



Original Article

Comparative evaluation of ambulation patterns and isokinetic muscle strength for the application of rehabilitation exercise in patients with patellofemoral pain syndrome

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Abstract. [Purpose] The aim of this study was to evaluate the differences in the ambulation patterns and knee joint performance between people with and without patellofemoral pain. The present study also aimed to utilize these results as a basis for the development of pain-alleviating and performance-improving treatment programs. [Subjects and Methods] Subjects consisted of 32 adult females diagnosed with patellofemoral pain syndrome and 25 adult females without patellofemoral pain (controls). Contact ratio patterns during ambulation and isokinetic muscle strength around the knee joint were measured in both groups and then compared. [Results] Ambulation patterns, specifically the contact ratios of the left forefoot and right forefoot, differed significantly between patients with patellofemoral pain syndrome and controls. An isokinetic muscle strength test demonstrated that left and right knee extensor and flexor torques also significantly differed between these two groups. [Conclusion] Basic analysis based on ambulation patterns and muscle strength can be used to indicate functional recovery from patellofemoral pain syndrome and provide insight into improving the rehabilitation of patients.

Key words: Patellofemoral pain syndrome, Ambulation patterns, Isokinetic muscle strength

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INTRODUCTION

Patellofemoral pain syndrome (PFPS) is a disease most commonly characterized by pain and instability of the knee joint. In particular, knee weakness and discomfort or pain in the anterior or posterior knee are observed when movements requiring weight bearing, flexion, and extension are performed^{1,2)}. These movements include activities such as ascending and descending stairs or a hill, squatting, sitting, standing, and exercising^{3–6)}. PFPS has a prevalence of 7–40% and is considered to be an overuse syndrome that is more common in highly active young people and females^{7,8)}. Patellofemoral pain and instability are frequently overlooked in patients presenting with knee problems because most mechanical derangements of the knee can instead be attributed to meniscus cartilage lesions⁹⁾. Further accumulation of injuries, dislocation, or malalignment of the patella due to trauma or increased pressure on the patella (e.g., from being overweight or lifting) can also cause primary osteoarthritis. This can then result in osteoarthritis of the patellofemoral joint, a process that is accelerated in overweight patients^{10,11)}. PFPS is thought to be caused by abnormal movements resulting from physical changes in the patellofemoral joint, namely, a mechanical imbalance between the quadriceps and surrounding muscles. Patellofemoral joint pain can also be caused by a knee sprain or other injury and results in instability during daily activities such as ambulation^{12,13)}. Although the symptoms and causes of PFPS have been identified, the criteria for measuring and evaluating patellofemoral joint pain remain inconsistent, leading to differences in the reporting of results across different studies. To more effectively treat patel-

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Table 1. Comparison of ambulation patterns

		PFPG (n=32)	NG (n=25)
Foot Rotation (deg)	Left	5.8 ± 1.4	5.8 ± 1.7
	Right	7.3 ± 2.7	7.3 ± 2.4
Forefoot (%)	Left	76.6 ± 3.3	79.5 ± 5.3*
	Right	75.3 ± 4.5	78.6 ± 5.9*
Midfoot (%)	Left	68.6 ± 4.1	68.4 ± 5.1
	Right	68.3 ± 3.9	69.3 ± 4.1
Heel (%)	Left	59.8 ± 5.4	59.2 ± 7.6
	Right	59.3 ± 5.6	59.6 ± 7.2

PFPG: patellofemoral pain group; NG: normal group
Values are mean ± SD, *p<0.05

lofemoral pain, which progresses in a scattered fashion, more systematic and methodological research is needed. Therefore, the present study aimed to provide a basis for developing a pain-attenuating and performance-enhancing treatment program by evaluating and comparing ambulation patterns and knee function between people with and without patellofemoral pain.

SUBJECTS AND METHODS

Subjects consisted of 32 female patients in their 20s who were admitted to hospital and diagnosed with PFPS by a medical specialist (PFPS group; 21.6 ± 3.2 years; 162.7 ± 5.6 cm; 52.8 ± 7.0 kg) and 25 adult females in their 20s without any abnormal findings (control group; 21.1 ± 2.2 years; 161.5 ± 4.1 cm; 52.7 ± 6.3 kg). All subjects understood the purpose of this study and provided their written informed consent prior to participation in the study in accordance with the ethical standards of the Declaration of Helsinki. To measure foot rotation while walking, contact time ratios of the forefoot, midfoot, and heel in the stance phase and the swing phase were measured as the subjects ambulated on a treadmill with a built-in pressure plate (FDM-T; Zebris Medical GmbH, Allgäu, Germany). The treadmill was set to a speed of 3.5 km/h, and measurements were recorded for 1 minute. The isokinetic muscle function of the knee joint was the main experimental variable of the study and was measured using the Humac Norm Testing and Rehabilitation system (CSMi, Stoughton, MA, USA). Subjects sat in the measurement chair and the torque of the knee joint was aligned with the rotating axis of the dynamometer by adjusting the position with a table tube cross clamp and a pedestal column clamp. The thigh area and the upper body were tightly fixed using a strap and a belt so that quadriceps exercise would not be affected by external force during flexion and extension exercise of the knee joint resulting from moving areas other than the joint being measured. Additionally, to isolate the muscle strength of the area of interest, the ankle was fixed with a strap by adjusting the length of the lower leg and the adjustment axis with an adapter; afterward, flexion and extension exercise of the knee was performed. Range of motion was determined by measuring the maximum flexion from the position in which the joint was extended (0°) in a sitting position. Measurements were recorded by group. As a warm-up exercise, subjects performed flexion and extension exercise of the lower limb 3 times below maximum and 1 time at maximum at angle speeds of 60°/sec. Then, measurements were recorded 5 times at the angle speed of 60°/sec. After measurements were recorded at each speed, subjects were told to repeat flexion and extension of the knee joint. The measurement results were processed by SPSS for Windows version 23.0 software (SPSS Inc., Chicago, IL, USA). Mean and standard deviation were calculated for each measurement variable using the independent sample t-test, with p<0.05 indicating statistical significance.

RESULTS

Ambulation patterns (specifically the left and right forefoot contact ratios) significantly differed between the PFPS group and control group (Table 1). During the isokinetic muscle strength test, left and right knee extensor and flexor torques also significantly differed between the two groups (Table 2).

DISCUSSION

PFPS has diverse causes and is mostly observed while performing daily activities that bear weight on the knee. Observations include pain and clicking in the knee joint when weight-bearing movements are performed for long periods¹⁴. Other typical symptoms include recurrence of restricted movement and confined range of motion of the knee joint¹⁵. These recurring aberrations are characterized by defects in proprioception and muscle reflexes around the knee joint, which can be caused by both acute and chronic damage^{16, 17}. These problems can eventually cause muscle weakness and chronic abnormal movements such as malalignment and giving-way of the knee during ambulation^{13, 18}. Ambulation, which is the most basic

Table 2. Comparison of isokinetic muscle strength of the knee joints

		PFPG (n=32)	NG (n=25)
Extensor (Nm)	Left	81.1 ± 18.6	115.4 ± 21.5***
	Right	84.7 ± 14.8	135.1 ± 15.4***
Flexor (Nm)	Left	51.4 ± 15.1	71.9 ± 13.6***
	Right	53.0 ± 13.1	80.8 ± 13.3***

PFPG: patellofemoral pain group; NG: normal group
 Values are mean ± SD, ***p<0.001

daily movement of humans, is a functional movement produced by symmetrical and continuous alternations between the stance and swing phases. The pressure transmitted to the patellofemoral joint during ambulation or during ascending and descending of stairs is 0.5- to 6-times that of body weight^{19, 20}. This increased burden on the knee joint, which is due to an increased knee flexion angle caused by increased knee extension movement, enhances patellofemoral pain^{21, 22}. The present study showed that the forefoot contact ratio was significantly higher in the PFPS group than in the control group, which is consistent with past research^{21, 22}. This difference can therefore be attributed to decreased stance contact caused by increased stress on the patellofemoral joint during ambulation. Patellofemoral joint pain can also be related to weakening of the quadriceps and hamstrings. Stable movements are produced by extension and flexion of the knee. The quadriceps muscles are the main extensors of the knee and are responsible for bearing body weight and facilitating balancing abilities such as body alignment, stabilization, and ambulation²³. When the extension function of the knee is weakened, functional impairments such as malalignment are produced, potentially causing PFPS^{2, 24}. Weakened extensor muscle strength due to weakened extension function can, in turn, produce pain or other ailments¹⁸. In agreement with this, the PFPS group in the present study showed significantly lower extension and flexion strength than did the control group. These results demonstrate that an abnormal decrease in muscle strength can be used as an indicator of PFPS, thereby aiding in the prevention of its pathogenesis. One strategy for prevention is isokinetic muscle exercise, which is necessary for efficient functional enhancement²⁵. It has been shown that pain-alleviating rehabilitation can successfully treat two-thirds of PFPS patients²⁶. In conclusion, the present study demonstrates that basic analysis based on ambulation patterns and muscle strength, along with the evaluation of electromyograms, motion analysis, and ground reaction force, can provide relevant information about functional recovery from PFPS. Importantly, this was not previously possible with fractional evaluations of muscle exercise, balance, and flexibility. The present study may also have implications beyond the treatment of PFPS, potentially providing insight for improving the rehabilitation process of patients with other types of anterior knee joint lesions.

REFERENCES

- 1) Kannus P, Natri A, Paakkala T, et al.: An outcome study of chronic patellofemoral pain syndrome. Seven-year follow-up of patients in a randomized, controlled trial. *J Bone Joint Surg Am*, 1999, 81: 355–363. [[Medline](#)]
- 2) Fredericson M, Yoon K: Physical examination and patellofemoral pain syndrome. *Am J Phys Med Rehabil*, 2006, 85: 234–243. [[Medline](#)] [[CrossRef](#)]
- 3) Devereaux MD, Lachmann SM: Patello-femoral arthralgia in athletes attending a Sports Injury Clinic. *Br J Sports Med*, 1984, 18: 18–21. [[Medline](#)] [[CrossRef](#)]
- 4) Malek MM, Mangine RE: Patellofemoral pain syndromes: a comprehensive and conservative approach. *J Orthop Sports Phys Ther*, 1981, 2: 108–116. [[Medline](#)] [[CrossRef](#)]
- 5) Nijs J, Van Geel C, Van der auwera C, et al.: Diagnostic value of five clinical tests in patellofemoral pain syndrome. *Man Ther*, 2006, 11: 69–77. [[Medline](#)] [[CrossRef](#)]
- 6) Alba-Martín P, Gallego-Izquierdo T, Plaza-Manzano G, et al.: Effectiveness of therapeutic physical exercise in the treatment of patellofemoral pain syndrome: a systematic review. *J Phys Ther Sci*, 2015, 27: 2387–2390. [[Medline](#)] [[CrossRef](#)]
- 7) Zhang F, Wang J, Wang F: Comparison of the clinical effects of open and closed chain exercises after medial patellofemoral ligament reconstruction. *J Phys Ther Sci*, 2014, 26: 1557–1560. [[Medline](#)] [[CrossRef](#)]
- 8) Tan SS, van Linschoten RL, van Middelkoop M, et al.: Cost-utility of exercise therapy in adolescents and young adults suffering from the patellofemoral pain syndrome. *Scand J Med Sci Sports*, 2010, 20: 568–579. [[Medline](#)] [[CrossRef](#)]
- 9) O'Sullivan SB, Schmitz TJ, Fulk G: Physical rehabilitation: assessment and treatment. Philadelphia: F. A. Davis Company, 2014, pp 1122–1174.
- 10) Pattyn E, Mahieu N, Selfe J, et al.: What predicts functional outcome after treatment for patellofemoral pain? *Med Sci Sports Exerc*, 2012, 44: 1827–1833. [[Medline](#)] [[CrossRef](#)]
- 11) Kwon O, Yun M, Lee W: Correlation between intrinsic patellofemoral pain syndrome in young adults and lower extremity biomechanics. *J Phys Ther Sci*, 2014, 26: 961–964. [[Medline](#)] [[CrossRef](#)]
- 12) Peng HT, Song CY: Effect of leg press training on patellar realignment in patients with patellofemoral pain. *J Phys Ther Sci*, 2015, 27: 3873–3878. [[Medline](#)] [[CrossRef](#)]
- 13) Jeon K, Seo BD, Lee SH: Comparative study on isokinetic capacity of knee and ankle joints by functional injury. *J Phys Ther Sci*, 2016, 28: 250–256. [[Medline](#)] [[CrossRef](#)]
- 14) Anderson G, Herrington L: A comparison of eccentric isokinetic torque production and velocity of knee flexion angle during step down in patellofemoral pain

syndrome patients and unaffected subjects. *Clin Biomech (Bristol, Avon)*, 2003, 18: 500–504. [[Medline](#)] [[CrossRef](#)]

- 15) McKeon PO, Ingersoll CD, Kerrigan DC, et al.: Balance training improves function and postural control in those with chronic ankle instability. *Med Sci Sports Exerc*, 2008, 40: 1810–1819. [[Medline](#)] [[CrossRef](#)]
- 16) Noehren B, Sanchez Z, Cunningham T, et al.: The effect of pain on hip and knee kinematics during running in females with chronic patellofemoral pain. *Gait Posture*, 2012, 36: 596–599. [[Medline](#)] [[CrossRef](#)]
- 17) Gross P, Marti B: Risk of degenerative ankle joint disease in volleyball players: study of former elite athletes. *Int J Sports Med*, 1999, 20: 58–63. [[Medline](#)] [[CrossRef](#)]
- 18) Bily W, Trimmel L, Mödlin M, et al.: Training program and additional electric muscle stimulation for patellofemoral pain syndrome: a pilot study. *Arch Phys Med Rehabil*, 2008, 89: 1230–1236. [[Medline](#)] [[CrossRef](#)]
- 19) Loudon JK, Wiesner D, Goist-Foley HL, et al.: Intrarater reliability of functional performance tests for subjects with patellofemoral pain syndrome. *J Athl Train*, 2002, 37: 256–261. [[Medline](#)]
- 20) Ferber R, Kendall KD, Farr L: Changes in knee biomechanics after a hip-abductor strengthening protocol for runners with patellofemoral pain syndrome. *J Athl Train*, 2011, 46: 142–149. [[Medline](#)] [[CrossRef](#)]
- 21) Ho KY, Blanchette MG, Powers CM: The influence of heel height on patellofemoral joint kinetics during walking. *Gait Posture*, 2012, 36: 271–275. [[Medline](#)] [[CrossRef](#)]
- 22) Hsue BJ, Su FC: Kinematics and kinetics of the lower extremities of young and elder women during stairs ascent while wearing low and high-heeled shoes. *J Electromyogr Kinesiol*, 2009, 19: 1071–1078. [[Medline](#)] [[CrossRef](#)]
- 23) Ott B, Cosby NL, Grindstaff TL, et al.: Hip and knee muscle function following aerobic exercise in individuals with patellofemoral pain syndrome. *J Electromyogr Kinesiol*, 2011, 21: 631–637. [[Medline](#)] [[CrossRef](#)]
- 24) Sacco IC, Konno GK, Rojas GB, et al.: Functional and EMG responses to a physical therapy treatment in patellofemoral syndrome patients. *J Electromyogr Kinesiol*, 2006, 16: 167–174. [[Medline](#)] [[CrossRef](#)]
- 25) Waryasz GR, McDermott AY: Patellofemoral pain syndrome (PFPS): a systematic review of anatomy and potential risk factors. *Dyn Med*, 2008, 7: 9. [[Medline](#)] [[CrossRef](#)]
- 26) Alaca R, Yilmaz B, Goktepe AS, et al.: Efficacy of isokinetic exercise on functional capacity and pain in patellofemoral pain syndrome. *Am J Phys Med Rehabil*, 2002, 81: 807–813. [[Medline](#)] [[CrossRef](#)]