferable to be used by athletes during the games thus can cause the dominant side to be overused while the strength gap with non-dominant side will become bigger.

CONCLUSIONS

Findings of this study demonstrate the kinematics during movement are affected by the loading lifted and the dominant and non-dominant sites of limb used. Coaches and athletes need to stress the important of non-dominant side training to reduce the imbalances for improving performance besides to reduce the risk of injury.

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