The Effects of Loadings during Forward Lunge on Force Output in Dominant and Non-Dominant Leg

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Abstract. The aim of this study was to determine and compare the force output during lunge exercises with different loadings; i) high load forward lunge (70\% 1RM) and ii) low load forward lunge (30\% 1RM). Thirty recreationally active, untrained men were recruited and were assigned to perform forward lunge with 70\% 1RM (70FL) and 30\% 1RM (30FL) with both their dominant and non-dominant leg. For both dominant and non-dominant leg, all the force variables during 70FL were significantly greater compared to 30FL. Results also showed that time to peak force and stance time was significantly shorter during 30FL compared to 70FL. Besides that, all the force variables were greater in the dominant limb compared to the non-dominant limb. Time to peak force and stance time were also shorter in dominant limb compared to the non-dominant limb. As the conclusion, assymetries exist among untrained men during forward lunge exercise for both low loads and high loads.

1. Introduction

One of the major movement in sport is the lunge [1-4]. During physical conditioning training session, the lunge training could be manipulated as manipulations of exercise has demonstrated different training adaptations [5]. One of the variables that can be adjusted is the loadings that were lifted during the movement. In order to obtain information on what happened to body during the movement, the measurement of kinetics data can be performed. While kinetic is the study of force that cause motion, the knowledge on kinetic responses will give clear picture on the demands of the individuals so that training program can be planned accordingly. It is important to be aware of the force production in both dominant and non-dominant sites during the movement as this will show if assymetries exist, in which several precautions need to be planned if assymetries do exist.

Despite several previous studies had shown the force production during lunge [6], until now, lack of research existed on kinetics data of both dominant and non-dominant limb in lunge with different loadings lifted. It is the aim of this study to determine and compare the force output during both dominant and non-dominant limb during low and high loadings forward lunge and also between dominant and non-dominant limb during both loading protocols.
2. Methodology

2.1. Participant
Thirty recreationally active, resistance-untrained men (age 20-25 years old) was involved as study participants in this study. Participants were screened prior to testing using PAR-Q. Each participant read and signed an informed consent for testing approved by the Universiti Pendidikan Sultan Idris.

2.2. Procedure

2.2.1 30% 1RM AND 70% 1RM Forward Lunge
Figure 1 showed the step for 30FL and 70FL. 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 to be parallel with the ground, and then returned back to the starting position. Participants were needed to make a big step as during downward position, the knee should not extend beyond the toe. 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.

![Figure 1. Forward Lunge](image)

2.2.2 Movement Kinetics
Participants performed the lunge on a tri-axial force platform (BP400600HF-2000, AMTI Inc., USA) (width: 400 mm X length: 600 mm X height: 82.5 mm). Force Plate data sampling rate were set at 1000 Hz [24] with filter cut-off frequency rate of 25 Hz [7]. The kinetics data that were measured in this study were the; i) peak concentric force (PCF), ii) mean concentric force (MCF), iii) mean eccentric force (MEF), iv) time to peak force (TPF) and x) stance time (ST). Peak concentric force was defined as the highest force before the takeoff. Mean concentric force was the average of force produced between the beginning of concentric phase and the end of concentric force. Mean eccentric force was the average of force produced between the start of participant step on the force platform until the point where the concentric force begin. Time to peak force was the time taken between the beginnings of concentric force to the production of peak force during concentric phase. Stance time was the time taken from the start until the end time participants stepped on the force platform.
2.2.3 Data Collection

All participants involved in familiarization session in order to make sure all the participants were able to perform all the tests with correct technique. After familiarization session, participants were tested for their forward lunge one repetition maximum (1RM). The 1RM test score were used as determinant of lifting loads during this study.

Participants were required to refrain from any exercise for at least 48 hours and refrain from alcohol for at least 24 hours prior to the 1RM test and experimental session. To prevent risks of injury incidence during 1RM test, multiple-RM method were implemented as it was recommended to be safer [8].

Uniformed testing protocols were applied to all the participants. Participants were tested on three days to allow for full recovery and to avoid from contamination of test results due to inadequate recovery from earlier tests. The three days consisted of; (i) forward lunge 1RM, ii) 30% 1RM forward lunge kinetics test, ii) 70% 1RM forward lunge kinetics test. All the tests were conducted in randomized order to minimise order effects. In order to ensure maximal performance, participants were instructed to “lunge as far as possible and as fast as possible”.

2.3. Statistical Analyses

Repeated measure analysis of variances (ANOVA) was used to compare the difference of force production. Statistical significance were accepted at an α-level of p < 0.05. All statistical analyses were conducted using SPSS version 23 (IBM, New York, USA).

3. Result

3.1 Physical Characteristic

Table 1 showed the physical characteristics of participants involved.

| Variables      | Mean ± SD       |
|---------------|----------------|
| Age (years)   | 21 ± 0.83      |
| Body Mass (kg)| 71.00 ± 1.88   |
| Height (cm)   | 171.41 ± 2.55  |
| 1RM (kg)      | 70.97 ± 6.57   |

3.2 Dominant Lower Limb

Analysis on the dominant lower limb showed a significant main effect for all the kinetic variables: i) PCF, F(1,29) = 5576.249; p < 0.001, ii) MCF, F(1,29) = 1320.782; p < 0.001, iii) MEF, F(1,29) = 3131.786; p < 0.001, iv) TPF, F(1,29) = 245.634; p < 0.001 and x) ST, F(1,29) = 278.145, p < 0.001.

Table 2 showed the kinetics data during the two lunge protocols. Results showed that all the force variables (PCF, MCF, and MEF) during 70FL were significantly higher compared to 30FL, p < 0.05. Results also showed that TPF and ST were significantly shorter during 30FL compared to 70FL.

| Kinetics          | 30FL            | 70FL            |
|-------------------|-----------------|-----------------|
| PCF (N)           | 1041.45 ± 49.26 | 1249.45 ± 42.24 |
| MCF (N)           | 994.25 ± 41.56  | 1124.25 ± 41.56 |
| MEF (N)           | 921.60 ± 20.06  | 1041.90 ± 28.47 |
| TPF (s)           | 0.61 ± 0.03     | 0.67 ± 0.03     |
| ST (s)            | 1.06 ± 0.05     | 1.26 ± 0.05     |

* = significantly difference from 30FL, p < 0.05
3.3 Non-dominant Lower Limb

Analysis on the non-dominant lower limb showed significant main effect for all the kinetic variables: i) PCF, $F(1,29) = 4376.049; p < 0.001$, ii) MCF, $F(1,29) = 218049.782; p < 0.001$, iii) MEF, $F(1,29) = 3040.353; p < 0.001$, iv) TPF, $F(1,29) = 5823.727; p < 0.001$ and v) ST, $F(1,29) = 247.34, p < 0.001$.

Table 3 showed the kinetics data during the two lunge protocols. Results showed that all the force variables (PCF, MCF and MEF) during 70FL were significantly higher compared to 30FL, $p < 0.05$. Results also showed that TPF and ST were significantly shorter during 30FL compared to 70FL.

| Table 3. Kinetics Data of Non-Dominant Lower Limb During 30FL and 70FL |
|---------------------------|-----------------------------|
| **Kinetics** | **30FL** | **70FL** |
| PCF (N) | 1009.82 ± 47.89 | 1205.25 ± 41.85* |
| MCF (N) | 952.35 ± 40.15 | 1063.58 ± 40.40* |
| MEF (N) | 859.87 ± 19.30 | 981.23 ± 27.35* |
| TPF (s) | 0.64 ± 0.04 | 0.71 ± 0.04* |
| ST (s) | 1.09 ± 0.05 | 1.29 ± 0.05* |

* = significantly difference from 30FL, $p < 0.05$

3.4 30% 1RM Forward Lunge (Dominant versus Non-dominant Lower Limb)

Analysis on the dominant and non-dominant lower limb during 30FL showed significant main effect for all the kinetic variables: i) PCF, $F(1,29) = 981.526; p < 0.001$, ii) MCF, $F(1,29) = 1511.211; p < 0.001$, iii) MEF, $F(1,29) = 4433.376; p < 0.001$, iv) TPF, $F(1,29) = 229.959; p < 0.001$ and x) ST, $F(1,29) = 376.805, p < 0.001$. Pairwise comparison test showed that during 30FL, all the forces variables were greater in the dominant limb compared to the non-dominant limb. Besides that, TPF and ST were also shorter in dominant limb compared to the non-dominant limb.

3.5 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 kinetic variables: i) PCF, $F(1,29) = 4219.630; p < 0.001$, ii) MCF, $F(1,29) = 4492.965; p < 0.001$, iii) MEF, $F(1,29) = 4492.965; p < 0.001$, iv) TPF, $F(1,29) = 343.139; p < 0.001$ and x) ST, $F(1,29) = 376.805, p < 0.001$. As during 30FL, pairwise comparison test showed that all the forces variables were greater in the dominant limb compared to the non-dominant limb. Besides that, TPF and ST were also shorter in dominant limb compared to the non-dominant limb.

4. Discussion

In this study, PCF, MCF, MEF, TPF and ST were assessed and compared between each lunge protocols in this study. Results showed all the force variables during 70FL were significantly higher compared to 30FL, $p < 0.05$. Results also showed that TPF and ST was significantly shorter during 30FL compared to 70FL. These conditions were also observed in both dominant and non-dominant limbs.

Results demonstrated force production was higher during lunge with greater loadings. Although participants were able to move faster during 30FL, this was not enough to produce force as high as 70FL. This thus shown that participants needed time in order for them to produce greater force production. Training with greater loads might provide more stress to the muscle and joints and provide more opportunities for positive adaptation [9]. However, due to the greater impact force, care should be taken to avoid any uncontrolled movement during landing that can induce greater injury risks. The kinetic data results in this current study are consistent with that obtained in several previous studies thus demonstrate that the increment of external loading will increase peak forces during movement [10-12] while time to complete the lunge movement was increased.
Despite the force production data that obtained in this study, it was suggested that future studies to include power production during each lunge protocols. This is as a way to find the optimal loadings for power production in lunge exercise. The meta analysis conducted by Soriano et al. [13] demonstrated the differences in optimal load between the squat, jump squat, power clean, and hang power clean exercise. The intensity for optimal power production for each exercise was found to be different. It is currently lack of data to find out the optimal loadings to be used in lunge exercise. Future studies need to be conducted on this so that more information available for the selection of loads during different kind of exercises.

Comparing the dominant and non-dominant site, it was found that all the forces output were greater in the dominant site besides shorter stance time during all the lunge protocols. These showed the importance of non-dominant site training to avoid strength imbalances that can negatively affect performance besides increase injury risk. This current findings for kinetic data was in line to the previous findings of Hsieh, Huang, and Huang [14] that found significant differences to be exist between dominant and non-dominant limb in kinetics variables during 360° turning roundhouse kick. However, this is in contrast to the findings of Niu et al. [15] that found no differences of kinetic variables during drop landing. Similar to Niu et al. [15], Van der Harst et al. [16] in their study also did not found any kinetic differences between dominant and non-dominant site during landing from a single-leg hop. The differences of findings in this study could be due to the differences of movement executed and participants recruited for the study [17, 18]. No comparison could be made to lunge movement as lack of study has been found on the differences of dominant and non-dominant lower limb kinetics during lunge.

5. Conclusion
Findings of the study demonstrate greater force production during movement with heavier loadings for both dominant and non-dominant leg thus showed that loadings played a greater role in force production during lunge. Even lighter loadings enable participant to lift faster, the velocity was not enough to attain similar stress that will affect the force production. Findings also found that asymmetries exist among untrained men during forward lunge exercise for both low loads and high loads. Therefore, it is suggested for the coach and athlete to perform additional training on the non-dominant side as a way to increase functionality during the movement.

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