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ORIGINAL ARTICLE

Patients with early-stage knee osteoarthritis and knee pain have decreased hip abductor muscle strength while descending stairs

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Abstract

Introduction/objectives This study aimed to investigate the association between hip abductor muscle strength and knee pain in patients with early-stage knee osteoarthritis (OA) while ascending and descending stairs.

Method This cross-sectional study included individuals with early-stage knee OA (Kellgren/Lawrence grades 1 or 2). Knee pain while ascending and descending stairs was evaluated using a knee OA-related health domain measure (Japanese Knee Osteoarthritis Measure). Knee extension and hip abductor muscle strength were also evaluated. The association between hip abductor muscle strength and knee pain while ascending and descending stairs was evaluated using multiple regression analysis.

Results A total of 157 participants were included in the final analysis. After the adjustment for age, sex, and knee extension strength, those with knee pain while descending stairs showed significantly decreased hip abductor muscle strength (β, − 0.09; 95% confidence interval [CI], − 0.19 to − 0.003). In contrast, after the adjustment for age, sex, and knee extension muscle strength, those with knee pain while ascending stairs did not have significantly decreased hip abductor muscle strength (β, − 0.06; 95% CI, − 0.15 to 0.02).

Conclusions Patients with early-stage knee OA and knee pain while descending stairs had significantly reduced hip abductor muscle strength.

Keywords Early stage · Hip abductor muscle · Knee osteoarthritis · Pain · Stair descent

Introduction

Patients with knee osteoarthritis (OA) have reduced hip muscle strength compared with healthy subjects [1–3]. Hip abductor muscle strength plays an important role in knee adduction moment (KAM) reductions [4] and stair climbing functional improvements [5] in patients with knee OA. Besides, knee pain is most likely to first appear during stair climbing in patients with OA [6, 7]. Amin et al. reported that knee joint pain worsened in patients with a high KAM while ascending and descending stairs [8]. Therefore, an important association has been recognized between ascending and descending stairs and knee pain in patients with early-stage knee OA (i.e., Kellgren/Lawrence [K/L] grades 1 or 2).

This study was based on a hypothesis that an association exists between hip abductor muscle strength and knee pain while ascending and descending stairs. However, no studies to date have examined this association. Therefore, this study aimed to investigate the association between hip abductor muscle strength and knee pain in patients with early-stage knee OA while ascending and descending stairs.

Materials and methods

Study design

This cross-sectional study included only individuals with knee OA.

Participants

Subjects who currently reported pain in one or both knees were identified through a mailed survey and invited to visit a

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research center at Kyoto University between September 2017 and February 2018. The recruitment was done through public relations magazine ads. The study protocol was approved by the ethics committee of Kyoto University (approval No. C1297), and written informed consent was obtained from all participants before enrollment. The eligibility criteria were (1) age ≥ 45 years; (2) early-stage knee OA (i.e., K/L grades 1 or 2, original version [9]) in the medial tibiofemoral compartment of one or both knees evaluated using weight-bearing anteroposterior radiographs; and (3) ability to walk independently on a flat surface without the use of an ambulatory assistive device. The exclusion criteria were (1) history of knee surgery, (2) rheumatoid arthritis, (3) periarticular fracture, (4) any neurological disorder, or (5) pre-radiographic or severe-stage radiographic knee OA (i.e., K/L grades 0, 3, and 4). Participants with bilateral knee OA were not considered separately from those with unilateral knee OA.

Outcome measurements

For all participants, the following outcomes were evaluated: (1) demographic data, (2) radiographic findings, (3) knee OA-related health domain measure (Japanese Knee Osteoarthritis Measure [JKOM]) score, and (4) lower limb muscle strength.

Demographic data

Data on age, sex, and height were self-reported. Weight was measured on a scale with the participants dressed but barefoot.

Radiographic evaluation

Anteroposterior weight-bearing radiographs of both knees were taken in full extension on foot map positions. The radiographic severity of the medial compartment of the tibiofemoral joint was assessed by a trained examiner. The intra- and inter-rater agreements for the K/L grade determination were excellent (intra-rater $\kappa = 0.88$, 95% CI, 0.83–0.92; inter-rater $\kappa = 0.84$, 95% CI, 0.79–0.90) [10].

Knee pain severity during ascending or descending stairs

Knee pain severity during ascending or descending stairs was evaluated using the JKOM, a self-administered disease-specific questionnaire for patients with knee OA [11]. Each question is graded on a scale of 0–4 points as follows: 0 points, no pain at all; 1–3 points, slightly/moderately/quite painful; and 4 points, extremely painful, indicating no, some, and severe pain, respectively. The concurrent and construct validities of the JKOM were established by comparison with the Western Ontario and McMaster Universities Arthritis Index and the Medical Outcomes Study 36-item Short-Form Health Survey [11].

Muscle strength

Maximum isometric knee extensor strength was measured bilaterally using a hand-held dynamometer (HHD) in accordance with a previously validated method for community-dwelling elderly fallers [12]. The HHD, a simple tool for objectively quantifying muscle strength, is widely used in clinical practice. Maximum force was recorded in Newtons (N), and two repetitions were performed for each test. The participants were instructed to remain seated in an upright position during the tests.

The method for measuring maximum isometric knee extensor strength is as follows. The knee was placed at 90° of flexion with the HHD attached 10 cm proximal to the lateral malleolus and held in place with an inelastic strap looped around the therapy bed. The length of the strap allowed for isometric contraction with the knee at 90° of flexion during the testing. The participants were instructed to extend the leg for 5 s [13].

The method for measuring maximum isometric hip abductor strength is as follows. The participants were placed supine on a therapy bed. The hip was placed in a neutral position with the knee extended, and the HHD attached just superior to the lateral epicondyle of the femur and held in place with an inelastic strap. The hip and knee were slightly flexed. The participants were instructed to abduct the leg for 5 s [13].

To calculate the moment (Nm), the lever arm (length of the femur or tibia) between the knee joint and HHD, was manually measured and subsequently normalized to the mass (Nm/kg). The average of two repetitions was used in the statistical analysis. Strong verbal encouragement was provided to ensure maximal effort.

Sample size

A sample size of 85 participants for the multiple linear regression analysis was calculated using the G*Power 3 program (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) [14] with a power of 80%, significance level of 0.05, and moderate effect size ($f = 0.15$) [15]. Moreover, to allow for a potential data loss of 20%, the required sample size in this study was 102 participants.

Statistical analysis

All data analyses were performed using JMP Pro 12.2 (SAS Institute, Cary, NC, USA). P values < 0.05 were considered statistically significant. To minimize any bias introduced by similarities between the right and left knees in the same patient, only one knee per patient (index knee) was analyzed. The index knee was defined as the more painful knee in the past or at present. If patients perceived that their knees were equally painful, the index knee was randomly selected using a

Table 1 Subject characteristics (values are mean ± SD or number [percentage])

Variable	Subjects ($n = 157$)
Age (years)	65.35 ± 8.97
Women (%)	121 (77.1)
Height (cm)	158.33 ± 7.49
Weight (kg)	57.90 ± 11.52
BMI (kg/cm^2)	22.99 ± 3.64
K/L grade	
Grade 1 (%)	99 (63.1)
Grade 2 (%)	58 (36.9)
VAS score for knee pain (mm)	30.97 ± 20.27
Knee extension muscle strength (Nm/kg)	1.22 ± 0.45
Hip abductor muscle strength (Nm/kg)	0.79 ± 0.28
JKOM (Q5) have knee pain while ascending stairs	123 (78.3)
JKOM (Q6) have knee pain while descending stairs	125 (79.6)

BMI, body mass index; *JKOM*, Japanese Knee Osteoarthritis Measure; *VAS*, visual analog scale

computer-generated permuted block randomization scheme [16]. The subjects' characteristics are shown as mean ± standard deviation (SD) for continuous variables and as number and percentage for nominal and ordinal variables.

Multiple regression analysis

In defining knee pain while ascending and descending stairs, the answers to the two individual questions of the pain-related JKOM subcategory were dichotomized into two categories: no pain at all and slightly/moderately/quite/extremely painful according to the absence (0) or presence (1) of pain. Pain scores of 1–4 were collapsed into a single level because few patients had a score ≥ 2. The participants were divided into two groups based on the presence or absence of knee pain while ascending or descending stairs, which is the result of two items in the JKOM subcategory. To test the hypothesis that there exists a statistical association between hip abductor muscle strength and knee pain while ascending and descending stairs, a multiple regression analysis was performed with hip abductor muscle strength as an independent variable and the absence or presence of knee pain while ascending or descending stairs as a dependent variable (0, absence of knee pain; 1, presence of knee pain). Age (years), sex, and knee extension muscle strength were used as covariates.

Results

Of 336 recruited participants, 107 (31.8%) were excluded because of the absence of knee pain, three (1.0%) because of a history of knee surgery, 29 (9.0%) because of pre-radiographic knee OA (K/L grade 0), 28 (8.3%) because of severe-stage radiographic knee OA (K/L grades 3 or 4), and 12 (3.6%) due to missing data. Thus, 157 participants were included in the final analysis. Table 1 shows their baseline demographic and clinical characteristics.

Association between hip abductor muscle strength and knee pain while ascending stairs

After the adjustment for age and sex, those with knee pain when ascending stairs did not show significantly decreased hip abductor muscle strength (β, − 0.09; 95% confidence interval [CI], − 0.20 to 0.012). Moreover, after the adjustment for age, sex, and knee extension muscle strength, those with knee pain while ascending stairs did not show significantly decreased hip abductor muscle strength (β, − 0.06; 95% CI, − 0.15 to 0.02; Table 2).

Association between hip abductor muscle strength and knee pain while descending stairs

After the adjustment for age and sex, those with knee pain while descending stairs showed significantly decreased hip abductor muscle strength (β, − 0.11; 95% CI, − 0.22 to − 0.0002). Moreover, after the adjustment for age, sex, and knee extension muscle strength, those with knee pain when descending stairs showed significantly decreased hip abductor muscle strength (β, − 0.09; 95% CI, − 0.19 to − 0.003; Table 3).

Table 2 Association between knee pain while ascending stairs and hip abductor muscle strength

Variable	With knee pain* ($n = 123$)	Without knee pain* ($n = 34$)	Unadjusted β (95% CI)	Adjusted β (95% CI)†	Adjusted β (95% CI)‡
Hip abductor muscle strength (Nm/kg)	0.77 ± 0.27	0.87 ± 0.30	− 0.09 (− 0.20 to 0.009)	− 0.09 (− 0.20 to 0.012)	− 0.06 (− 0.15 to 0.02)

*Values are mean ± SD

† Adjusted for age (years) and sex

‡ Adjusted for age (years), sex, and knee extension muscle strength

Table 3 Association between knee pain while descending stairs and hip abductor muscle strength

Variable	With knee pain* ($n = 125$)	Without knee pain* ($n = 32$)	Unadjusted β (95% CI)	Adjusted β (95% CI)[†]	Adjusted β (95% CI)[‡]
Hip abductor muscle strength (Nm/kg)	0.77 ± 0.28	0.88 ± 0.25	− 0.11 (− 0.22 to − 0.001)	− 0.11 (− 0.22 to −0.0002)	− 0.09 (− 0.19 to − 0.003)

*Values are mean ± SD

[†] Adjusted for age (years) and sex

[‡] Adjusted for age (years), sex, and knee extension muscle strength

Discussion

The hypothesis of this study was that an association exists between hip abductor muscle strength and knee pain while ascending and descending stairs. This was partially proven by our finding that patients with early-stage knee OA and knee pain while descending stairs had significantly reduced hip abductor muscle strength after the adjustment for age, sex, and knee extension muscle strength.

Associations between knee pain while descending stairs and reduced hip abductor muscle strength

In knee OA patients, the peak KAM was higher while descending stairs than while ascending stairs [17]. KAM is an index that is used to indirectly evaluate medial-to-lateral knee joint load [18]; previous studies reported that the higher the peak value and impulse of KAM, the worse the knee pain [8, 19]. Moreover, the peak knee extensor moment was significantly reduced in patients with knee pain while ascending and descending stairs; the observed knee extensor moment is suggestive of quadriceps avoidance (reduced quadriceps muscle force), which may serve as a primary strategy to avoid knee pain [20]. In subjects with knee pain while descending stairs, quadriceps muscle force may be reduced as a strategy to avoid knee pain. In addition, previous studies reported that patients with knee OA and decreasing knee extension muscle strength showed increased pelvic movement in the frontal plane while descending stairs [21]. Weak hip abductor muscles may impair the mediolateral stability of the pelvis during the single-leg stance, leading to abnormal loading of the knee in the frontal plane [22]. Hence, patients with knee OA and decreased hip abductor muscle strength appeared to show decreased pelvic stability while descending stairs and increased stress on the knee joint, which may cause knee pain. One study supporting the functional decline and occurrence of pain based on the mechanism described above reported that the ability to climb stairs improved when hip abductor muscle strength improved [2]. This could be the reason why patients with early-stage knee OA in this study who had decreased hip abductor muscle strength experienced knee pain while descending stairs.

Study limitations

This study has several limitations. First, the participants were motivated individuals because they actively enrolled by responding to e-mails and were recruited via public relations magazine ads; thus, there may have been selection bias. Second, self-reported questionnaires may not always provide precise data due to recall bias. Third, during the muscle strength measurements, the patients were seated in an upright spinal position. If the muscle strength measurements had been performed in a weight-loading position, the results may have been different. Fourth, this was a cross-sectional study and did not measure distinct stages when pain appeared; therefore, the cause-effect association between hip abductor muscle strength and knee pain in patients with early-stage knee OA while descending stairs remains unknown. Further investigations, including prospective studies that can clarify the distinct stages and cause-effect association, are required to confirm our results.

Conclusions

Here, we investigated the association between hip abductor muscle strength and knee pain in patients with early-stage knee OA while ascending and descending stairs. Patients with knee pain while descending stairs showed significantly reduced hip abductor muscle strength after the adjustment for age, sex, and knee extension muscle strength.

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Compliance with ethical standards

The ethics committee of Kyoto University approved the study (no. C1297), and written informed consent was obtained from all participants before enrollment.

Disclosures None.

Appendix

Table 4 STROBE statement—checklist of items that should be included in reports of cross-sectional studies

	Item no.	Recommendation	Reported on page no.
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6–8
Bias	9	Describe any efforts to address potential sources of bias	N/A
Study size	10	Explain how the study size was arrived at	8–9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	N/A
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	9–10
		(b) Describe any methods used to examine subgroups and interactions	
		(c) Explain how missing data were addressed	
		(d) If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—e.g., numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed	10
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (e.g., demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10–11
		(b) Report category boundaries when continuous variables were categorized	
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions and sensitivity analyses	N/A
Discussion			
Key results	18	Summarize key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11–12
Generalizability	21	Discuss the generalizability (external validity) of the study results	11–12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for exposed and unexposed groups

An explanation and elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLOS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org

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