Ultrasonographic Changes of the Knee Joint Cartilage Associated with Physical Characterization in Middle-Aged Women: 6-Month Observational Survey

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Abstract. Our objective was to examine the influence of leg muscle weakness and body mass index (BMI) on ultrasonography (US) of the knee joint in middle-aged women. US and measurements of leg muscle strength and BMI were performed at the beginning of the study and after 6 months. Subjects with US abnormalities at the first examination were excluded from the study. Muscle strength and BMI were compared between subjects with normal US findings at the beginning of the study and after 6 months (N) and those in whom initially normal US findings became abnormal after 6 months (A). Analysis was performed for 20 knees with a mean age of 52.9 years old. In Group N, there were no significant changes in muscle strength and BMI between the initial results and those after 6 months. Significant changes in muscle strength occurred in Group A, but there was no significant change in BMI. There were significant differences between Groups N and A in the changes after 6 months; however, there was no significant difference in the change in BMI between the two groups. We conclude that abnormal knee-joint findings in US of the knee are associated with leg muscle weakness in middle-aged women.

Key words: Ultrasonography, Knee cartilage, Leg muscle strength

INTRODUCTION

The incidence of musculoskeletal disorders has increased markedly, and the associated medical costs have also been increasing rapidly1). In Sweden, medical costs for musculoskeletal disorders are reported to account for 22.6% of all medical costs2), and $ 254 billion are spent on treatment of musculoskeletal disorders in the United States, which accounts for 25.4% of all medical costs, based on an estimation of annual medical costs of $ 1 trillion. A similar tendency is apparent in Japan, suggesting that the prevention of musculoskeletal disorders will not only reduce medical costs but also decrease the cost of long-term care insurance, which is of concern given the significant increase in the elderly population.

Musculoskeletal disorders frequently develop from osteoarthritis (OA)3, 4) and 10% of the world population is considered to have OA5). In Japan, the prevalence of OA is the second highest after that of spinal disorders, and OA patients under treatment
by physicians account for about 0.7% of the population\(^6\). Therefore, prevention of OA is an essential issue in an aging population.

Ultrasonography (US) is performed in Europe to investigate the pathology of rheumatism and can be used to evaluate articular cartilage conditions. Aisen et al.\(^7\) compared ultrasonographic findings of the femoral condylar cartilage before total knee replacement with pathological findings of samples from the same region that were excised during surgery, and found that US abnormalities were consistent with pathological findings. In summarizing US abnormalities in cartilage in OA, McCune et al.\(^8\) showed that an unclear boundary between the articular cartilage and soft tissue (anterior margin) was a common abnormal feature. These results indicate that pre-osteoarthritis evaluation of the knee may serve as a useful method in preventive medicine.

The objective of this study was to examine the influence of leg muscle weakness and body weight on ultrasonographic findings of the knee joint cartilage in evaluation of pre-osteoarthritis evaluation of the knee. The study was performed as a comparison between cases in which normal US findings in articular cartilage were maintained for 6 months and cases in which normal US findings became abnormal over 6 months.

**METHODS**

The subjects of this study were middle-aged women who attended the Kansai Medical University Health Science Center and requested exercise therapy to improve obesity, hypertension, and hyperlipidemia. The number of participants was 33 (66 knees). The mean age of the participants was 58.2 ± 9.3 years old (range: 42–74 years old), and the mean body mass index (BMI) was 28.1 ± 6.1 kg/m\(^2\) (range: 16.9–46.6 kg/m\(^2\)). The subjects consented to participate in the study after they were given a written explanation of the planned work. The study was approved by the Kansai Medical University Ethics Committee.

In the first examination at the Center, an internal medical examination, X-ray and ultrasonographic examinations of the knee joint, physical measurements, and muscle strength measurements were performed. Evaluation of knee pain (WOMAC: VAS 10 cm)\(^9\) and a questionnaire-based survey of past medical history were also performed. Based on these investigations, subjects under treatment for OA and rheumatism, those with a past history of trauma, such as meniscus and ligament injuries, those whose parents or grandparents had suffered from OA, and those with ballottement of the patella were excluded from the study.

A SONOS-5500 (Philips Electronics Japan Medical Systems, Boston, USA) was used for ultrasonography. The instrument was fitted with an 11-MHz linear probe for most measurements, but a 7.5-MHz probe was concomitantly used as needed to rule out the influence of soft tissue on the image. The same probe used in the initial test was used in the second examination after 6 months.

The knee joint was flexed at 130° for the ultrasonographic measurements to reduce the influence of synovial fluid and edema on the image. The measurement site was set at 2 cm above the upper end of the patella and the condition of the cartilage of the femoral medial and lateral condyle (P-F joint; medial side, lateral side) was evaluated by transverse scanning of this region. In addition, the condition of the cartilage of the femoral medial condylar weight-bearing region (F-T joint; medial side) was evaluated by longitudinal scanning of the region 0.5 cm from the medial end of the patella.

An image was judged to be ‘normal’ if the boundary between the cartilage and articular cavity (anterior boundary) was identified as a continuous high-echo line and the contrast to a low-echo zone of the cartilage was clear; all other images were judged to be ‘abnormal’\(^8, \(^10\). This evaluation was made by three specialists, with a decision made through consultation for cases judged inconsistently by the evaluators.

A Strength Ergo 240 (Mitsubishi Engineering, Tokyo, Japan) instrument was used for muscle strength measurements. This instrument is capable of measuring muscle strength during movement under conditions similar to the closed kinetic chain in walking (semi-closed kinetic chain conditions).

Since muscle strength exerted during movement may be important with regard to OA and joint cartilage impairment, muscle strength was measured during isokinetic movements at 50 rpm (low-speed) and 70 rpm (high-speed), and the pedaling peak torques during movement (50 rpm pedaling peak torque: PPT\(_{50}\), 70 rpm pedaling peak torque: PPT\(_{70}\) [Nm/kg]) were regarded as the muscle strength. The pedaling torque at the peak of
the 10th cycle of 50 rpm pedaling (10th-PPT [Nm/kg]) was also measured as an index of muscular endurance.

During the measurement, the subject sat on a recumbent Ergo with support for the back at 110°; the subject held the bars on the bilateral sides and the trunk was fixed to avoid lifting. The seat position was adjusted such that the knee joint moved within a range from –20° to 100°, and the examiner encouraged the subject to make maximum effort during the test and confirmed whether knee pain limited the movement. Similar tests were performed at the first examination and after 6 months.

The study comprised only middle-aged female subjects (40–59 years of age), since our previous study suggested the importance of muscle strength in this subject population11). To clarify the relationship between leg muscle strength and US findings, only subjects judged to be ‘normal’ in the first US examination were studied. The final number of subjects was 10 (20 knees), and the mean age of the subjects was 52.9 ± 5.0 years old (range: 40–59 years old).

The subjects were divided into a group (Group N) in which ‘normal’ US findings were maintained for 6 months, and a group (Group A) in which initially normal US findings had become ‘abnormal’ after 6 months. Cases in which the normal US findings became abnormal are shown in Fig. 1.

SPSS for Windows Ver. 11 was used for statistical analysis. The relationship between the initial values for BMI and leg muscle strength and changes in US findings, and changes in BMI and leg muscle strength in relation to changes in US findings were analyzed using the Mann-Whitney U test. Differences in changes in BMI and leg muscle strength between groups N and A were analyzed using the Wilcoxon signed rank test. The significance level was set to 5%.

RESULTS

The mean WOMAC pain score was 0.8 ± 2.3 in the first test and 0.3 ± 1.1 after 6 months, out of a maximum score of 100. These data were not significantly different between the time points and show that the subjects were pain-free at the beginning of the study and after 6 months.

A comparison of the initial values of BMI and leg muscle strength between patients with normal US images (Group N) and those with abnormal US images (Group A) after 6 months is shown in Table 1. There were no significant differences between the initial values of either item in the two groups.

Changes in BMI and leg muscle strength in Group N are shown in the upper part of Table 2. No significant changes were noted for any US sites between the initial examination and the examination performed 6 months later. Changes in BMI and leg muscle strength in Group A are shown in the lower part of Table 2. In the lateral condyle, significant differences were found in PPT50 (p=0.043) and 10th-PPT (p=0.043) between the first and second measurements, and significant differences were also noted in 10th-PPT (p=0.018) in the medial condyle and in PPT50 (p=0.028), PPT70 (p=0.028), and 10th-PPT (p=0.028) in the medial condylar weight-bearing region. However, there was no significant change in the mean BMI in Group A between the initial measurements and those after 6 months.

A comparison of changes in test values between Groups N and A are shown in Table 3. Significant
differences were noted in changes in PPT\textsubscript{50} (p=0.018) and 10th-PPT (p=0.007) in the lateral condyle, in 10th-PPT (p=0.007) in the medial condyle, and in PPT\textsubscript{50} (p=0.002) PPT\textsubscript{70} (p=0.002), and 10th-PPT (p=0.002) in the medial condylar weight-bearing region, but the change in BMI did not differ significantly between the two groups.

**DISCUSSION**

A comparison of patients maintaining normal ultrasonography findings with those with abnormal changes over a 6-month period showed that there were no significant differences in parameters of muscle strength at the initial examination. However, as shown in Tables 1, 2 and 3, differences in the 6-month course of each muscle strength parameter were found between the two groups. Muscle strength was maintained 6 months after the first examination in the normal US group, but significant decreases in some parameters were noted in the abnormal US group. Since both groups had no pain at the time of the first examination and 6 months later, no aggravation was noted, and changes in articular cartilage without pain are unlikely to reduce the muscle strength directly; therefore, we assumed that reduction of muscle strength induced the abnormal US findings in the

**Table 1.** Comparison of the initial values of BMI and muscle strength between the groups with normal and abnormal ultrasonographic changes

<table>
<thead>
<tr>
<th></th>
<th>Lateral femoral condyle cartilage (F-T joint: Transverse)</th>
<th>Medial femoral condyle cartilage (F-T joint: Transverse)</th>
<th>Medial femoral condyle cartilage (P-F joint: Vertical line)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal maintenance group (n=7)</td>
<td>Abnormal maintenance group (n=5)</td>
<td>P</td>
</tr>
<tr>
<td>BMI (kg / m(^2))</td>
<td>26.9 ± 8.3</td>
<td>24.2 ± 2.5</td>
<td>0.682</td>
</tr>
<tr>
<td>PPT 50 (Nm / kg)</td>
<td>1.33 ± 0.11</td>
<td>1.28 ± 0.21</td>
<td>0.290</td>
</tr>
<tr>
<td>PPT 70 (Nm / kg)</td>
<td>1.15 ± 0.21</td>
<td>1.05 ± 0.22</td>
<td>0.465</td>
</tr>
<tr>
<td>10th PPT 50 (Nm / kg)</td>
<td>1.20 ± 0.14</td>
<td>1.18 ± 0.18</td>
<td>0.684</td>
</tr>
</tbody>
</table>

Mann-Whitney U test. Abbreviations: F-T joint, femoro-tibial joint; P-F joint, patello-femoral joint; BMI, body mass index; PPT, pedaling peak torque; PPT \textsubscript{50}, PPT at 50 rpm; PPT \textsubscript{70}, PPT at 70 rpm; 10th PPT, 10th PPT at 50 rpm.

**Table 2.** Changes in BMI and muscle strength in the groups with normal and abnormal ultrasonographic changes

<table>
<thead>
<tr>
<th></th>
<th>Lateral femoral condyle cartilage (F-T joint: Transverse) (N=7)</th>
<th>Medial femoral condyle cartilage (F-T joint: Transverse) (N=5)</th>
<th>Medial femoral condyle cartilage (P-F joint: Vertical line) (N=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Primary 6M</td>
<td>p</td>
<td>Primary 6M</td>
</tr>
<tr>
<td>BMI (kg / m(^2))</td>
<td>26.9 ± 8.3</td>
<td>26.7 ± 8.3</td>
<td>0.497</td>
</tr>
<tr>
<td>PPT 50 (Nm / kg)</td>
<td>1.33 ± 0.11</td>
<td>1.32 ± 0.07</td>
<td>0.686</td>
</tr>
<tr>
<td>PPT 70 (Nm / kg)</td>
<td>1.15 ± 0.21</td>
<td>1.09 ± 0.20</td>
<td>0.225</td>
</tr>
<tr>
<td>10th PPT 50 (Nm / kg)</td>
<td>1.20 ± 0.14</td>
<td>1.19 ± 0.14</td>
<td>0.686</td>
</tr>
</tbody>
</table>

Changes in BMI and muscle strength in the normal maintenance group

<table>
<thead>
<tr>
<th></th>
<th>Lateral femoral condyle cartilage (F-T joint: Transverse) (N=5)</th>
<th>Medial femoral condyle cartilage (P-F joint: Vertical line) (N=6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Primary 6M</td>
<td>p</td>
</tr>
<tr>
<td>BMI (kg / m(^2))</td>
<td>24.2 ± 2.5</td>
<td>23.7 ± 2.0</td>
</tr>
<tr>
<td>PPT 50 (Nm / kg)</td>
<td>1.28 ± 0.21</td>
<td>0.95 ± 0.38</td>
</tr>
<tr>
<td>PPT 70 (Nm / kg)</td>
<td>1.05 ± 0.22</td>
<td>0.83 ± 0.39</td>
</tr>
<tr>
<td>10th PPT 50 (Nm / kg)</td>
<td>1.18 ± 0.18</td>
<td>0.86 ± 0.32</td>
</tr>
</tbody>
</table>

Wilcoxon signed rank test. Abbreviations: F-T joint, femoro-tibial joint; P-F joint, patello-femoral joint; BMI, body mass index; PPT, pedaling peak torque; PPT \textsubscript{50}, PPT at 50 rpm; PPT 70, PPT at 70 rpm; 10th PPT, 10th PPT at 50 rpm.
articular cartilage.

Lloyd et al.\textsuperscript{12) reported that 20\% of lateral stability of the knee joint is provided by muscle, indicating the importance of muscle during movement of loose joints. Schipplein et al.\textsuperscript{13) reported that high muscle strength around the knee maintains the lateral closure of the joint and helps resist the adduction moment by increasing the stability of the knee. Therefore, as noted in our study, reduction of muscle strength induces mild loosening in the joint during walking and other movements, or weight is concentrated on a local site, and these events may cause mechanical stress and lead to abnormalities in US images. Jefferson et al.\textsuperscript{14) also reported that reduction of muscle strength of the knee increases the impact of the heel upon reaching the ground in the walking cycle, and that this is likely to cause injury to the knee joint cartilage.

Regarding the reduction of muscle strength in the abnormal US group, none of the subjects had functional impairment and their daily lives were normal. However, these subjects moved less spontaneously compared to subjects who maintained muscle strength, and this was the sole difference between the groups of subjects. The muscle strength measurement used in this study reflects normal exercise experience, since it measures muscle strength during isokinetic movement. Neuromuscular units participating in movement differ depending on exercise; therefore, the reduction in muscle strength in our subjects may have been due to reduction of neuromuscular units, rather than to muscular atrophy.

Our findings show that US abnormalities in the knee joint cartilage are associated with reduction of leg muscle strength in middle-aged women. This suggests that adequate exercise in middle age to maintain muscle strength is important for women to prevent and delay the onset of knee OA. Furthermore, Roos et al.\textsuperscript{15) found that moderate exercise improved not only articular symptoms and function but also the quality of the knee joint cartilage in middle-aged men and women at high risk of developing knee OA. Therefore, preventive muscle strength maintenance training and early screening of joint cartilage by US are important for the maintenance and promotion of health in an aging society.

\textbf{REFERENCES}

9) Bellamy N: Outcome measures in osteoarthritis

\begin{table}
\centering
\caption{Amount of change in BMI and muscle strength in the groups with normal and abnormal ultrasonographic changes}
\small
\begin{tabular}{|c|c|c|c|c|c|c|c|c|}
\hline
 & \multicolumn{2}{c|}{Lateral femoral condyle cartilage} & \multicolumn{2}{c|}{Medial femoral condyle cartilage} & \multicolumn{2}{c|}{Medial femoral condyle cartilage} \\
 & (F-T joint: Transverse) & (F-T joint: Transverse) & (P-F joint: Vertical line) & (P-F joint: Vertical line) & (P-F joint: Vertical line) & (P-F joint: Vertical line) & (P-F joint: Vertical line) \\
\hline
 & Normal maintenance group (n=7) & Abnormal change group (n=5) & \(P\) & Normal maintenance group (n=7) & Abnormal change group (n=5) & \(P\) & Normal maintenance group (n=8) & Abnormal change group (n=6) & \(P\) \\
\hline
BMI (kg/m\(^2\)) & \(-0.17 \pm 0.39\) & \(-0.54 \pm 0.61\) & 0.158 & \(-0.08 \pm 0.68\) & \(-0.07 \pm 0.88\) & 0.869 & \(0.30 \pm 0.75\) & \(-0.45 \pm 0.61\) & 0.118 \\
PPT 50 (Nm/kg) & \(-0.01 \pm 0.06\) & \(-0.32 \pm 0.18\) & 0.018 & \(-0.03 \pm 0.04\) & \(-0.23 \pm 0.23\) & 0.220 & \(0.001 \pm 0.06\) & \(-0.33 \pm 0.13\) & 0.002 \\
PPT 70 (Nm/kg) & \(-0.06 \pm 0.12\) & \(-0.23 \pm 0.21\) & 0.222 & \(-0.05 \pm 0.08\) & \(-0.17 \pm 0.20\) & 0.368 & 0 & \(0 \pm 0.06\) & \(-0.27 \pm 0.13\) & 0.002 \\
10\(^{th}\) PPT 50 (Nm/kg) & \(-0.01 \pm 0.10\) & \(-0.32 \pm 0.16\) & 0.007 & \(0.02 \pm 0.09\) & \(-0.24 \pm 0.19\) & 0.007 & \(-0.01 \pm 0.08\) & \(-0.32 \pm 0.12\) & 0.002 \\
\hline
\end{tabular}
\textsuperscript{Mann-Whitney U test. Abbreviations: F-T joint, femoro-tibial joint; P-F joint, patello-femoral joint; BMI, body mass index; PPT, pedaling peak torque; PPT 50, PPT at 50 rpm; PPT 70, PPT at 70 rpm; 10\(^{th}\) PPT, 10\(^{th}\) PPT at 50 rpm.}


