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

INTRODUCTION

Degenerative knee osteoarthritis (OA) is a common and painful disease with advancing age and leads to functional disorder1). 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 function1).

Quadriceps muscle weakness leads to a change in the biomechanics and axis of the knee joint1), negatively affecting joint mobility, posture, and gait5). These changes also cause increased dynamic loading in the medial knee joint, resulting in degenerative knee OA5). Changes in the ankle joint especially affect lower extremity alignment during the stance phase and result in overuse of the knee joint6). In clinical practice, rehabilitation for knee OA typically aims to increase muscle strength and enhance proprioceptive function7). 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 quadriceps8). Since quadriceps weakness strongly contributes to disability in knee OA, this may alter local contact stress in a manner detrimental to articular cartilage9). It may also lead to increased impulse loading, which has been associated with knee pain and may contribute to knee OA8). Anwer et al. indicated that quadriceps exercises can significantly improve knee pain and quadriceps strength10).

In patients with degenerative OA, there is a prominent loss of proprioception compared with healthy people of the same age and gender11). 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 position12). A previous study reported proprioceptive deficits with age progression and reported a greater decrease in patients in knee OA13). It is clear that in knee OA, proprioceptive deficits may play a role in OA development and also as contributing risk factors for the progression of OA13). Another study demonstrated the effects of proprioceptive training and strengthening exercise on knee pain, joint function, and proprioception14). However, studies related to the
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 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, and (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 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, 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
movement19). In the current study, ankle proprioceptive training facilitates joint stability by creating a reaction to concentric loading18). The present study showed the effect of proprioceptive training, focusing on movement of the foot and ankle, and they repeatedly performed ankle tilting during proprioceptive training, with mild to moderate knee OA 17). Therefore, several interventions are aimed at reducing knee medial compartment load has been suggested to contribute to the markedly greater incidence of advanced OA in the medial knee compartment24). 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 varus25) and an even greater adduction moment about the knee during gait26). 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 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 progression23), and a useful outcome measure following an intervention22). 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 compartment24). 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 varus25) and an even greater adduction moment about the knee during gait26). 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 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 progression23), and a useful outcome measure following an intervention22). 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 compartment24). 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 varus25) and an even greater adduction moment about the knee during gait26). 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 quadriceps strengthening group; CG: control group

### 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                  | PTG (n=12) | QSG (n=13) | CG (n=12) |
|-----------------------------|------------|------------|-----------|
| Foot progression angle (°)  | 9.84 (4.86) | 11.84 (3.96) | 8.02 (5.03) |
| Loading response            | 8.34 (5.03) | 7.34 (5.90) | 9.00 (7.83) |
| Terminal stance             | 10.33 (4.52) | 11.11 (3.79) | 10.23 (5.78) |
| Weight-bearing ratio (%)    | 31.00 (10.16) | 43.67 (14.51) | 35.43 (9.60) |
| Knee adduction moment (Nm/kg) | 0.57 (0.20) | 0.44 (0.22) | 0.47 (0.14) |

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
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.

REFERENCES

1) Lawrence RC, Helmick CG, Arnett FC, et al.: Estimates of the prevalence of arthritis and selected musculoskeletal disorders in the United States. Arthritis Rheum, 1998, 41: 778–799. [Medline] [CrossRef]
2) Sharma L, Dunlop DD, Cahn S, et al.: Quadriceps strength and osteoarthritis progression in malaligned and lax knees. Ann Intern Med, 2003, 138: 613–619. [Medline] [CrossRef]
3) Thorstensson CA, Henriksson M, von Porat A, et al.: The effect of eight weeks of exercise on knee adduction moment in early knee osteoarthritis—a pilot study. Osteoarthritis Cartilage, 2007, 15: 1163–1170. [Medline] [CrossRef]
4) Blanpied P, Smidt GL: The difference in stiffness of the active plantarflexors between young and elderly human females. J Gerontol, 1993, 48: M58–M63. [Medline] [CrossRef]
5) Hurwitz DE, Ryals AB, Case JP, et al.: The knee adduction moment during gait in subjects with knee osteoarthritis is more closely correlated with static alignment than radiographic disease severity, toe out angle and pain. J Orthop Res, 2002, 20: 101–107. [Medline] [CrossRef]
6) James SL, Bates BT, Ostering LR: Injuries to runners. Am J Sports Med, 1978, 6: 40–50. [Medline] [CrossRef]
7) Jan MH, Tang PF, Lin JJ, et al.: Efficacy of a target-matching foot-stepping exercise on proprioception and function in patients with knee osteoarthritis. J Orthop Sports Phys Ther, 2008, 38: 19–25. [Medline] [CrossRef]
8) Huang MH, Yang RC, Lee CT, et al.: Preliminary results of integrated therapy for patients with knee osteoarthritis. Arthritis Rheum, 2005, 53: 812–820. [Medline] [CrossRef]
9) O'Reilly SC, Jones A, Muir KR, et al.: Quadriceps weakness in knee osteoarthritis: the effect on pain and disability. Ann Rheum Dis, 1998, 57: 588–594. [Medline] [CrossRef]
10) Anwerr S, Alghadri A: Effect of isometric quadriceps exercise on muscle strength, pain, and function in patients with knee osteoarthritis: a randomized controlled study. J Phys Ther Sci, 2014, 26: 745–748. [Medline] [CrossRef]
11) Gardsen LR, Bullock-Saxton JE: Joint reposition sense in subjects with unilateral osteoarthritis of the knee. Clin Rehabil, 1999, 13: 148–155. [Medline] [CrossRef]
12) Martel-Pelletier J: Pathophysiology of osteoarthritis. Osteoarthritis Cartilage, 1998, 6: 374–376. [Medline] [CrossRef]
13) Knoop J, Steultjens MP, van der Leeden M, et al.: Proprioception in knee osteoarthritis: a narrative review. Osteoarthritis Cartilage, 2011, 19: 381–388. [Medline] [CrossRef]
14) Tunay VB, Balint G, Atay AO: Hospital-based versus home-based proprioceptive and strengthening exercise programs in knee osteoarthritis. Acta Orthop Traumatol Turc, 2010, 44: 270–277. [Medline] [CrossRef]
15) Kellgren JH, Lawrence JS: Radiological assessment of osteo-arthritis. Ann Rheum Dis, 1957, 16:494–502. [Medline] [CrossRef]
16) Nakajima M, Kawamura K, Takeda I: Electromyographic analysis of a modified maneuver for quadriceps femoris muscle setting with co-contraction of the hamstrings. J Orthop Res, 2003, 21: 559–564. [Medline] [CrossRef]
17) Rutherford DJ, Hubley-Kozey CL, Deluzio KJ, et al.: Foot progression angle and the knee adduction moment: a cross-sectional investigation in knee osteoarthritis. Osteoarthritis Cartilage, 2008, 16: 883–889. [Medline] [CrossRef]
18) Andriacchi TP: Dynamics of knee malalignment. Orthop Clin North Am, 1994, 25: 395–403. [Medline] [CrossRef]
19) Braun Ferreira LA, Pereira WM, Rossi LP, et al.: Analysis of electromyographic activity of ankle muscles on stable and unstable surfaces with eyes open and closed. J Bodyw Mov Ther, 2011, 15: 496–501. [Medline] [CrossRef]
20) Kim JK, Kim YE, Jun HJ, et al.: Which treatment is more effective for functional ankle instability: strengthening or combined muscle strengthening and proprioceptive exercises? J Phys Ther Sci, 2014, 26: 385–388. [Medline] [CrossRef]
21) Andrews M, Noyes FR, Hewett TE, et al.: Lower limb alignment and foot angle are related to stance phase knee adduction in normal subjects: a critical analysis of the reliability of gait analysis data. J Orthop Res, 1996, 14: 289–295. [Medline] [CrossRef]
22) Shimada S, Kobayashi S, Wada M, et al.: Effects of disease severity on response to lateral wedge shoe insole for medial compartment knee osteoarthritis. Arch Phys Med Rehabil, 2006, 87: 1436–1441. [Medline] [CrossRef]
23) Amin S, Luepponsak N, McGibbon CA, et al.: Knee adduction moment and development of chronic knee pain in elders. Arthritis Rheum, 2004, 51: 371–376. [Medline] [CrossRef]
24) Andriacchi TP, Mündermann A: The role of ambulatory mechanics in the initiation and progression of knee osteoarthritis. Curr Opin Rheumatol, 2006, 18: 514–518. [Medline] [CrossRef]
25) Dearborn JT, Eakin CL, Skinner HB: Medial compartment arthrosis of the knee. Am J Orthop, 1996, 25: 18–26. [Medline] [CrossRef]
26) Specogna AV, Birmingham TB, Hunt MA, et al.: Radiographic measures of knee alignment in patients with varus gonarthrosis: effect of weight-bearing status and associations with dynamic joint load. Am J Sports Med, 2007, 35: 65–70. [Medline] [CrossRef]
27) Self BP, Greenwald RM, Pflaster DS: A biomechanical analysis of the reliability of gait analysis data. J Orthop Res, 2000, 18: 191–197. [Medline] [CrossRef]
28) Kerrigan DC, Lelas JL, Goggins J, et al.: Effectiveness of a lateral-wedge insole on knee varus torque in patients with knee osteoarthritis. Arch Phys Med Rehabil, 2002, 83: 889–893. [Medline] [CrossRef]
29) Miyazaki T, Wada M, Kawahara H, et al.: Dynamic load at baseline can predict radiographic disease progression in medial compartment knee osteoarthritis. Ann Rheum Dis, 2002, 61: 617–622. [Medline] [CrossRef]