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Original Article

Effect of proprioceptive training on foot posture, lower limb alignment, and knee adduction moment in patients with degenerative knee osteoarthritis: a randomized controlled trial

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Abstract. [Purpose] The purpose of this study was to determine the effect of proprioceptive training on foot progression angle, weight-bearing ratio, and knee adduction moment in patients with degenerative osteoarthritis of the knee. [Subjects] The subjects were 37 patients diagnosed with Kellgren-Lawrence grade 2 or 3 degenerative knee osteoarthritis. They were randomly allocated to three groups: a proprioceptive training group (PT group), quadriceps strengthening group (QS group), and control group. [Methods] The study parameters of the three groups were compared before and after a 12-week training period. Therapeutic exercises were performed twice per week for 12 weeks. Outcomes included the foot progression angle, weight-bearing ratio, and knee adduction moment. [Results] First, a significant difference in the foot progression angle was observed among the groups, significantly increasing in the PTG compared with the CG. Second, a significant difference in the weight-bearing ratio was observed among the groups, significantly increasing in the PTG compared with the CG. Third, a significant difference in the first peak knee adduction moment was observed among the groups, significantly decreasing in the PTG compared with the CG. [Conclusion] The results of the present study indicate that proprioceptive training increased the foot progression angle and weight-bearing ratio and decreased the first peak knee adduction moment. Moreover, incorporating proprioceptive training into a physical therapy exercise program could improve functional ability and delay the progression of degenerative osteoarthritis.

Key words: Knee osteoarthritis, Knee adduction moment, Proprioceptive training

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INTRODUCTION

Degenerative knee osteoarthritis (OA) is a common and painful disease with advancing age and leads to functional disorder[1)]. Patients with degenerative knee OA clinically complain of pain, decreased muscle strength, joint instability, joint stiffness, and proprioceptive deficits, all of which lead to a decrease in or loss of function[2)].

Quadriceps muscle weakness leads to a change in the biomechanics and axis of the knee joint[3)], negatively affecting joint mobility, posture, and gait[4)]. These changes also cause increased dynamic loading in the medial knee joint, resulting in degenerative knee OA[5)]. Changes in the ankle joint especially affect lower extremity alignment during the stance phase and result in overuse of the knee joint[6)]. In clinical practice, rehabilitation for knee OA typically aims to increase muscle strength and enhance proprioceptive function[7)]. In particular, due to the contribution of the quadriceps to shock absorption and stability at the knee during gait, previous studies focused more on strengthening knee joint muscles, mainly the quadriceps[8)]. Since quadriceps weakness strongly contributes to disability in knee OA, this may alter local contact stress in a manner detrimental to articular cartilage[9)]. It may also lead to increased impulse loading, which has been associated with knee pain and may contribute to knee OA[9)]. Anwer et al. indicated that quadriceps exercises can significantly improve knee pain and quadriceps strength[10)].

In patients with degenerative OA, there is a prominent loss of proprioception compared with healthy people of the same age and gender[11)]. OA can cause changes that affect not only intracapsular tissues but also periarticular tissues such as ligaments, capsules, tendons, and muscle, leading to proprioceptive deficits both in extremes of joint position and body position[12)]. A previous study reported proprioception deficits with age progression and reported a greater decrease in patients in knee OA[13)]. It is clear that in knee OA, proprioception deficits may play a role in OA development and also as contributing risk factors for the progression of OA[13)]. Another study demonstrated the effects of proprioceptive training and strengthening exercise on knee pain, joint function, and proprioception[14)]. However, studies related to the

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effects of proprioceptive training and strengthening exercise on joint kinetics in patients with degenerative OA of the knee are rare. Therefore, the aim of this study was to determine the effects of proprioceptive training using a balance pad and quadriceps strengthening exercise on foot progression angle, weight-bearing angle, and peak knee adduction moment in patients with degenerative knee OA.

SUBJECTS AND METHODS

The subjects included 60 female patients over the age of 65 years from Seoul A Senior Welfare Center. The inclusion criteria were (1) diagnosis with degenerative OA and had radiologically stage 2 and 3 bilateral knee OA according to the Kellgren and Lawrence scale[15] and (2) deficits in sensation, circulation, balance, or range of motion,; lower extremity MMT; or serious foot problems according to the index of Speechley and Tinetti. The exclusion criteria were (1) a history of other neurologic or circulatory diseases or disorders, (2) any cardiovascular system abnormality, or (3) any history of knee, hip, or ankle surgery.

This study used a randomized three-group pretest-posttest design. Subjects were randomly allocated to a proprioceptive training group (PTG; n=16), quadriceps strengthening group (QSG; n=16), or control group (CG; n=16). All 37 participants completed the intervention. Randomization was accomplished with a computer using a basic random number generator. Prior to the subjects' participation, all procedures were explained, and each subject provided written informed consent to participation. This study was approved by the Sahmyook University Institutional Review Board.

The PTG and QSG therapeutic exercises[16] were performed for 30 min twice per week for 12 weeks. Therapeutic exercise programs were performed one-on-one with a physical therapist. The ankle proprioceptive training program focused on improvement of the proprioception sense of an ankle to correct the joint's position. The PTG performed its exercise program with a Torsiomed (Haider Ltd, 2000, Germany), which and consisted of frontal and sagittal plane exercise. The frontal plane exercise comprised maintenance of balance, lateral tilting, and medial tilting, and the sagittal plane exercise comprised forward tilting and backward tilting. Both the frontal and sagittal plane exercises were performed 40 times repeatedly. In the first four weeks, the exercises were performed while standing on both legs with the eyes open and with verbal commands to provide the subjects with visual and auditory feedback. In the next four weeks, they were performed while alternating between standing on the left or right leg. In the last four weeks, the exercises were performed without any visual or auditory feedback. We performed that without a visual and auditory feedback at last 4 weeks. The QSG performed isometric exercise for improvement of muscle power. The subjects performed 10 repetitions per set for a total of three sets in the long sitting and supine positions and gradually increased the training intensity every 4 weeks. We offered both groups 3 minutes of rest between sets for recovery from fatigue. On the other hand, the CG only applied a hot pack to both knee for 20 minutes and then TENS at 80 to 120 Hz for 15 minutes.

To evaluate the foot progression angle and weight-bearing ratio, radiographs were taken with a Shimadzu 500 X-ray generator on 35.56 × 91.44 films in a long cassette. The focus-film distance (FED) was set at 183° to minimize distortion evaluations. Subjects were positioned on a foot-hold standing with the knees extended, and a radiographer measured the foot progression angle in the same manner before and after the intervention. After this, the angle of the superior side leg was measured.

Peak external knee adduction moment was measured using a 3D motion analysis system (Orthostat 6.29, Motion Analysis Ltd, USA, 2005) with eight cameras and two force plates (piezoelectric force plate, 600 × 900, Kistler, Winterthur, Switzerland) embedded in the center of an 8-m walkway. Participants walked in their own low-heeled shoes at a self-selected pace for five trials, and single-leg force platform contacts were recorded. The peak knee adduction moment was normalized to body weight multiplied by height (force [N]/body weight × distance [m]/height [m]). Outcome measures included knee adduction moment magnitude (knee adduction impulse, loading response [1st] peak and terminal stance [2nd] peak).

The SPSS ver. 12.0 statistical software was used for all analyses. Descriptive statistics were used to describe patient characteristics after confirming the data were normally distributed. Comparisons of all groups' general characteristics were performed using the independent t-test or chi-squared test. Pre- and post-intervention data were analyzed using the paired t-test to test within-group differences and one-way ANOVA to test differences among the groups. Duncan's post hoc test was used to test the significance of differences between the groups. A significance level of 0.05 was used for all measurements.

RESULTS

General subject characteristics are presented in Table 1. No significant differences in general characteristics were observed among the PTG, QSG, and CG. Differences in pre- and post-intervention values within groups and between groups are summarized in Table 2. Specifically, the PTG showed a significant increase in foot progression angle ($p < 0.05$), and the difference was significantly greater than that of the CG. In addition, the PTG showed a significant increase in weight-bearing ratio ($p < 0.05$), and the difference was significantly greater than that of the CG. In addition, the first peak knee adduction moment was significantly different between before and after the intervention, and the differences in the PTG were significantly greater than those of the CG ($p < 0.05$).

DISCUSSION

This study showed that, in response to 12 weeks of proprioceptive training, participants with degenerative OA exhibited an increase in foot progression angle and weight-bearing ratio and a decrease in first peak knee adduction moment.

In this study, there was a significant difference in foot progression angle during the initial stance phase after the intervention. Previous studies have reported that the foot

Table 1. General characteristics of the participants

Parameters	PTG (n=12)	QSG (n=13)	CG (n=12)
Age, years	71.2 (7.0)	69.4 (3.6)	71.2 (3.4)
Height, (cm)	156.0 (8.0)	153.2 (2.2)	153.5 (1.9)
Weight, (kg)	65.2 (9.1)	62.5 (5.2)	63.7 (9.1)
Kellgren-Lawrence grade	2.4 (0.5)	2.6 (0.4)	2.7 (0.5)

Mean (SD). PTG: proprioceptive training group; QSG: quadriceps strengthening group; CG: control group

Table 2. Comparison of foot progression angle, weight- bearing ratio, and knee adduction moment within groups and between groups

Parameters		Values					
		PTG (n=12)		QSG (n=13)		CG (n=12)	
		pre	post	pre	post	pre	post
Foot progression angle (°)	Loading response	9.84 (4.86)	11.84 (3.96) *†	8.02 (5.03)	7.34 (5.90)	9.00 (7.83)	8.51 (6.01)
	Terminal stance	10.33 (4.52)	11.11 (3.79)	10.23 (5.78)	9.54 (6.99)	10.21 (8.45)	9.43 (6.21)
Weight-bearing ratio (%)		31.00 (10.16)	43.67 (14.51) *†	35.43 (9.60)	36.28 (9.99)	30.14 (3.84)	29.14 (3.72)
Knee adduction moment (Nm/kg)	First peak	0.57 (0.20)	0.44 (0.22) * †	0.54 (0.15)	0.50 (0.12)	0.53 (0.03)	0.53 (0.12)
	Second peak	0.49 (0.26)	0.43 (0.28) *	0.47 (0.14)	0.41 (0.11)	0.44 (0.14)	0.52 (0.06)

Values are means (SD). *Within-group difference ($p<0.05$). †Significantly greater than the CG (post hoc test). PTG: proprioceptive training group; QSG: quadriceps strengthening group; CG: control group

progression angle directly affects the medial compartment compressive load in asymptomatic individuals and those with mild to moderate knee OA[17)]. Therefore, several interventions are aimed at reducing knee medial compartment loading[18)]. The present study showed the effect of proprioceptive training, focusing on movement of the foot and ankle joints. During proprioceptive training, subjects controlled the ankle joint in multiple directions to maintain balance on the balance pad, and they repeatedly performed ankle tilting in the frontal and sagittal planes. Movement of the ankle in various directions, causing changes in ankle ligament length, facilitates joint stability by creating a reaction to concentric movement[19)]. In the current study, ankle proprioceptive training improved proprioception and enhanced ankle stability in elderly individuals[20)]. These results are in accordance with findings showing that changing the foot position improves position sense and joint stability.

Another interesting result was that the weight-bearing ratio significantly increased in the PTG after the intervention. In a previous study, a weight-bearing ratio of < 50% was defined as genu varus, and a weight-bearing ratio of > 50% was defined as genu valgus[21)]. Of the PTG, 31% were classified as having genu varus. However, after the intervention, the percentage increased to 43.67%. It is common to move the weight-bearing line laterally to the center of gravity with a lateral wedge in shoes to correct varus deformities[22)]. The changes in the weight-bearing ratio in the present study are in accordance with this effect of a lateral wedge. Based on this, changes in foot progression angle may result in changes in the weight-bearing ratio by shifting the center of mass and the biomechanical axis to the lateral side.

In the present study, the peak knee adduction moment was used to determine the effects of proprioceptive training and quadriceps muscle strengthening exercises. In particular, the external adduction moment of the knee has been demonstrated to be a valid measure for load on the knee medial compartment, a risk factor for disease progression[23)], and a useful outcome measure following an intervention[22)]. The normal predominance of the knee adduction moment throughout the stance phase of gait and its subsequently larger medial knee compartment load relative to the lateral knee compartment load has been suggested to contribute to the markedly greater incidence of advanced OA in the medial knee compartment[24)]. Moreover, in the presence of medial compartment knee OA, articular cartilage degeneration leads to a decreased medial joint space, creating a further shift in the lower limb alignment toward varus[25)] and an even greater adduction moment about the knee during gait[26)]. This study demonstrated that participants with degenerative OA exhibited a decrease in first peak knee adduction moment after proprioceptive training. A previous study showed that proprioceptive training increased lower extremity strength and neuromuscular control and reduced peak knee adduction moment in patients with knee OA[4)]. Another study showed that valgus bracing[27)] and lateral heel wedges[28)] reduced the magnitude of knee adduction moment during gait. In the present results, the first peak knee adduction moment in the PTG decreased 24% after the intervention. Previous studies of valgus bracing[27)] and wedged insoles[28)] showed reductions of 13 and 8%, respectively. It has been suggested that every 20% increase in knee adduction moment increases the six-year risk of radiographic progression sixfold[29)] and that an 8% increase in peak adduction moment increases the risk of developing chronic knee pain four years later[23)]. Therefore, the current study demonstrated that proprioceptive training decreased the adduction moment and delayed disease progression.

Despite demonstrating the effectiveness of proprioceptive training on leg alignment and knee adduction moment in patients with degenerative OA, this study had some limitations. First, the statistical power was not calculated, and only a small number of subjects were recruited. Second, because the participants consisted of only female patients over the age of 65 years, the results of this study cannot be generalized to all patients with degenerative OA. Therefore, we suggest that further studies include subjects of both genders and a wider age range.

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