

Comparative Analysis of Lunge Techniques: Forward, Reverse, Walking Lunge

Sanghoon Park¹, Chulsoo Chung¹, Jaebum Park^{1,2}, Jonghyun Yang², Siddhartha Bikram Panday^{1,3}, Jiseop Lee¹, Prabhat Pathak⁴

Department of Physical Education, Seoul National University, Seoul, Korea¹

Institute of Sport Science, Seoul National University, Seoul, Korea²

Department of Fitness Management, University of Suwon, Suwon, Korea³

Department of Mechanical and Aerospace Engineering, Seoul National University, Seoul, Korea⁴

The study aims to find the basis for the efficiency of lunge and risk of injury by comparing mechanical variables in various lunges (forward lunge, reverse lunge, and walking lunge). Four participants who were familiar with the three lunge movements were recruited to achieve the purpose of the study. The resultant hip joint moment, resultant knee joint moment, and resultant knee joint force were analyzed during the three lunge movements. Eight muscle of lower extremity were also analyzed using EMG. In conclusion, reverse lunge movement was found to be favorable in achieving the primary goal of lunge exercise, which is the development of gluteus maximus and quadriceps femoris, as it resulted in higher agonist muscle activities with relatively low momentary maximum knee shearing force compared to the other lunge techniques.

KEYWORD: Lunge, Moment, Shear Force, Muscle Activation

INTRODUCTION: Known as an exercise that can easily be performed at gym or home, the lunge is recognized as an effective exercise for the lower body, particularly for developing the gluteus maximus as well as the quadriceps. A lunge exercise can also be described as an effective way to enhance lower body muscles but rather a challenging training exercise that would require significant coordination and balance since it trains one leg at the time. Previous studies have assessed the effects of dumbbell-carrying position on muscle activities in walking lunge (Stastny et al. 2015), the kinetic influences of trunk position in forward lunge (Farrokhi et al. 2008), and the impacts of forward and lateral lunge on older adults' joints (Flanagan et al. 2003). Aforementioned studies above are mainly limited on describing characteristics of different lunge techniques only under particular circumstances. Up to our knowledge, there are no direct studies that have focused on comparisons of the kinematics and kinetics in these three basic lunge movements (forward lunge, reverse lunge, and walking lunge). Subsequently, if the pros and cons of each technique are known, lunge training can be performed much more efficiently and safely. Therefore, the purpose of the study was to perform a comparative analysis of mechanical variables (joint moment, joint force and muscle activation) among three different lunge techniques (forward lunge, reverse lunge, and walking lunge).

METHOD

For the pilot study, we recruited four participants who were familiar with the three lunge movements, had no orthopedic medical history in the knee or back. The participants were professional fitness trainers and were likely to have the lowest risks of injury while performing the exercises (mean age: 28±3, height: 172±4, weight: 77±10).

Eight infrared cameras (Qualisys Oqus 500, Sweden) and two force plates (AMTI OR-6, USA) were used to measure kinematic and kinetic variables during the three lunge movements. Further, an inverse kinematic model of the legs was used to compute resultant hip joint moment, resultant knee joint moment, and resultant knee joint force during the three lunge movements (Chowdhury, S., & Kumar, N. 2013). Activity of a total of eight muscles, including rectus abdominis (RA), erector spinae (ES), gluteus maximus (G-MAX), rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), biceps femoris (BF), and semitendinosus (ST), were collected using a wireless electromyography (EMG) system (Noraxon DTS wireless EMG, USA). All data were collected using Qualisys Motion Capture System with a sampling rate of 100 Hz for image data, 1,000 Hz for ground reaction force, and 1,500 Hz for EMG.

A warm-up exercise was performed for at least 10 minutes prior to the experiment. A total of 36 markers were placed in order to define the lower body segments, and dual electrodes were applied at 2cm-intervals on the muscles to be evaluated. All of the lunge moves were completed to a tempo of 60 bpm with a help of metronome sound; the beginning and the end of all movements were controlled to 4 beats (4 seconds). A stride of reverse lunge was measured prior to the experiment in order to ensure the consistency of the lunge movements. Before the lunge movement, the stride of the individual subject was measured and marked on the ground. The participants then performed the three lunge movements according to the stride of individual subjects. At the point where the center of the body was at the lowest point, the leading leg's femoral muscles were directed to stay parallel to the floor in each lunge movement. The remaining movements were completed by following the recommended methods by National Strength & Conditioning Association (NSCA).

For normalization of the EMG data, maximum voluntary isometric contractions (MVIC) were performed and recorded prior to the experiment. Rather than performing the conventional MVC test on each body part, EMG data on eight markers were collected at once when the subjects were using their maximum strengths at the moment of switching from the end of the downward motion to upward motion during the NSCA-recommended lunge movements. The EMG data were rectified and digitally low-pass filtered with a zero-lag, fourth-order Butterworth filter at 50Hz. The rectified EMG data was integrated over 1% time windows of each trial ($\int EMG$). The noise was removed from the collected image data by using a low-pass filter with a cut-off frequency of 6 Hz.

RESULT: The maximum and mean values of moments of hip and knee joints, anterior-posterior force (shearing force) on the knee of average value across subjects during the three lunge movements are shown in Table 1.

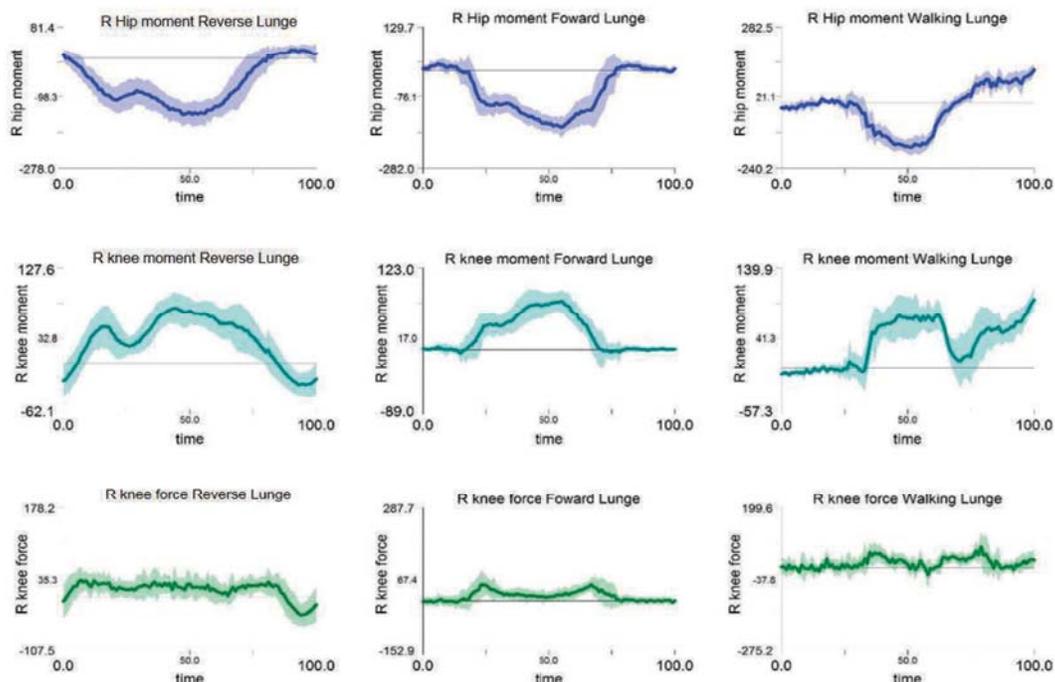


Figure 1. Hip and knee moment($N \cdot m$), knee force(AP direction, N) during three lunge techniques. X coordinate: Time (normalized)

Table 1
Max and Mean values of extension moment of hip and knee joint, and knee force
(AP direction)

Variable		Reverse lunge	Forward lunge	Walking lunge
Max	hip moment(N · m)	141.66	164.52	169.20
	knee moment(N · m)	82.34	81.95	103.19
	knee force(N)	116.61	312.64	247.19
Mean	hip moment(N · m)	62.91	58.21	25.58
	knee moment(N · m)	30.35	25.20	35.94
	knee force(N)	60.77	67.86	18.04

The maximum hip moment (169.20 Nm) and knee moment (103.19 Nm) were the highest in the walking lunge and lowest in the reverse lunge. The maximum knee shearing force was the highest in the forward lunge (312.64 N) and lowest in a reverse lunge(116.61N). On the other hand, the mean hip moment was the highest in the reverse lunge (62.91Nm). The mean knee moment was the highest in the walking lunge (35.94 Nm) while the mean knee shearing force was the highest in the forward lunge (67.86 N).

Table 2
Max, mean of muscle activation of during three lunge techniques(%MVIC)

		BF	ES	GM	RA	RF	ST	VL	VM
Max	RL	0.56	0.86	0.78	2.01	2.36	1.04	1.51	1.36
	FL	1.42	0.82	1.10	11.44	2.77	2.72	1.62	1.55
	WL	0.83	1.11	0.83	9.06	4.02	2.17	1.63	1.43
Mean	RL	0.18	0.25	0.22	0.52	0.69	0.37	0.54	0.46
	FL	0.24	0.20	0.17	1.81	0.61	0.52	0.43	0.40
	WL	0.19	0.32	0.17	1.14	0.68	0.52	0.51	0.40

Note.

BF: Biceps femoris, ES: Erector spinae, GM: Gluteus maximus, RA: Rectus abdominis, RF: Rectus femoris, ST: Semitendinosus, VL: Vastus lateralis, VM:Vastus medialis, RL: Reverse Lunge, FL: Forward Lunge, WL: Walking lunge

The maximum and mean values of each muscle activity of average value across subjects during the three lunge tasks are shown in Table 2. The agonist muscles (gluteus maximus, rectus femoris, vastus lateralis, and vastus medialis) in the lunge tasks had higher mean muscle activity in reverse lunge movement compared to the other lunge movements.

DISCUSSION: During the forward lunge, the maximum resultant joint torque of the front knee was greater in comparison to other lunge types and our results also coincides with the study by Comfort, P., Jones, P. A., Smith, L. C., & Herrington, L. (2015). However, it cannot be simply concluded that forward lunge is an effective exercise for knee extensors because the greater shear force was also observed during the forward lunge, which possibly increases the strain of the knee joint and the knee extensors.

During the reverse lunge, the average hip joint resultant torque of the front leg and the muscle activity of the gluteus maximus was significantly different from those of lunge types. On the other hands, the maximum knee joint resultant torque during the reverse lunge was the smallest. Therefore, it is assumed that the reverse lunge has a lower risk of knee injury than

other lunge types have. Also, the reverse lunge can be regarded as an effective exercise technique to strengthen gluteus maximus.

CONCLUSION: In conclusion, reverse lunge movement was found to be favorable in achieving the primary goal of lunge exercise, which is the development of gluteus maximus and quadriceps femoris, as it resulted in higher agonist muscle activities (gluteus maximus, rectus femoris, vastus lateralis, vastus medialis) compared to the other lunges. It also can be seen as having a lower risk of knee injuries due to its relatively low momentary maximum knee shearing force compared to the other lunges. We have to admit that the current outcomes were from an ongoing study. Thus, the sample size should increase to generalize the main messages of the study with supports of the statistical significance. If future studies with increased the sample size are conducted as such, the findings of the study will be able to suggest safe and effective exercise methods for different people with beginner- and advanced-level exercise proficiency.

REFERENCES

- Chowdhury, S., & Kumar, N. (2013). Estimation of forces and moments of lower limb joints from kinematics data and inertial properties of the body by using inverse dynamics technique. *Journal of Rehabilitation Robotics*, 1(2), 93-98.
- Comfort, P., Jones, P. A., Smith, L. C., & Herrington, L. (2015). Joint kinetics and kinematics during common lower limb rehabilitation exercise. *Journal of athletic training*, 50(10), 1011-1018.
- Farrokhi et al (2008). Trunk position influences the kinematics, kinetics, and muscle activity of the lead lower extremity during the forward lunge exercise. *Journal of Orthopedic and Sports Physical Therapy*, 38(7), 403-409
- Flanagan et al (2003). Lower extremity biomechanics during forward and lateral stepping activities in older adults. *Clinical Biomechanics*, 18(3), 214-221
- Roger W. Earle (2005). Essential of personal training. *National Strength and Conditioning Association*.
- Stastny et al (2015). Does the dumbbell-carrying position change the muscle activity in split squats and walking lunges?. *Journal of Strength and Conditioning Research*, 29(11), 3177-3187
- Thomas R. Baechle et al (2013) Essentials of strength training and conditioning. *National Strength and Conditioning Association*.