



Original Article

Associations of knee muscle force, bone malalignment, and knee-joint laxity with osteoarthritis in elderly people

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Abstract. [Purpose] From the viewpoint of prevention of knee osteoarthritis, the aim of this study was to verify how muscle strength and joint laxity are related to knee osteoarthritis. [Subjects and Methods] The study subjects consisted of 90 community-dwelling elderly people aged more than 60 years (22 males, 68 females). Femorotibial angle alignment, knee joint laxity, knee extensors and flexor muscle strengths were measured in all subjects. In addition, the subjects were divided into four groups based on the presence of laxity and knee joint deformation, and the muscle strength values were compared. [Results] There was no significant difference in knee extensor muscle strength among the four groups. However, there was significant weakness of the knee flexor muscle in the group with deformation and laxity was compared with the group without deformation and laxity. [Conclusion] Decreased knee flexor muscle strengths may be involved in knee joint deformation. The importance of muscle strength balance was also considered.

Key words: Osteoarthritis, Knee muscle strength, Femorotibial joint

(This article was submitted Oct. 20, 2016, and was accepted Nov. 29, 2016)

INTRODUCTION

Knee osteoarthritis (knee OA) is a multifactorial disease caused by aging, obesity, certain genetic factors, mechanical load, etc. In Japan, it is estimated that approximately 50% of the population over 50 years of age have OA. Knee and joint disease, including knee OA, is the first largest cause of need for assistance in the elderly and the fourth largest cause of need for care¹⁾. Although deformation of the knee accelerates with age, knee OA patients without severe disease do not seek medical help because the activities of daily living (ADL) would have not been overly compromised; however this eventually leads to worsening of the condition²⁾.

Several studies on various aspects of knee OA have been reported, including its cause, therapy, and prevention. According to the 2014 non-surgical treatment guidelines by the Osteoarthritis Research Society International³⁾, exercise on land, and in water, weight management, self-management, patient education, and muscle strengthening exercises are core elements of treatment. Therefore, in many countries, including Japan, the establishment of methods for the prevention and treatment of knee OA is urgently needed with an increasing role for physical therapists as exercise specialists.

The knee joint muscles, particularly weakening of the knee extensors and flexors, are reportedly involved in the development of knee OA⁴⁾. Recently, the hip muscles, which are involved in frontal and horizontal plane alignment of the lower extremities, have also been reported to be involved in the development of knee OA⁵⁾. In addition, a relationship between knee joint muscle strengths and physical activity has been reported⁶⁾; therefore, there is little doubt that lower limb muscle strength is very important in terms of both prevention and treatment of knee OA.

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On the other hand, if there is joint laxity, involving the bone and ligaments, muscles, and joint capsule, with joint movement beyond a certain range of motion, joint disruption will be marked. Joint laxity is considered to be a developmental factor in sports injuries^{7,8}. Furthermore, knee-joint instability (e.g., chronic syndromes after anterior ligament injuries) could precede knee OA^{9,10}. Therefore, consideration of knee-joint laxity and structural instability from the viewpoint of knee OA prevention is crucial.

As described above, both of muscle strength and knee-joint laxity in lower extremities are involved in the onset of knee OA. However, when muscle strength and laxity overlap, the effects on knee deformation remain unclear. This study examined the associations between knee muscle strength, knee bone malalignment, and knee-joint laxity; with OA from the viewpoint of knee OA prevention, in the community-dwelling elderly.

SUBJECTS AND METHODS

The subjects consisted of 90 healthy elderly persons (22 males, 68 females; mean age \pm SD: 72.5 \pm 5.13 years), who had no disease or pain that would make participation in this study difficult. The right leg was taken as the measurement side in all subjects. Knee extensor and knee flexor muscle forces, knee-joint laxity, and alignment of the femorotibial angle (FTA) were evaluated for each participant. Therefore, a total of 90 legs was evaluated.

In order to evaluate knee-joint malalignment, the Kellgren-Lawrence Grading classification based on X-ray imaging¹¹ and pathology using MRI (magnetic resonance imaging)¹² are commonly used. However, it has been reported that abnormal findings on simple X-ray and MRI examinations may not necessarily match subjective pain and clinical symptoms¹³. In this study, all measurements were taken at a regional community center rather than at a medical venue; therefore the following method for simple knee-joint malalignment assessment was used. The angle between the two lines combined with the anterior superior iliac spine, the center of the patellar, and the center of the angle joint in a single barefoot standing position [modified FTA (MFTA)] was measured (Fig. 1). All subjects could stand on their one-leg by oneself and during being measured they were using their forefinger for support, and for all legs, the MFTA values were higher than 170°. In the previous study^{14, 15}, it was reported that the range of FTA 174° to 177° in Japanese subjects, so in this study, legs with MFTA values higher than 175° were classified as deformed knee joints (i.e., malalignment possible). To evaluate knee-joint laxity, the range of motion of knee extension was measured according to Carter et al.¹⁶, and overextended knees were classified as loosening of the knee joint (i.e., laxity possible). Knee extensor and flexor muscle force was measured as isometric maximal force using a hand-held dynamometer (μ TasF-1, ANIMA Corporation, Japan). During muscle force measurement, all participants were seated on chairs with hip and knee joints flexed at 90° and lower legs secured by a belt (Fig. 2).

All legs were classified into 4 groups: (A) no malalignment, no laxity; (B) no malalignment, laxity possible; (C) malalignment possible, laxity possible; and (D) malalignment possible, no laxity. Knee extensor and flexor muscle force was compared among the four groups. Kruskal-Wallis rank sum data was used for knee extensor comparison and one-way analysis of variance (ANOVA) for knee flexor comparison. The significance level was set at 5% and all statistical processing was performed using SPSS ver.21 for Windows. And in order to compare the balance of the both muscles, the knee flexor muscle strength/knee extensor muscle strength ratio, just like the hamstring/quadriceps ratio (H/Q ratio), was calculated and used as

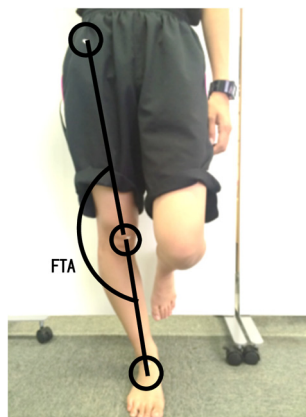


Fig. 1. MFTA: modified femorotibial angle
The angle between the two lines combined with the anterior superior iliac spine, the center of the patellar, and the center of the angle joint

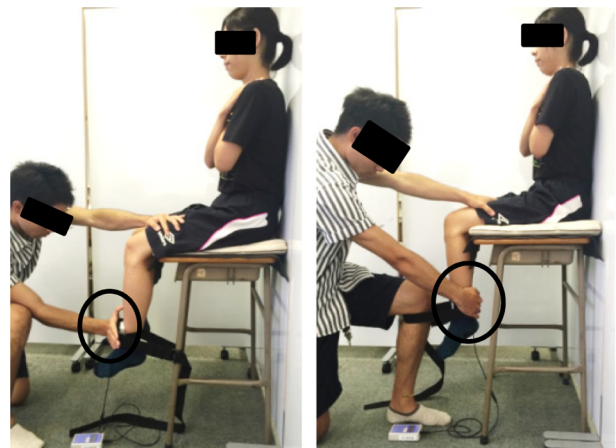


Fig. 2. Measurement of muscular forces
(Lt: knee extensor muscles, Rt: knee flexor muscles)
The forces were measured as isometric maximal force using a hand-held dynamometer (μ TasF-1, ANIMA Corporation, Japan) with seated on a chair with hip and knee joints flexed at 90° and lower legs secured by a belt.

a material for consideration.

As an ethical consideration, all subjects were informed of the purpose and procedure of the study, and provided written informed consent before participation. And there was no conflict of interest related to this study.

RESULTS

Group A included 25 knees (6 males and 19 females, height: 153.8 ± 5.68 cm, weight: 51.2 ± 10.08 kg), group B included 25 knees (6 males and 19 females, height: 153.4 ± 4.75 cm, weight: 54.3 ± 8.75 kg), group C included 15 knees (3 males and 12 females, height: 155.1 ± 6.28 cm, weight: 52.2 ± 7.28 kg), and group D included 25 knees (7 males and 18 females, height: 153.3 ± 8.83 cm, weight: 53.6 ± 7.31 kg). Among each group there was no significant difference of the ratio of men and women. Knee extensor muscle force was higher in group B than in groups C and D (A: 1.59 ± 0.78 Nm/kg, B: 1.64 ± 0.66 Nm/kg, C: 1.27 ± 0.44 Nm/kg, and D: 1.33 ± 0.65 Nm/kg). Knee flexor muscle force was higher in group A compared to groups B, C, and D, with a significant difference between groups A and C (A: 1.03 ± 0.35 Nm/kg, B: 0.86 ± 0.36 Nm/kg, C: 0.63 ± 0.27 Nm/kg, D: 0.81 ± 0.42 Nm/kg).

No significant difference in knee extensor muscle force among the four groups was observed ($p=0.171$). However, when each group was compared, although there was no significant difference, several low values were observed in groups C and D compared to groups A and B. For knee flexor muscle force, a significant difference was observed among the four groups ($p=0.012$) and a significant difference between groups A and C ($p<0.01$) was observed on multiple comparison.

The results of calculated knee flexor muscle strength/knee extensor muscle strength ratio in each group was below; group A was 65%, group B was 52%, group C was 50%, and group D was 60%.

DISCUSSION

In this study, the presence of knee-joint malalignment and laxity were measured and classified in the four groups and knee flexor and extensor muscle strengths among the groups were compared. As a result, a significant reduction in knee flexor muscle strength in group C compared to group A was confirmed, which suggests that the knee flexor muscles are also very much involved in the development of knee OA.

No significant difference in knee extensor muscle force was observed among the four groups; however, the groups with malalignment tended to have lower values. Screw home movement (SHM)¹⁷ is thought to be a possible reason. In order to extend the knee joint smoothly, SHM is very important. Its function is to stabilize the knee joint by a rotation movement and lack of this movement is believed to influence ADL adversely. It is thought that there is some abnormal knee extension with malalignment of the knee joint and that knee extensor muscle strength is reduced in unstable knee states.

Regarding the knee flexors, a significant difference was observed between group A (10.2 ± 3.44 kg) and group C (6.2 ± 2.64 kg). Although weakness of the quadriceps has been frequently to be a cause of deformation, this result raises the possibility of conflict between the hamstrings and the quadriceps muscles. Because biceps femoris is a two-joint muscle, weakness of the knee flexor may also affect the pelvis and trunk. For example, weakness caused by pelvis posterior tilting and displacement of the femur in external rotation may result in varus positioning of the knee joint. The observed difference between groups A and C may be due to a vicious kinetic chain of overload on the knee joint, leading to difficulties with hamstrings contraction.

And from the perspective of the knee flexor muscle strength/knee extensor muscle strength ratio, compared to 65% in group A, group C at 50% had a low value. While a H/Q ratio of 60–70% has been reported to be ideal for balance^{18, 19}, decrease was seen in group C. In group A, it can be seen that the knee flexors are able to take advantage of the well-balanced knee extensors at 65%; however, in group C, the knee flexors successfully used antagonistic muscles to the knee extensors, which potentially brought about a significant drop in muscle force. In order to prevent knee-joint deformation by direct transmission of external forces, knee extensors and surrounding muscles play a role in stability of shock absorption to the knee joint by working cooperatively with muscles such as the knee flexors. Therefore, it is necessary to take into account the balance between the knee flexors and extensors.

Compared to the results of group B and D, there was no significant difference, but it might be possible that knee extensor muscle force of group D was weak and knee flexor muscle force of group B and D was weak. From the results of this study, those with a mixed of laxity and malalignment of the knee joint might have the weak knee flexor muscle force, but additionally, it was thought to be possible that laxity would be related to the knee flexor muscle force and malalignment would be involved to both of the knee extensor muscle and flexor muscle forces. It is necessary in the future to further study what kind of influence the laxity and malalignment would bring to the knee joint muscles.

As a limitation of the present study, it was unclear if the original MFTA in this study correctly measure the presence or absence of deformation; therefore, its association with OA cannot be mentioned in detail. Furthermore, knee-joint laxity and muscle strength were only measured in the sagittal plane, and for the knee OA variant in the frontal plane, it is necessary to capture frontal plane laxity. As mentioned above, the hip muscles are also involved in horizontal plane alignment of the lower extremities⁵, and low lateral stability has been reported in people who easily²⁰. In the future, it will also be necessary to consider laxity and muscle strength of the lateral side.

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