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Comparative analysis of quadriceps activity during stair ascending with varied seated postures in adult women

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Background Adults in modern society spend most of their time in a sitting position. However, sitting for long periods of time can affect the length and sensation of the quadriceps muscle and negatively affect the performance of functional tasks required in daily life. In addition, it may have different characteristics according to sitting postures. **Aim** The aim of this study is to confirm the difference in quadriceps muscle activity during climbing and descending stairs according to maintenance sitting postures and sitting postures. **Methods** Thirty-six healthy adult women were classified into sitting upright (SU), sitting with legs crossed (SLC), and sitting with ankles crossed over knees (SAC). The muscle activities of the vastus medialis, vastus lateral, and rectus femoris were collected during climbing and descending the stairs three times each. After which a sitting posture was maintained for 15 minutes, the post-measurement was performed in the same way as the pre-measurement. **Results** The result, vastus medialis muscle were significantly decreased after maintaining a sitting posture during descending stairs of SU and SAC ($p<0.05$). In conclusion, this study indicates that maintaining a sitting posture for a certain period causes a temporary decrease in muscle activity of the vastus medialis muscle during descending stairs.

Comparative Analysis of Quadriceps activity during Stair Ascending with Varied Seated Postures in Adult Women

Abstract

Background

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Aim

The aim of this study is to confirm the difference in quadriceps muscle activity during climbing and descending stairs according to maintenance sitting postures and sitting postures.

Methods

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Results

The result, vastus medialis muscle were significantly decreased after maintaining a sitting posture during descending stairs of SU and SAC ($p<0.05$). In conclusion, this study indicates that maintaining a sitting posture for a certain period causes a temporary decrease in muscle activity of the vastus medialis muscle during descending stairs.

Introduction

The quadriceps muscle consists of the vastus medialis, vastus lateral, and rectus femoris muscles, surrounds the knee joint from the front of the thigh and is involved in knee extension and flexion. Even quadriceps muscle contributes to this patella stabilization (Elias & White, 2004). The patella is in the pulley groove at the bottom of the femur and serves as a lever during knee extension and provides a mechanical advantage to the quadriceps. However, anterior knee pain can occur due to a variety of potential reasons, such as increased patella pressure, tibial rotation, and impaired normal tracking (Cesarelli, Bifulco, & Bracale, 1999; Lorenz et al., 2012; Mesfar & Shirazi-Adl, 2005). Normal tracing of the patella depends on the structure of the kneecap, but also on the magnitude and direction of forces in the soft tissue structures surrounding the knee joint. Weakness or imbalance of this muscle group can cause the patella to move out of its normal tracing and cause knee pain (Lorenz et al., 2012). The reduced action of the vastus medialis, which has a horizontal direction of contraction compared to other muscles, is explained as an important factor in patella kinematics (Lin et al., 2010; Powers, 2000). Pain can negatively affect performance of functional tasks required in daily life, such as climbing stairs, running, and squatting. In addition, women are reported to be more vulnerable to these problems than men due to structural characteristics and biomechanical and biochemical factors (Fulkerson & Arendt, 2000).

Sitting is an essential activity in daily life, such as watching TV, playing video games, working, and relaxing. However, it corresponds to activities with a metabolic equivalent task (MET) of less than 1.5, such as lying down and sleeping, which do not increase energy expenditure (Pate, O'neill, & Lobelo, 2008). Studies have confirmed that modern adults spend up to 9 hours of their waking hours sitting (Thorp et al., 2010). However, it is confirmed that maintaining a sedentary lifestyle for a long time has a negative effect on health and life span (Pate et al., 2008; Van der Ploeg, Hidde P, Chey, Korda, Banks, & Bauman, 2012). In addition, it has been reported that sitting for a long time increases hip joint pressure and causes muscle stiffness and fatigue, which can affect the performance of functional tasks required in daily life (Kett & Sichting, 2020; Lee, Park, & Yoo, 2011). Another previous study observed delays and changes in muscle activity after static stretching (Irawan, Sinsurin, & Sonsukong, 2022; Sánchez-Zuriaga, Adams, & Dolan, 2010). These results may be attributed to creep, which delays the recovery of muscles to their original length (Shin & Mirka, 2007). This phenomenon can affect the response speed of sensory receptors such as muscle spindles and interfere with afferent signals, reducing the accuracy and reliability of sensory information (Irawan et al., 2022; Sánchez-Zuriaga et al., 2010).

people from various populations while sitting, are confirmed to maintain various postures, such as sitting with ankles crossed over knee or sitting with legs crossed (Jung, Jung, & In, 2020; Kang, Kim, Ahn, Kim, & Jeon, 2012; Snijders, C. J. et al., 1995). These sitting postures can have various effects on the body depending on their characteristics. For example, a cross-legged sitting posture requires significant flexion and adduction of the hip joint, which is confirmed to cause deformation of the muscle length of the lower extremity (Snijders, Chris J., Hermans, & Kleinrensink, 2006; Zhou et al., 2013), and may exert disadvantageous postural effects resulting from craniometrical and trunk flexion angles (Lee et al., 2011). additionally increases the and gluteal pressure (Lee et al., 2011), and is reported to affect the imbalance of the spine and pelvis (Woo, Oh, & Won, 2016). Irawan et al., checked the muscle activity of the quadriceps femoris while climbing and descending stairs before and after maintaining a sitting position on the floor for 15 minutes and found changes in muscle activity of the vastus medialis and vastus lateralis (Irawan et al., 2022). These results mean that maintaining a sitting posture for a certain period can affect the immediate activity change of the quadriceps muscle. However, since most of the studies observed lower extremity kinematics and muscle activity in the condition of sitting on the floor, in order to maintain a sitting posture for a long time and explain the mechanism of quadriceps nerve root control according to the characteristics of the posture, sitting in a chair and using various It is necessary to understand the difference before and after holding the posture for a long time.

Therefore, this study aims to confirm the difference in activity of the quadriceps femoris muscle by performing up and down stairs corresponding to the functional task before and after applying the three postures sitting upright group (SU), sitting with legs crossed group (SLC), and sitting with ankles crossed over knees group (SAC) for a long time. The results of this study can provide improved knowledge for understanding the effects of sitting posture characteristics when maintaining a sitting posture for a long time and for preventing and managing potential knee pain. It can also provide scientific evidence supporting the use of active rest. In this study, we hypothesized that different characteristics would be seen depending on the sitting posture, as previous studies that confirmed differences in quadriceps muscle activity when sitting on the floor and maintaining various postures for a long-time revealed differences in muscle activity according to sitting posture.

Materials & Methods

Participants

In this study, 36 healthy women in their 20s with left and right leg length > 2 cm and Quadriceps-angle > 20 degrees were recruited (Irawan et al., 2022), and all subjects completed the International Physical Activity Questionnaire (IPAQ). Based on their physical activity levels, the participants were classified into three groups using the Stratified Random Sampling method: SU group (n=14), SLC (n=12), and SAC group (n=10). The study was approved by the bioethics committee of the university (1041386-202211-HR-76-02), and all participants provided voluntary consent after receiving a detailed explanation of the study's purpose and procedures. The dominant foot was determined based on the leg used when kicking a ball (Behm & Chaouachi, 2011). Demographic characteristics of each group are presented in Table 1.

[Insert Table 1 here]

Procedures

All subjects performed the functional task of going up and down the stairs three times each at a self-selected speed on the emergency stairs in the building. Sufficient rest was provided between each measurement. If the subject unconsciously grabbed the wall or handrail, or if there was a malfunction of the equipment, the data was immediately discarded and remeasured. After the pre-measurement, subjects were requested to sit for 15 minutes in a posture as classified, using a chair with a height of 46.5 cm and without a backrest. The SU kept the ankles and torso vertical from the ground, and SLC kept the body vertical from the ground, bringing the knees together and crossing the legs. The SAC kept the torso perpendicular to the ground, knees apart and one ankle resting on the other knee (Figure 1). Additionally, personal smartphones were used to ensure that the body was not unconsciously supported by a desk or other objects. Once the time limit was over, climbing and descending the stairs were performed three times each, following the same procedure as in the pre-measurement (Irawan et al., 2022).

[Insert Figure 1 here]

Electromyography

All participants wore shorts for quadriceps muscle activity measurement. The muscle activities of the vastus medialis (VM), vastus lateralis (VL), and rectus femoris (RF) were measured using a wireless surface electromyography (EMG) Noraxon mini DTS sensors (Noraxon, USA) at a sampling rate of 1,500 Hz. The disposable surface electrode (single electrode T246H) made of Ag/Agcl was attached to the muscle abdomen by referring to Surface Electromyography for the non-invasive Assessment of Muscles (SENIAM, n.d.). To minimize resistance, the skin surface of each muscle was prepared by removing hair and cleaning with alcohol cotton, and the electrodes were then affixed by two researchers. The maximum voluntary isometric contraction (MVIC) of each muscle was measured using a leg-extension machine. All subjects were instructed to hold the handle and extend their knees with maximum effort while keeping their hips and knees flexed at 90°, and to hold this position for 5 seconds (Amiri-Khorasani & Kellis, 2013). Sufficient rest was provided between 3 repetitions.

All data were collected using Noraxon MR3 3.14 software. The raw data of each muscle were processed by applying a band-pass filter of 20 to 450 Hz to remove noise, and a root mean square (RMS) smoothing with a window of 100 milliseconds (ms) was applied. The analysis time point was selected as 50 ms before and after the maximum value of each movement during climbing and descending stairs, which is a functional performance task (Figure 2). An average value of 100 ms in total was calculated for each time point (Irawan et al., 2022). The quadriceps activity during both stair climbing and down was normalized by calculating the percentage of MVIC (%MVIC) (Mok, Bahr, & Krosshaug, 2018). Values exceeding MVIC were treated as missing values and used in analysis. (Insert Figure 2 here)

Statistical Analysis

All analyses were performed using IBM SPSS version 27.0 (Armonk, USA). Normal distribution was evaluated using the Shapiro–Wilk test. One-way analysis of variance (ANOVA) was used to identify demographic differences and differences in quadriceps muscle activity according to sitting posture, a paired t-test was conducted to confirm the difference between the groups before and after maintaining the sitting posture. Repeated-measures analysis of variance was used to confirm the interaction effect between sitting posture and sitting posture maintenance. All results are presented as mean ± standard deviation (SD), and the statistical significance level was set at $p<.05$.

Results

Table 2 shows the results for the quadriceps muscle activity during stairs walking according to sitting postures and maintained sitting postures. Aa a result of confirming quadriceps activity during stair climbing and descending before and after applying three different postures for a long time, there was no difference in quadriceps activity during stair walking before and after maintaining all postures and sitting posture. However, in the SU group and SAC group while stair descending, the VM muscle activity was significantly lower after (respectively 48.52 ± 17.17 %MVIC and 35.00 ± 9.98 %MVIC) maintaining the sitting posture compared to before (respectively 59.20 ± 19.30 %MVIC and 48.97 ± 17.54 %MVIC) maintaining the sitting posture (respectively t = 2.475, p = .031 and t = 2.341, p = .047; Figure 3). The interaction effect maintaining a sitting posture for a long time and sitting posture was not confirmed for all muscles during stair climbing and descending.

[Insert Table 2 & Figure 3 here]

Discussion

Although the research hypothesis was not satisfied in this study. However, the main finding was that the activity of the vastus medialis muscle decreased after 15 minutes of sitting in both the SU and SAC groups when descending. These results thought to be related with previous research (Beutler, Cooper, Kirkendall, & Garrett, 2002; Sousa & Tavares, 2012) that has demonstrated a decrease in muscle strength and activity in the quadriceps muscle immediately after static stretching. Prolonged sitting posture may lead to changes in neural factors, such as alterations in Golgi tendon organ reflex activity, mechanoreceptors, and pain feedback, or fatigue-related mechanisms, which could contribute to changes in quadriceps muscle activity and spasticity (Behm & Chaouachi, 2011; Morse, Degens, Seynnes, Maganaris, & Jones, 2008; Winchester, Nelson, & Kokkonen, 2009). In addition, Static stretching is known to reduce force generation ability by increasing the compliance of the muscle-tendon units, and it has been reported that muscle elasticity characteristics can change when the muscle is held in a stretched position for a prolonged period (Amiri-Khorasani & Kellis, 2013). Therefore, it is possible that the altered activation strategy of the vastus medialis muscle during stair descent observed in this study may be a result of maintaining a sitting posture for a long time. However, it has explained that vastus medialis muscle weakness and delayed activity can cause patella lateral displacement and cause knee joint diseases such as patellofemoral pain syndrome in woman (Arumugam & Parikh, 2015; Grabiner, Koh, & Draganich, 1994). Thus, in these results could potentially be important for the pathogenesis, progression, and management of individuals with knee osteoarthritis (Hinman, Bennell, Metcalf, & Crossley, 2002). On the other hand, previous studies have not explained the relationship between people who have a habit of sitting with their knees bent and holding them for a long time with knee pain (Arumugam & Parikh, 2015). Also, since muscle activity cannot be directly correlated with knee pain, these limitations must be considered when interpreting the results.

The commonly reported meaning of correct posture or good posture means that it contains a minimum of stress and strain and is conducive to maximum efficiency of body use (Claus, Hides, Moseley, & Hodges, 2009). However, because of observing the characteristics of sitting posture with SU, SLC, and SAC group in this study, muscle activity of the vastus medialis muscle decreased during descending stairs in the group with SU and SAC group. These results mean that regardless of posture, maintaining a static posture for a long time causes abnormal changes in quadriceps muscle activity. However, since this study only observed muscle activity in the quadriceps muscle while performing functional tasks after maintaining a sitting posture for a long time, there may be insufficient evidence that these changes contribute to immediate affects the efficiency of body use. However, sitting is an essential motion required for daily life. For practical, work, and various reasons, most modern adults spend most of their waking hours sitting (Pate, O'neill, & Lobelo, 2008). Therefore, the results of this study suggest the need to encourage dynamic relaxation in modern people.

Although no change in quadriceps muscle activation was observed during stair climbing in this study, the decrease in muscle activation of the vastus medialis muscle confirmed during stair descent is thought to be related to differences in gait characteristics. Climbing stairs during stair walking consumes a lot of energy in the knee joint to lift and move the body vertically and horizontally and is characterized by requiring high joint loads and moments (McFadyen & Winter, 1988). On the other hand, descending stairs has the characteristics of short single limb support time, anteroposterior ground reaction force directed backward, and using the ankle joint to reduce the flexion moment of the knee joint (Liikavainio et al., 2007; Spanjaard, Reeves, Van Dieen, Baltzopoulos, & Maganaris, 2008). In fact, in a previous study conducted to investigate differences in gait patterns, time, and muscle activity of the lower extremities when going up and down stairs, it was confirmed that different gait patterns were shown when going up and down stairs (Kim, Kim, & Seo, 2006; Nam & Lee, 2017). However, the maximum vertical force confirms when descending the greater than ascending the stairs. One of the key mechanisms for protecting the lower limbs and the whole body from impact loading is the pre-activation of muscles before ground contact, which has been described as important in controlling shock loading, particularly in individuals with asymptomatic knee osteoarthritis (Liikavainio et al., 2007). While this study recruited healthy subjects and muscle activities were used in the analysis, however, prolonged postures or stretched muscles, it suggests that may lead to alterations in the musculoskeletal protective mechanisms against impact loading such as during stair descent.

The quadriceps muscle plays a crucial role in daily functional tasks such as walking and climbing stairs, as it controls the flexion and extension movements of the knee. However, in modern society, adults often spend prolonged periods of time sitting in various positions throughout the day. Therefore, to confirm the effect of these various posture characteristics on the quadriceps muscles, this study applied the three representative postures of sitting upright, sitting with legs crossed, and sitting with ankles crossed over knees for 15 minutes, and then during climbing and descending stairs, quadriceps muscle activity was confirmed. As a result, it was confirmed that sitting upright and sitting with ankles crossed over knees for 15 minutes had an immediate effect on the vastus medialis activity during descending the stairs. However, since this study confirmed the muscle activation pattern by applying only 15 minutes of sitting posture, it is not possible to clearly explain what effect the additional time has on quadriceps muscle activity, and only healthy adults were targeted. Therefore, there is insufficient evidence that various postures for a long time can negatively affect knee dynamic stabilization in a group with knee joint disease. Thus, to better understand these effects, it is necessary to examine the difference in quadriceps muscle activity over time when sitting for 30 minutes or 1 hour. In addition, it is emphasized that additional research is needed to confirm the change in quadriceps femoris activity before and after applying various sitting postures for a long-time targeting group with knee joint diseases such as anterior knee pain or patellofemoral pain syndrome.

Conclusions

In healthy women, prolonged sitting can lead to decreased muscle activity in the vastus medialis muscle, particularly during descending stairs. This reduction in muscle activity may negatively impact knee dynamic stabilization, which refers to the ability of the knee joint to maintain stability during movement.

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Figure 1

Sitting position. Sitting upright group (a), sitting with legs crossed group (b), and sitting with ankles crossed over knees group (c).

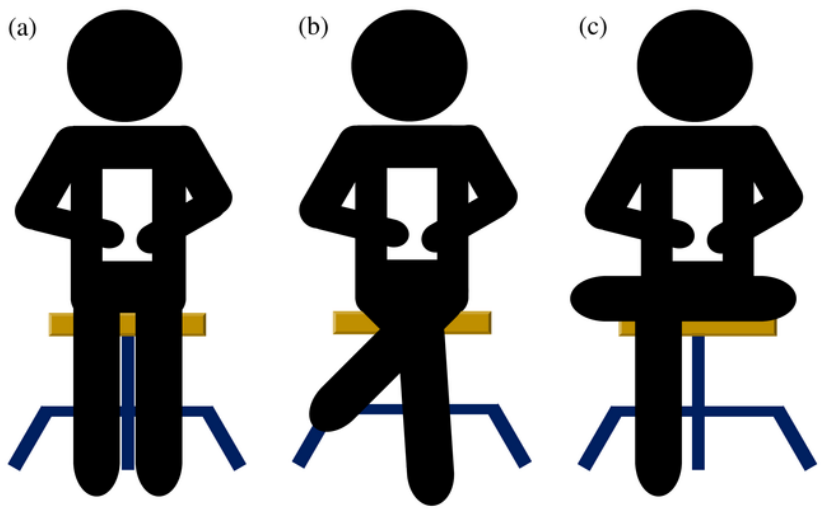

Figure 2

An example of 50 ms intervals before and after peak EMG.

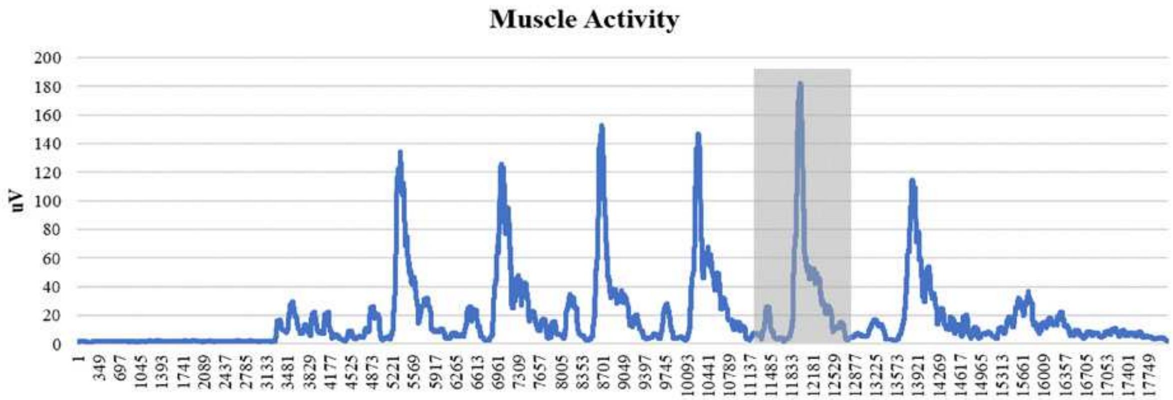

Figure 3

Comparison of the vastus medialis activity during descending stairs (expressed in %MVIC). SU = sitting upright; SLC = sitting with legs crossed; SAC = sitting with ankles crossed over knees group. * $p < 0.05$.

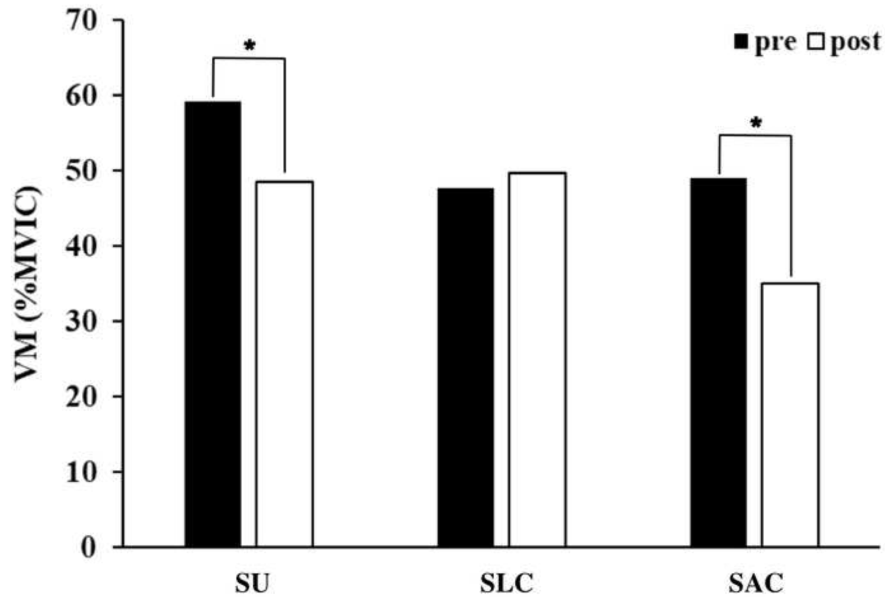

Table 1(on next page)

Demographic characteristics of participants.

* non-parametric statistics. IPAQ = international physical activity questionnaire; SU = sitting upright; SLC = sitting with legs crossed; SAC = sitting with ankles crossed over knees group.

Table 1. Demographic characteristics of participants.

	Dominant leg (n, %)		IPAQ (n, %)			Height (cm)	Weight (kg)	Age (years)
	Right	**Left**	**High**	**Moderate**	**Low**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**
SU (n = 14)	13 (92.9)	1 (7.1)	0 (0)	10 (71.4)	2 (8.4)	163.79 ± 5.52	55.71 ± 7.20	20.93 ± 1.54
SLC (n = 12)	12 (100)	0 (0)	0 (0)	11 (91.7)	1 (8.3)	165.33 ± 2.70	56.42 ± 8.99	22.42 ± 3.20
SAC (n = 10)	9 (90)	1 (10)	0 (0)	8 (80)	2 (20)	160.70 ± 5.03	53.30 ± 6.94	21.90 ± 1.52
$t(p)/Z(p)$	1.150 (.563)		1.692 (.429)			2.803 (.075)	0.476 (.625)	2.059 (.357) *

* non-parametric statistics.

IPAQ = international physical activity questionnaire; SU = sitting upright; SLC = sitting with legs crossed; SAC = sitting with ankles crossed over knees group.

Table 2 (on next page)

Difference in quadriceps muscle activity (expressed in %MVIC) between and within pre- and post-intervention during stairs walking depending on sitting posture.

VM = vastus medialis; VL = vastus lateralis; RF = rectus femoris; SU = sitting upright; SLC = sitting with legs crossed; SAC = sitting with ankles crossed over knees group.

Table 2. Difference in quadriceps muscle activity (expressed in %MVIC) between and within pre-and post-intervention during stairs walking depending on sitting posture.

	Muscle	Group	Pre Mean ± SD	Post Mean ± SD	*t*(*p*)	*F*(*p*)
Stair climbing	VM	SU	73.12 ± 18.53	69.47 ± 19.09	0.883 (.400)	0.198 (.822)
		SLC	71.40 ± 20.04	69.26 ± 20.12	0.618 (.554)	
		SAC	66.31 ± 18.11	61.01 ± 21.01	1.894 (.091)	
		t(*p*)	0.558 (.579)	0.635 (.537)		
	VL	SU	69.56 ± 16.81	67.07 ± 13.24	0.331 (.751)	0.691 (.551)
		SLC	62.96 ± 21.54	62.42 ± 18.01	0.121 (.907)	
		SAC	72.82 ± 10.54	78.98 ± 13.08	-1.841 (.108)	
		t(*p*)	1.199 (.319)	2.442 (.107)		
	RF	SU	43.48 ± 13.57	47.06 ± 15.21	-1.279 (.225)	0.134 (.875)
		SLC	43.30 ± 19.57	47.54 ± 25.36	-1.547 (.161)	
		SAC	39.13 ± 15.31	44.86 ± 20.61	-1.638 (.136)	
		t(*p*)	0.860 (.433)	0.050 (.951)		
Stair descending	VM	SU	59.20 ± 19.03	48.52 ± 17.17	**2.476 (.031)**	3.289 (.052)
		SLC	47.76 ± 14.44	49.64 ± 17.44	-0.520 (.614)	
		SAC	48.97 ± 17.54	35.00 ± 9.98	**2.341 (.047)**	
		t(*p*)	1.256 (.299)	2.980 (.065)		
	VL	SU	53.02 ± 16.52	48.54 ± 14.80	1.497 (.158)	1.742 (.191)
		SLC	41.23 ± 15.36	44.62 ± 18.58	-0.892 (.393)	
		SAC	46.43 ± 7.59	45.03 ± 6.74	0.771 (.460)	
		t(*p*)	2.165 (.131)	0.169 (.845)		
	RF	SU	34.61 ± 15.47	34.86 ± 12.33	-0.081 (.937)	0.191 (.827)
		SLC	38.72 ± 27.16	41.46 ± 31.18	-0.952 (.362)	
		SAC	31.61 ± 14.41	33.39 ± 18.25	-0.589 (.570)	
		t(*p*)	0.356 (.703)	0.451 (.641)		

VM = vastus medialis; VL = vastus lateralis; RF = rectus femoris; SU = sitting upright; SLC = sitting with legs crossed; SAC = sitting with ankles crossed over knees group.