Original Article

Analysis of the lower extremity muscle activity depending on the use of a knee aid in elderly people with osteoarthritis

DONGGEON LEE[1], SOUNGKYUN HONG[1], KYEONGBONG LEE[2], GYUCHANG LEE[3]

[1]*Department of Physical Therapy, Graduate School of Kyungnam University, Changwon, Republic of Korea*
[2]*Department of Physical Therapy, Kangwon National University, Samcheok, Republic of Korea*
[3]*Department of Physical Therapy, Kyungnam University, Changwon, Republic of Korea*

ABSTRACT

This study analysed the lower extremity muscle activity depending on the use of the Power Leg, a wearable knee aid, in elderly people with osteoarthritis. Eight participants who had osteoarthritis were asked to repeat sit-to-stand from a chair first without the knee aid, following which they were asked to repeat the same movement with the knee aid. Surface electromyography (EMG) was used to analyse muscle activities of the vastus medialis, rectus femoris, and vastus lateralis on the quadriceps femoris of the right leg while performing sit-to-stand motion. The result showed an 11.25% decrease in muscle activity of the vastus medialis, from 50.43% without the knee aid to 39.18% with the knee aid, which was significant ($p < .05$). Muscle activity of the rectus femoris decreased by 5.17%, from 29.49% without the knee aid down to 24.32% with the knee aid. However, the difference was not significant. The vastus lateralis had reduced muscle activity by 16.22%, from 57.15% without the knee aid to 40.93% with the knee aid, which was significant ($p < .05$). The results of this study showed that the Power Leg knee aid may decrease muscle activity by assisting lower extremity muscles during the sit-to-stand motion and effectively support the knee extensor during knee extension. Given these findings, as well as the ease of wearing and using the Power Leg knee aid, it is concluded that the wearable knee aid is very useful for the elderly with knee osteoarthritis.
Keywords: Knee aid; Elderly; Osteoarthritis; Electromyography.

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Corresponding author. *Department of Physical Therapy, Kyungnam University, 7 Kyungnamdaehak-ro, Masanhappo-gu, Changwon, Gyeongsangnam-do, 51767 Republic of Korea.*
E-mail: leegc76@kyungnam.ac.kr
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INTRODUCTION

Osteoarthritis, one of the most common degenerative joint diseases associated with the musculoskeletal system, causes degeneration and loss of muscle strength associated with joints and their surrounding tissues (Dulay et al., 2015; Kittelson et al., 2017). Osteoarthritis is a major factor for pain and physical disability in the elderly (McAlindon et al., 2014) that causes stiffness and joint pain as well as a reduction in muscle strength, proprioception, and stability of joints, while lowering the quality of life (Peat et al., 2001; Henriksen et al., 2012; Richmond et al., 2009). Osteoarthritis occurs in various joints including the hip, hand, spine, and ankle, and it is most common in the knee, which is a major weight-bearing joint of the body (Dulay et al., 2015; Xie et al., 2008). It is reported that osteoarthritis of the knee causes clinical symptoms, such as knee-joint pain, inflammation, and weakness of the quadriceps femoris (Palmieri-Smith et al., 2010).

Sit-to-stand, which involve switching from knee flexion in a closed chain of the lower extremity to knee extension, is the most frequently used functional movement in ordinary life (Marks, 2017). It is reported that, when sit-to-stand is performed, the vastus medialis and rectus femoris are activated before extension of the knee begins, and the hamstring and hip muscles are activated after extension of the knee begins (Anan et al., 2016). Hence, individuals with a reduction in muscle strength in the quadriceps femoris due to knee osteoarthritis experience difficulties in performing such movement (Anan et al., 2016; Palmieri-Smith et al., 2010).

Power Leg, a wearable knee aid, helps with movements, such as sit-to-stand, walking up and down the stairs, and biking, by assisting knee extension. It does so by means of repulsive force from 6 special springs on the back of the knee in the knee-flexed state. However, it has not been investigated if Power Leg can help the lower extremity muscles during knee extension movement.

Therefore, this study analysed the muscle activities during sit-to-stand motion with a Power Leg worn and without a Power Leg worn in order to determine its effect on lower extremity muscle activity in elderly with knee osteoarthritis.

METHODS

Participants

This study was conducted with the elderly whose have knee osteoarthritis. Through a bulletin board in a Community Health Center, volunteers who were willing to participate in the study were recruited. Recruited participants were screened according to the following criteria: 1) age over 65 years old, 2) diagnosis of knee osteoarthritis for more than 6 months, 3) no difficulties with communication, 4) have not undergone an orthopaedic operation for the lower extremity during the last 6 months. A total of 10 volunteers were recruited, with two being excluded according to the selection criteria, and the final eight were selected. There were 3 males and 5 female participants with an average age of 68.5 (3.38) years, height 163.9 (6.62) cm, weight 62.8 (5.39) kg.

Procedures

This study was a cross-over design. The purpose and methods involved in the study were fully explained to the participants prior to the experiments, and their basic information (age, gender, height, and weight) was collected through a brief interview.

The participants were asked to repeat a sit-to-stand motion from a chair without the knee aid, and then they were asked to repeat the same with the Power Leg knee aid (Power Leg spring iron, head tech Ltd., Osan-si, Gyeonggi-do, KOR) on both knees. The Power Leg consists of six torsion springs (15 or 17 mm). The torsion spring is constructed to support the movement of the leg using the elasticity of the spring during knee flexion of 30 degrees or more (Figure 1). Considering the height of the participants, the angle of flexion in the knee joint was at a right angle when seated on a chair. Lower extremity muscle activity was analysed while the sit-to-stand motion was performed and 2 research assistants were standing nearby to prevent any accidental falls. In consideration of the participants' fatigue, 5 minutes of rest were ensured between each trial, and 10 minutes between the two conditions (with and without Power Leg).

Figure 1. Power Leg knee aid.

Electromyographic analysis

Surface electromyography (EMG) is a method used to analyse electric signals generated in muscles. In order to analyse the electrical signals of the quadriceps femoris during the sit-to-stand motion, an EMG system (sEMG, TrigonoTM Wireless, Delsys, Boston, MA, and USA) was used. The sample rate was set to 2,000 Hz and the bandwidth to 20~450 Hz to eliminate noise from the signal. Analog signals from each muscle were converted to digital signals in the EMG system and the data was collected and analysed using Delsys EMG Works Acquisition software on a personal computer.

Electrodes were attached on the vastus medialis, rectus femoris, and vastus lateralis of the right leg, and the part being attached was cleaned and wiped to remove impurities (sweat and foreign substances) for accurate signal collecting. The electrode on the vastus medialis was attached at the 80% location, on the line between the anterior spina iliaca superior (ASIS) and the joint space in front of the anterior border of the medial ligament the electrode on the rectus femoris was attached at the 50% location, on the line from the anterior spina iliaca superior (ASIS) to the superior part of the patella and the electrode on the vastus lateralis at the two-thirds location on the line from the anterior spina iliaca superior (ASIS) to the lateral side of the patella. All electrodes were attached in parallel with the alignment direction of the muscle fibre.

The EMG signal was converted to Root Mean Square (RMS). For analysis of EMG activity, Maximum voluntary isometric contraction (MVIC) was performed on each muscle for 5 seconds in the manual muscle test posture to measure RMS values. In addition, The RMS value of EMG signals from each muscle was converted to % MVIC for RMS, which was measured during MVIC to be used in the muscle activity analysis.

Data analysis

SPSS 18.0 software (SPSS Software Inc., Chicago, IL, USA) was used for statistical analysis. The basic information of the participants was expressed in frequency or mean (with standard deviation). To compare the two conditions, a paired T test was used. Statistical significance was set at α = .05.

RESULTS

The comparison of lower extremity muscle activity during the sit-to-stand motion with and without Power Leg use led to the following results (Table 1).

Table1. Comparison of electromyographic muscle activity with- and without knee aid (% MVIC).

Muscle	**Conditions**		**Variation**	**p-value**
	With knee aid	Without knee aid		
Vastus medialis (%)	50.43 (26.63)	39.18 (25.31)	-11.25%	.007*
Rectus femoris (%)	29.49 (12.31)	24.32 (10.13)	-5.17%	.068
Vastus lateralis (%)	57.15 (25.80)	40.93 (16.95)	-16.22%	.009*

*Values are presented as mean (standard deviation). Significant differences were presented as *p < .05.*

The muscle activity of the vastus lateralis decreased by 16.22%, from 57.15% without Power Leg to 40.93% with Power Leg. The muscle activity of the vastus medialis dropped by 11.25%, from 50.43% without Power Leg to 39.18% with Power Leg. Both results were significant (p < .05). However, the muscle activity of the rectus femoris decreased by 5.17%, from 29.49% without Power Leg to 24.32% with Power Leg, which was not significant.

DISCUSSION

This study analysed the lower extremity muscle activity depending on the use of the Power Leg, a wearable knee aid, in elderly through comparison of electromyographic muscle activities during a sit-to-stand motion with and without Power Leg. The results of this study showed that the muscle activity was significantly decreased in the vastus medialis and vastus lateralis during the sit-to-stand motion when the knee aid was worn compared to when it was not worn.

Sit-to-stand involve a very dynamic movement that requires broad joint movement of the lower extremity and trunk, which is typically repeated in activities of daily living. It is the most frequently used functional movement when the flexion of knee in closed chain changes to extension, and such posture change applies heavy load on the lower extremity (Hodge et al., 1989; Marks, 2017). According to previous studies, since the knee extensor is activated by a higher rate than other lower extremity muscles during sit-to-stand, the vastus medialis and rectus femoris are activated, especially before knee extension begins, while after knee extension begins, the hamstring and hip muscles are activated (Schenkman et al., 1996; Hughes et al., 1996; Anan et al., 2016). Thus, the elderly with knee osteoarthritis, who have decreased muscle strength of the quadriceps and reduced stability of the knee joint due to osteoarthritis, will experience pain and discomfort during such movement (Anan et al., 2016; Palmieri-Smith et al., 2010).

In the present study, when the participants performed the sit-to-stand motion with Power Leg, the reduction in muscle activity of the vastus medialis and vastus lateralis was significant, and that of the rectus femoris was reduced as well (although it was not significant). Sharma et al. (2017), claimed that the imbalance of muscle strength between the quadriceps femoris and hamstring, which is particularly common in the elderly, causes reduced stability of the knee joint and promotes the process of osteoarthritis. Furthermore, previous studies argued that an orthosis, when applied to the elderly with knee osteoarthritis, reduces knee pain and improves physical abilities for short and long terms. In particular, the use of a knee aid delays the progression of osteoarthritis and relieves the pain from osteoarthritis through reduction of high fatigue and activity of the quadriceps femoris, which is common among people with osteoporosis (Sharma et al., 2017; Mau-Moeller et al., 2017). Therefore, the Power Leg knee aid used for this study can assist compensation of the muscle strength weakness through reduced activity of the quadriceps femoris, which may increase the stability of the knee joint.

A significant amount of study on rehabilitation equipment and orthosis to assist sit-to-stand motion has been reported. Kasai et al. (Kasai et al., 2016), and other studies analysed the effect of a HAL Suit, which helps movement of the user's lower extremity; these studies analysed the changes in movement pattern and standing position during sit-to-stand motion of patients having undergone stroke. As a result, the angle of the trunk in a sitting position while leaning forward increased, and the muscle activity of the vastus medialis on the affected side decreased. This verified that the HAL Suit, which improves lower extremity muscle strength of stroke patients, helps the sit-to-stand motion and changes patterns in the standing position of patients with stroke. However, the HAL Suit has a limitation in that its structure is too complicated for patients with neurologic diseases to wear due to its robotic structure (Kasai et al., 2016). Roboknee, a knee joint extension orthosis, is a lower extremity orthosis that increases power for knee extension. In the analysis of the effect on the knee of healthy adults wearing Roboknee, it was found to assist knee extension as the activity of the quadriceps femoris decreased by 38% (Spring et al., 2011). However, since Roboknee is too heavy to carry and the battery does not last long due to its motors, it has limitations in that it is not sufficiently practical to be used in ordinary life. As a comprehensive result of our study and previous studies (Kasai et al., 2016; Spring et al., 2011), Power Leg is very simple to wear and use without influence from the surrounding environment, and it can be a very useful orthosis for the elderly with knee osteoarthritis because it is directly worn on the knee and effectively assists the knee extensor during extension of the knee.

However, this study has a few limitations. First, it is difficult to generalize the results of this study because the number the small sample size. Another limitation is that the analysing was only on the muscle activity of the quadriceps femoris. Therefore, further studies should be conducted.

CONCLUSION

In this investigation of the effect of Power Leg knee aid on lower extremity muscle activity during sit-to-stand motion in elderly with knee osteoarthritis, it was verified that the muscle activity of the vastus medialis and vastus lateralis of the quadriceps femoris decreased while wearing the knee aid in comparison to when the knee aid was not worn.

Therefore, Power Leg can be practically useful because it can effectively assist the knee extensor in the elderly with knee osteoarthritis and is easy to use in ordinary life thanks to its ease in wearing and using.

AUTHOR CONTRIBUTIONS

DGL and GCL participated in the design of the study and performed the statistical analysis. DGL and GCL interpreted collected data. SKH and KBL were main contributors in writing the manuscript. All authors read and approved the final manuscript.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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