Research Paper: Changes in Muscle Strategies During Landing Task in Subjects With and Without Knee Genu Varum

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ABSTRACT

Introduction: Onset and offset activation of lower limb and trunk muscles may change the knee with genu varum during landing. These motor control strategies can be different from those in healthy subjects and contribute to more injuries in lower extremities. This study aimed to compare the delay time of the onset activity of the abdominal and lower limb muscles in the specific landing task.

Materials and Methods: Ten females with genu varum deformity and ten females with normal knee participated in this case-control study. Genu varum deformity was measured by a camera capturing goniometer. The subjects were informed to land by preferred lower limb from a table (30 cm high) on a force plate. Vertical Ground Reaction Force (VGRF) was measured to clarify the onset of the landing task. Surface Electromyography (sEMG) of transverse abdominal/int. oblique (TA/IO), Vastus Medialis (VM), Vastus Lateralis (VL), Lateral Gastrocnemius (LG), and medial gastrocnemius (MG) muscles were recorded during landing. The difference between the onset activity of the above muscles and onset of VGRF was calculated as delay times and compared between muscles and between two groups. Also, the offset of activities and the intensity of muscle activation (normalized RMS) were compared between the two groups.

Results: Lower limb and trunk muscles showed significantly different onset of activities in the genu varum group (P<0.05), whereas there was no significant difference in the onset of muscle activities in the healthy group. Results indicated significant differences between two groups in TA/IO, LG, and MG muscles and the genu varum group had longer delay time for motor control strategy (especially ankle strategy) in the landing task. Offset time of all muscles in the genu varum and healthy subjects had a significant difference between muscles, especially in gastrocnemius muscles (P<0.05). Also, there were significant changes between the two groups in LG and MG muscles (P<0.05). Normalized muscle activities (nRMS) generally indicated an increase in muscle activation of genu varum subjects (TA/IO, LG, MG) compared with the normal subjects (P<0.05).

Conclusion: Motor control strategies in landing task is different in the genu varum group due to changes in biomechanics and properties of the knee joint. This variation may be due to changes in proprioception afferent pathways around the knee joint. An increase in muscle activation, delay, and offset time of muscle activities in these subjects, indicated that an increase in the degree of freedom may change motor control strategies. Internal anticipation and postural adjustment of the landing task in these subjects need more motor unit recruitment (an increase in nRMS). This deformity in the knee joint might affect some activities and possibly cause knee changes such as osteoarthritis.

Keywords:
Surface electromyography, Genu varum, Leg drop landing, Motor control

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1. Introduction

The lower extremities are involved in most daily activities and one of the common tasks is one-leg standing or landing. The deformities of the lower limbs such as genu varum mainly change in motor control strategies of gait and specific tasks. Some related studies showed the influence of quadriceps muscle activity and co-contraction between the Vastus Medialis (VM) and Vastus Lateralis (VL) in landing tasks [1]. Quadriceps muscle activity during landing tasks may change for different reasons such as fatigue that is shown to change the kinetics and kinematics of movements [2]. The reduction of quadriceps muscle activity after fatigue can increase the loss of balance and falling during landing [3].

Letafatkar A et al. reported the altered activity of the quadratus lumborum, gluteus maximus, gluteus medius, biceps femoris, semitendinosus, and medial gastrocnemius muscles, in subjects with genu varum and indicated instability of the spinal column, pelvis, and hip during jump-landing task. Their result showed that this complication might affect stability in these subjects [4]. Most of the related studies have been focused on knee and hip muscles in genu varum subjects. So, the role of abdominal and leg muscles need more studies to find the role of lower extremity muscles in motor control strategies for landing task and compare their role between the genu varum patients and healthy subjects.

This study aimed to detect the onset time, offset time, and muscle activation of the lower limb and the abdominal muscles in subjects with genu varum and compare them with healthy subjects in landing task.

2. Materials and Methods

Twenty subjects of 20-30 years old participated in this study. They were assigned into two groups of genu varum (n=10) and normal knee (n=10). Subjects would be excluded from the study if they had a history of neuromuscular and musculoskeletal disorders, surgery or fracture in the lower extremity over the past six months, and other lower limb abnormalities. All subjects were informed about the experimental procedure and they signed a consent form. The study was approved by the local Ethics Committee of Shahid Beheshti University of Medical Sciences.

To measure the varus angle, the subjects were asked to put their legs together and markers were attached to the center of the patella, and the middle of the medial and lateral malleolus on the dominant lower limb. The angle between lines of the umbilical to the center of the patella (as thigh angle) and the point of the medial and lateral malleolus to the center of the patella (as leg angle) were calculated. The difference between these two angles (thigh-leg) was named as knee varus angle.

An angle more than 11 degrees was classified as genu varum deformity according to Kenneth A. Krackow, Base [6, 7]. The detection of the above angle was based on camera capturing and software analysis [5] (Figure 1). Based on the knee angles assessment, the volunteers were assigned to the genu varum or normal groups.

A triaxial force plate (MIE model, Bertec Corp, UK) was used for recording and measuring vertical Ground Reaction Force (GRF). The Vertical GRF (VGRF) was used to detect the very first contact during landing. The time when the vertical force was reached to 10% of body

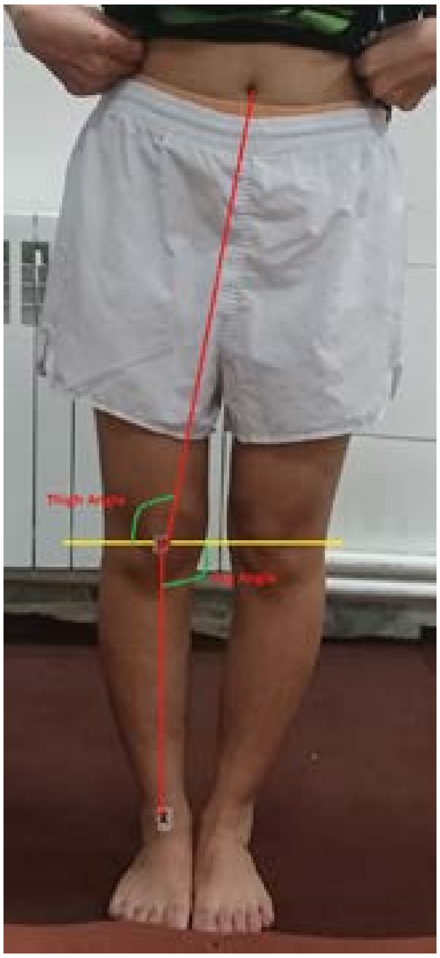

Figure 1. Measuring the varus angle by the difference between thigh angle and leg angle

weight was marked as the reference point for calculating the EMG onset time.

The force plate was recorded at a sampling rate of 1000 Hz. The subjects were trained to hang their dominant leg from a table with 30 cm height and land on the center of the force plate with the same leg after the command of the examiner. The force plate was synchronized with the electromyography device.

Surface electromyography (sEMG) of transverse abdominal/int.oblique (TA/IO), vastus medialis (VM), vastus lateralis (VL), lateral gastrocnemius (LG), and medial gastrocnemius (MG) were recorded during landing.

The skin's surface of the muscles was shaved and cleaned by alcohol wipes before attaching the electrodes. All sEMG signal recordings were made using the DataLOG, Biometrics Ltd England. Preamplifier bipolar active electrodes (Type NOS.SX230, Biometrics Ltd) with a fixed center-to-center interelectrode distance of 20 mm, recording diameter of 10 mm, with a gain of 1000, the input impedance of 1015 Ω, common-mode rejection ratio of 110 dB at 60 Hz, and bandwidth of 20–450 Hz and ground electrodes were located on the preferred wrist. The electrode positions and orientations were located according to EMG sensor locations described in SENIAM guidelines [8].

Before the recording of the landing task, submaximal voluntary contraction (sMVC) dependent on the specific task for each muscle was recorded three times and submaximal contraction was selected for normalization of muscles as described below:

A) Submaximal contraction for TA/IO task was in crook lying position and movement of the upper trunk to flex toward the preferred side and then return to primary position (5 s flexion, 5 s hold, and 5 s extension) and 60 s rest between each trial.

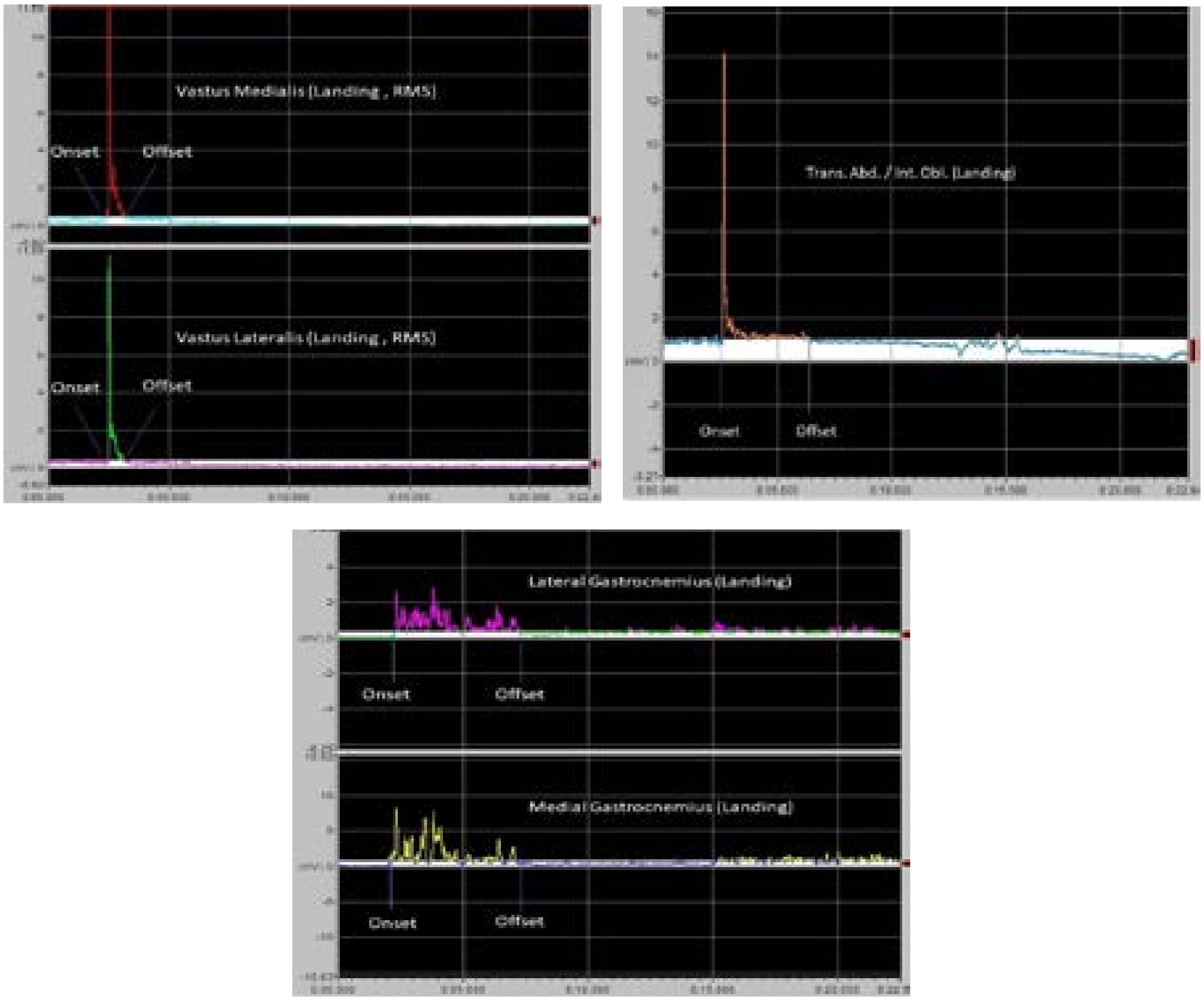

Figure 2. Onset and offset times detection of muscles in landing task, threshold measurement for the two group

B) Submaximal contraction for VM and VL was a semi-squat task on the preferred lower limb from the upright position to 60-degree knee flexion (monitored by the examiner) three times (5 s flexion, 5 s hold, and 5 s extension) and 60 s rest between each trial.

C) Submaximal contraction for LG and MG was heel rise task on the preferred lower limb from a quit stance position to maximum plantar flexion, three times (5 s plantarflexion, 5 s hold, and 5 s dorsiflexion) and 60 s rest between each trial.

Data analysis

After recording the sMVC, the subjects performed the landing task. They were asked to drop with the dominant leg. The onset and offset times of muscle activity for each muscle were detected as the point where the rectified signal was passed above or below a threshold, respectively, and remained for at least 25 ms. The threshold was calculated by adding the average EMG signal during 500 ms before the landing command to two times of standard deviation of the EMG signal during the same period. These EMG onset times were calculated for each muscle and were subtracted from the landing onset time that was measured from the force plate data as described earlier to obtain the activation onset time or delay time for each muscle (Figure 2).

The delay time of muscles was measured by the difference between the landing time (when the vertical force reached 10% of body weight) and the EMG onset time (Figure 3). Root Mean Squared (RMS) of muscles between the onset and offset were measured and then the ratio between muscle activity and sMVC of each muscle named as normalized RMS (nRMS).

Statistical analysis

After the results of the Kolmogorov-Smirnov (KS) test confirmed the normality of data distribution for all variables, we used the parametric statistical tests for data analysis. The independent t-test was used to compare the demographic characteristics of subjects between groups (Table 1). In each group, a 1-way analysis of variance (ANOVA) for repeated measures was used to determine the significant differences among onset and offset latencies of the muscles.

The independent t-test was used to identify whether there was any significant difference in nRMS, onset or delay time, and offset time of all muscles between genu varum and healthy participants. The level of statistical significance (alpha value) was set at 0.05, and SPSS v. 16.0 (SPSS Inc, Chicago, Illinois) was used for all statistical analyses. All data were presented as Mean±SD.

3. Results

Demographic characteristics

Two groups were matched by age, height, weight, and body mass index ($P>0.05$). Varus angle was significantly different between the two groups ($P<0.05$) (Table 1).

The onset latency of TA/IO, VM, VL, LG, and MG muscles

Repeated measures were used to determine the significant difference for onset latencies for each group.

a) Genu varum

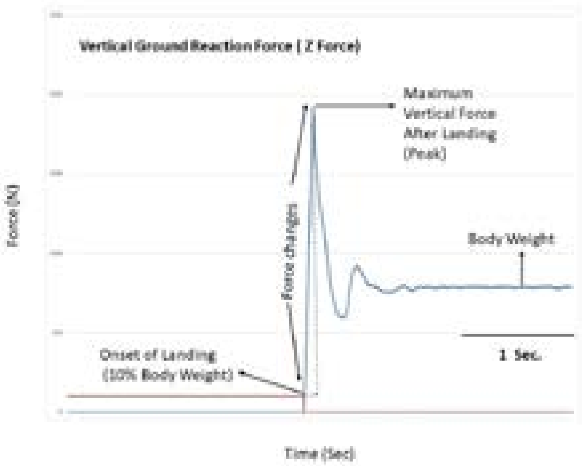

Figure 3. The onset of landing (10% body weight)

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Table 1. Demographic information (Mean±SD) of the two groups

Variables	Mean±SD				
	Age (y)	Weight (kg)	Height (m)	Body Mass Index (kg/m²)Mean	Varus angle (deg.)
Genu varum	25.10±5.97	61.40±11.23	1.64±0.08	22.69±2.76	14.134±2.52
Normal	21.50±4.84	57.40±6.96	1.65±0.06	21.13±1.90	6.499±1.88
P	0.08	0.18	0.41	0.08	0.000

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There was a significant difference in the muscle activation onset time (delay time) across the investigated muscles in the genu varum group ($F_{4,8}$=4.548, P=0.004, η^2P=0.336).

A paired t test was used to compare each pair of muscles and the result showed that the onset of activity of TA/IO, LG, and MG was significantly different in the VM and VL muscles (Figure 4).

b) Healthy

There was no significant difference in the muscle activity onset time (delay time) across the investigated muscles in the healthy group ($F_{4,8}$=0.331, P=0.812, η^2P=0.036).

c) Healthy vs genu varum

There was a significant increase in the delay time of TA/IO, LG, and MG in the genu varum group compared with the healthy group (Table 2).

Offset latency of TA/IO, VM, VL, LG, and MG muscles

Also, a repeated measurement analysis was used to determine a significant difference for offset latencies for each group.

a) Genu varum

There was significant difference in the muscle activity offset time across the investigated muscles in genu varum group ($F_{4,8}$=22.284, P=0.000, η^2P=0.712).

A paired t test was used to compare each pair of muscles and the result showed that activation offset of LG and MG were significantly different from the TA/IO, VM, and VL muscles (Figure 5).

b) Healthy

There was a significant difference in the muscular activation offset time across the investigated muscles in the healthy, ($F_{4,8}$=18.135, P=0.001, η^2P=0.668).

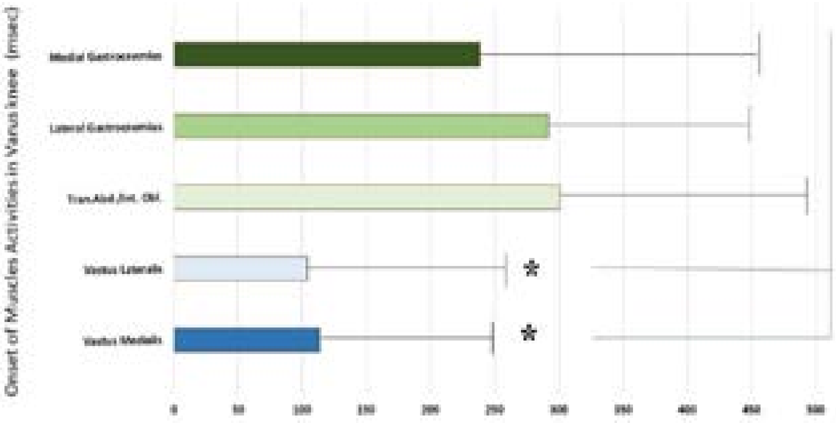

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Figure 4. Onset or delay time (onset of VGRF – the beginning time of muscle) increased in TA/IO, LG, and MG compared with VM and VL in the genu varum subjects

Table 2. The Independent t-test of delay time (ms) between the two groups (n=10 for each group)

Muscles	Group	Mean±SD	Mean Diff.	t	P	MDC
VM	Genu varum	217.533±134.66	-125.400	-2.613	0.096	30.22
	Healthy	92.133±180.23				
VL	Genu varum	185.100±106.50	-71.900	-0.973	0.347	41.33
	Healthy	113.200±208.10				
TA/IO	Genu varum	356.633±133.28	-294.833	-4.293	0.000	49.54
	Healthy	61.800±171.45				
LG	Genu varum	318.033±138.77	-253.633	-3.816	0.001	39.91
	Healthy	64.400±157.85				
MG	Genu varum	327.833±131.26	-284.800	-4.077	0.001	31.60
	Healthy	43.033±177.6				

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VM: vastus medialis; VL: vastus lateralis; TA/IO: transverse abdominal/int. oblique; LG: lateral gastrocnemius; MG: medial gastrocnemius.

A paired t test was used to compare each pair of muscles and the result shows that the activation offset of LG and MG were different from the TA/IO, VM, and VL muscles (Figure 6).

c) Healthy vs genu varum

A comparison between the two groups indicated an increase in the offset time of LG in genu varum (Table 3).

Normalized muscle activity (nRMS) of TA/IO, VM, VL, LG, and MG muscles

A comparison of muscle activities between the two groups indicated an increase in muscle activity in genu varum subjects, especially in VM and TA/IO (Table 4).

4. Discussion

Genu varum deformity changes postural motor control synergy in a specific landing task. The change may be due to an increase in the variability of proprioception receptors in muscles, ligaments, and tendons. All proprioceptive receptors that act as afferent input to the spinal cord, in the dynamic task and changes of subject position, refer to new input as re-afferent in serial series (adaptive model of motor control). These changes produce some new synergies and can increase the reduced degree of freedom (DOF) of all joints in the lower limb. At this condition, muscle timing (onset or offset) may be changed. The increase in delay time and offset time of muscle activities and also muscle contraction indicates an increase in the degree of freedom and variability in the adaptive model. Genu varum deformity can enor-

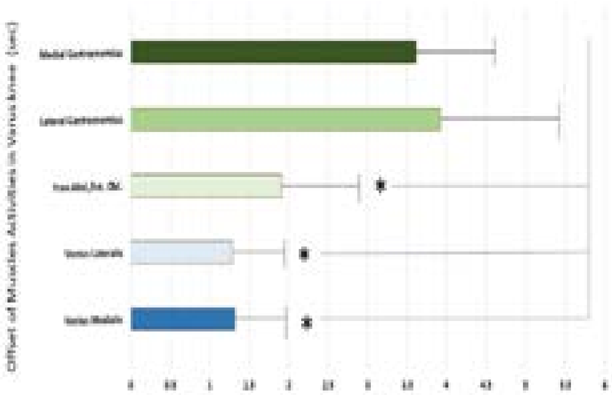

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Figure 5. Offset time increased markedly, in LG and MG in comparison to TA/IO, VM, and VL in the genu varum subjects

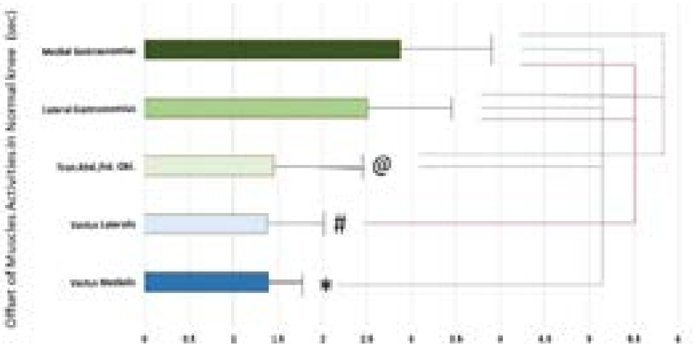

Figure 6. Offset time increased in LG and MG in comparison to TA/IO, VM, and VL, and also TA/IO offset time is more than VM in the normal subjects.

Table 3. The independent t-test of offset time (s) between two groups (n=10 each group)

Muscles	Group	Mean±SD	Mean Diff.	t	P	MDC
VM	Genu varum	1.440±0.46	0.05	-0.253	0.803	0.11
	Healthy	1.389±0.42				
VL	Genu varum	1.421±0.61	0.198	-0.897	0.381	0.12
	Healthy	1.221±0.34				
TA/IO	Genu varum	1.906±1.02	-0.850	-1.170	0.26	0.23
	Healthy	1.456±0.66				
LG	Genu varum	4.084±1.39	-1.573	-2.903	0.01	0.33
	Healthy	2.510±1.00				
MG	Genu varum	3.801±0.96	-0.916	-2.096	0.05	0.28
	Healthy	2.885±0.99				

VM: vastus medialis; VL: vastus lateralis; TA/IO: transverse abdominal/int. oblique; LG: lateral gastrocnemius; MG, medial gastrocnemius; MDC: minimally detectable change.

Table 4. The independent t test of normalized muscle activity (mV) between the two groups (n=10 for each group)

Muscles	Group	Mean±SD	Mean Diff.	t	P	MDC
VM	Genu varum	2.274±1.42	-1.276	-2.613	0.018	0.28
	Healthy	0.997±0.62				
VL	Genu varum	2.760±1.70	-0.494	-0.405	0.690	0.72
	Healthy	2.265±3.47				
TA/IO	Genu varum	2.870±2.33	-1.248	-2.987	0.008	0.39
	Healthy	0.622±0.49				
LG	Genu varum	0.637±0.36	-0.175	-2.903	0.220	0.08
	Healthy	0.461±0.25				
MG	Genu varum	0.695±0.44	-0.038	-0.204	0.481	0.12
	Healthy	0.656±0.41				

VM: vastus medialis; VL: vastus lateralis; TA/IO: transverse abdominal/int. oblique; LG: lateral gastrocnemius; MG: medial gastrocnemius; MDC: minimally detectable change.

mously increase the variability of the motor regulation for the control of posture after landing task.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles are considered in this article.

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Authors contributions

All authors in preparing this article.

Conflict of interest

The authors declared no conflict of interest.

References

[1] Podraza JT, White SC. Effect of knee flexion angle on ground reaction forces, knee moments and muscle co-contraction during an impact-like deceleration landing: Implications for the non-contact mechanism of ACL injury. The Knee. 2010; 17(4):291-5. [DOI:10.1016/j.knee.2010.02.013] [PMID]

[2] Coventry E, O'Connor KM, Hart BA, Earl JE, Ebersole KT. The effect of lower extremity fatigue on shock attenuation during single-leg landing. Clinical Biomechanics. 2006; 21(10):1090-7. [DOI:10.1016/j.clinbiomech.2006.07.004] [PMID]

[3] Arden NK, Crozier S, Smith H, Anderson F, Edwards C, Raphael H, et al. Knee pain, knee osteoarthritis, and the risk of fracture. Arthritis Care & Research. 2006; 55(4):610-5. [DOI:10.1002/art.22088] [PMID]

[4] Letafatka A, Mantashloo Z, Moradi M. Comparison the time to stabilization and activity of the lower extremity muscles during jump-landing in subjects with and without Genu varum. Gait & Posture. 2018; 65:256-61. [DOI:10.1016/j.gaitpost.2018.08.001]

[5] Gibson K, Sayers SP, Minor MA. Measurement of varus/valgus alignment in obese individuals with knee osteoarthritis. Arthritis Care & Research. 2010; 62(5):690-6. [DOI:10.1002/acr.20084] [PMID]

[6] Krackow KA. The measurement and analysis of axial deformity at the knee. Mahwah, NJ: Homer Stryker Center; 2008. https://books.google.com/books?id=llzstAEACAAJ&dq

[7] Cherian JJ, Kapadia BH, Banerjee S, Jauregui JJ, Issa K, Mont MA. Mechanical, anatomical, and kinematic axis in TKA: Concepts and practical applications. Current Reviews in Musculoskeletal Medicine. 2014; 7(2):89-95. [DOI:10.1007/s12178-014-9218-y] [PMID] [PMCID]

[8] Stegeman DF, Hermens HJ. Standards for surface electromyography: The European project "Surface EMG for Non-Invasive Assessment of Muscles (SENIAM). Paper presented at: 3rd General SENIAM workshop. 15-16 May 1998; Aachen, Germany. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.623.2040