J. Phys. Ther. Sci.
26: 281–284, 2014

Effectiveness of Thermotherapy Using a Heat and Steam Generating Sheet for Cartilage in Knee Osteoarthritis

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Abstract. [Purpose] Superficial heat treatment is one of the most widely used physical therapies for osteoarthritis (OA). We clinically evaluated the effects of local heat treatment and exercise therapy for knee OA, and evaluated the articular cartilage using magnetic resonance imaging (MRI) T2 mapping. [Subjects and Methods] Eighteen females aged 50–69 (59.5 ± 8.5 years, mean ± SD) years diagnosed with early-stage knee OA were randomly assigned using computer-generated random numbers to either a local heat treatment group (LH group, 9 subjects) or an exercise therapy group (EX group, 9 subjects). These groups were subjected to a 12-week intervention experiment. MRI T2 mapping was performed for cartilage imaging and quantitative evaluation. For clinical evaluation, the Japanese Knee Osteoarthritis Measure (JKOM) and the Timed Up and Go (TUG) test were performed. Both clinical and MRI evaluations were performed at the beginning and end of the intervention (0 week (Time 0) and 12 weeks). [Results] The total JKOM score had a significantly decreased in the LH group at 12 weeks. However, in the EX group the total JKOM scores at Time 0 and 12 weeks were not significantly different. The TUG time in the EX group was significant shorter at 12 weeks, whereas it showed no significant change in the LH group at 12 weeks, though the TUG times of 7 of the 9 patients decreased, exhibiting some improvement. The T2 value of the LH group was significantly shorter at 12 weeks. However, the T2 value in the EX group showed no significant change at 12 weeks. [Conclusion] After local heat treatment using heat- and steam moisture-generating sheets for 12 weeks, we observed improvements in clinical symptoms and walking abilities. Moreover, positive effects on cartilage metabolism were suggested.
Key words: Osteoarthritis, Thermotherapy, Cartilage

(This article was submitted Jun. 25, 2013, and was accepted Sep. 10, 2013)

INTRODUCTION

Because of the aging population, the number of patients with age-associated joint disorders has been increasing in Japan. These disorders are a major factor in the reduction of the activities in the daily lives of the middle-aged. In particular, the number of patients with knee osteoarthritis (OA) has been rapidly increasing in recent years.

For progressive knee OA, surgical methods such as arthroscopic surgery, osteotomy, or total knee arthroplasty are commonly used. Early-stage knee OA is treated mainly by oral administration or topical application of non-steroidal anti-inflammatory drugs (NSAIDs), intra-articular administration of drugs such as hyaluronic acid, physical therapy such as heat treatment, orthosis therapy such as use of a foot plate or knee orthosis, or exercise therapy such as muscle strength training[1)]. Superficial heat treatment is one of the most widely used physical therapies, and moist heat is considered to be more effective than dry heat, because heat is transferred to deep areas of the body, which promotes blood circulation[2–4)] and pain relief[5, 6)]. Recent in vitro studies have revealed the influences of heat treatment on the metabolism of cartilage matrix components such as proteoglycans and collagen[7, 8)].

We evaluated the effects of local heat treatment and exercise therapy for knee OA on knee joint symptoms and qualitative clinical changes in cartilage, as well as by magnetic resonance imaging (MRI) T2 mapping, which allowed quantitative assessment of articular cartilage, collagen fiber arrangement, and the water content in the cartilage[9)]. Irregularity in the collagen fiber arrangement and an increase in the water content may develop with cartilage degeneration. T2 in cartilage is generally prolonged in the early-stage of

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cartilage degeneration, therefore we evaluated the changes in T2 as a measure of quantitative changes in cartilage.

SUBJECTS AND METHODS

This study received ethical approval from Juntendo University Hospital Review Board, and the subjects provided their written informed consent. The subjects were 22 females aged 50–69 (59.5 ± 5.8 years, mean ± SD) years diagnosed as having early-stage knee OA. The 22 subjects were randomly assigned using computer-generated random numbers to either a local heat treatment group (LH group, 11 subjects), or an exercise therapy group (EX group, 11 subjects). These study groups were examined in a 12-week intervention experiment. Standing antero-posterior plain X-ray images were obtained of all patients, and the severity of knee OA was evaluated according to the Kellgren–Laurence Classification[10].

Subjects in the EX group performed 2 sets of straight leg raises, abductor training, and adductor training (20 repetitions per set) in the morning and evening every day.

In the LH group, heat- and steam-generating sheets (Kao Corporation, Tokyo, Japan) were used to apply moist heat. These sheets generate heat and steam by reacting with oxygen in the air, and can maintain the skin temperature at 40 °C for 8 h. The sheets were applied continuously for 6 h every day, except during sleep. Two sheets were applied to the patella on the left and right sides (total heating area using 2 sheets = 96 cm^2), and a thin flexible supporter was applied to prevent their movement. The application method is illustrated in Fig. 1.

For clinical evaluation, the Japanese Knee Osteoarthritis Measure (JKOM)[11] and the Timed Up and Go (TUG) test were performed. The TUG test measures the time taken by a subject to rise from a chair with arm rests, walk 3 m, turn, walk back to the chair, and sit down again. Following the original method of Mathias et al.[12], measurements were performed twice at a comfortable walking speed, and the shorter time was used for analysis.

For cartilage imaging, MRI T2 mapping was performed for quantitative evaluation. MRI was performed on the side with knee pain (heat application side), and the T2 values of before and after the intervention were compared.

For T2 mapping, coronal images passing through the center of the weight-bearing area were obtained using a 3.0 T MRI system (Siemens, Erlangen). For T2 measurement, imaging was performed using the multi-spin-echo method under the following conditions: TR, 1,800 ms; TE, 10–80 ms; FOV, 150 × 150 mm; section thickness, 3.0 mm; matrix, 384 × 384, bandwidth 241 kHz. Regions of interest involving the full thickness of the cartilage were located in the medial and lateral condyles of the femur and those of the tibia, and the mean values were obtained. To standardize the procedure, all measurements were performed by a single investigator.

Both clinical and MRI evaluations were performed at the beginning and the end of the intervention (0 week (Time 0) and 12 weeks). For statistical analysis, differences between measures taken before and after the intervention were evaluated using the paired t-test in each group; $p < 0.05$ was regarded as significant.

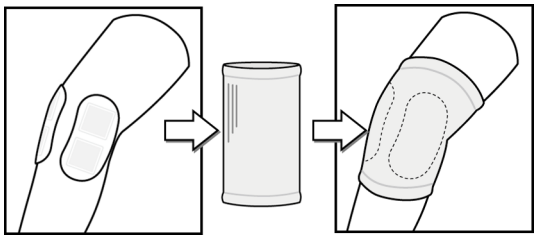

Fig. 1. Schema for the application of heat- and steam-generating sheets on the knee

Table 1. Baseline characteristics of the subjects

	Exercise therapy group	Local heat treatment group
Number of patients	9	10
Gender (male / female)	0/9	0/9
Age*(years,mean±SD)	59.4±6.0	58.3±5.7
BMI*(kg/m^2,mean±SD)	22.0±3.0	23.5±3.2
Kellgren-Laurence grade	I: 2, II: 6, III: 1	I: 1, II: 8

There was no significant difference with regard to age or BMI between the patient groups.
*At the time of MR imaging

RESULTS

A total of 18 patients (9 in the LH group, 9 in the EX group) participated in the entire study. Reasons for dropping out of the other subjects in the study were: admission to a hospital due to another disorder for 1 patient, dizziness during exercise therapy for 1, change of address for 1, and redness in areas other than the heat- and steam-generating sheet application area for 1. There was no significant difference in age, BMI, or KL-grade between the LH and EX groups (Table 1).

The total JKOM score was 16.4 ± 10.5 (mean ± SD) at Time 0 and 7.8 ± 4.5 (mean ± SD) at 12 weeks in the LH group, a significant decrease ($p < 0.05$). In the EX group, the total JKOM score was 13.3 ± 6.8 (mean ± SD) at Time 0 and 9.6 ± 9.1 (mean ± SD) at 12 weeks, without significant difference (Table 2).

The TUG time in the EX group was 9.2 ± 1.4 s (mean ± SD) at Time 0 and 7.7 ± 1.2 s (mean ± SD) at 12 weeks, a significant decrease ($p < 0.05$). In the LH group, the TUG time was 8.8 ± 2.0 s (mean ± SD) at Time 0 and 8.1 ± 1.3 s (mean ± SD) at 12 weeks. Although no significant change was observed in this group, the TUG time decreased in 7 of the 9 patients showing a tendency of improvement (Table 3).

The T2 value in the LH group was 32.5 ± 2.4 (mean ± SD) at Time 0 and 31.4 ± 2.6 (mean ± SD) at 12 weeks, a significant decrease ($p < 0.05$). In the EX group, the T2 value was 30.7 ± 3.6 (mean ± SD) at Time 0 and 30.4 ± 2.7 (mean ± SD) at 12 weeks, without significant change (Table 4).

Table 2. Total JKOM score of each group at time 0 and 12 weeks

		Time 0	12 weeks
Exercise therapy group	(points, mean±SD)	13.3±6.8	9.6±9.1
Local heat treatment group	(points, mean±SD)	16.4±10.6	7.8±4.5*

*p<0.05

Table 3. Timed Up & Go test of each group at time 0 and 12 weeks

		Time 0	12 weeks
Exercise therapy group	(sec, mean±SD)	9.2±1.4	7.7±1.2*
Local heat treatment group	(sec, mean±SD)	8.8±2.1	8.1±1.3

*p<0.05

Table 4. T2 value of cartilage in each group at time 0 and 12 weeks

		Time 0	12 weeks
Exercise therapy group	(msec, mean±SD)	30.7±3.6	30.4±2.7
Local heat treatment group	(msec, mean±SD)	32.5±2.4	31.4±2.6*

*p<0.05

DISCUSSION

A previous study using superficial dry heating sheets that use an iron powder to produce an oxidation reaction, which is also used in the heat- and steam-generating sheets, showed an increase in the human intracapsular temperature to 36–37 °C, which was about 4 °C higher than the intracapsular temperature under the control condition without heat treatment[13]. In addition, superficial heat treatment for 10 min using paraffin was reported to increase the intracapsular temperature to at least 37 °C[14]. The significant decrease in the JKOM score, i.e., significant improvement in OA symptoms and activities of daily living after heat treatment in the present study, may have been partly due to promotion of blood circulation[15, 16]. It is known that decreased blood circulation in tissue is associated with the development of pain[17, 18]. An association between decreased blood flow and knee pain has been reported[19, 20]. Long-term local heat treatment using heat- and steam-generating sheets may have improved blood flow in periarticular tissue, resulting in pain relief in the knee in daily life. In addition, the effects of local heat treatment include an increase in collagen fiber extensibility[21], analgesic effects due to an increase in the pain threshold[22], and effects on muscle metabolism[23, 24]. In this study, local heat treatment may have exerted complex effects on periarticular tissue, and contributed to the improvement in the symptoms of knee OA and activities of daily living. An improvement in JKOM scores after exercise treatment has previously been reported[25]. In this study, the total JKOM score in the EX group was lower at 12 weeks than that at Time 0, but the change was not significant. As a relatively small number of subjects participated in this study, further studies are necessary to determine whether exercise treatment solely improves the total JKOM score.

The TUG time was significantly shortened in the EX group. This may have been because exercise, which strengthens walking-associated muscles and widens the range of joint motions, contributed to improvements in walking abilities in this study. In the LH group, the TUG time did not significantly change, but in 7 of the 9 patients showed decreased times, and the improvement rate was similar to that in the EX group. In recent years, thermal stimulation alone or in combination with mild exercise has been reported to increase the muscle mass and strength in humans and rats[24, 26, 27]. On the basis of the JKOM and TUG test results of the present study, we consider there is a possibility that exercise therapy used in combination with local heat treatment further improves exercise function because of improvement in pain symptoms and muscle reinforcement. Further evaluation is necessary to verify this conjecture.

Concerning the effects of heat treatment on articular cartilage, in vitro studies have revealed that an increase in the cartilage temperature (37°C) promotes proteoglycan production as a cartilage matrix component[28, 29]. This has not been studied in vivo, but the effects of heat treatment associated with increased cartilage temperature, and the effects on cartilage metabolism due to promotion of blood circulation in the surrounding tissues have been considered[30]. In this study, a significant shortening of the T2 value in the LH group, i.e., after heat treatment using heat- and steam-generating sheets, was detected. Several possible reasons for this T2 shortening can be considered, including not only the direct effects of heat treatment on cartilage metabolism, but also a decrease in the water content of cartilage. Water content changes possibly result from increased weight-bearing resulting from an improved walking ability, associated with ameliorated knee joint symptoms. Further studies are necessary to determine whether T2 changes occur in cartilage after heat treatment, and whether such changes represent improvement in cartilage degeneration.

In this study, the subjects were patients with early-stage

OA primarily exhibiting KL I-II, a good indication for conservative therapy. Therefore, further studies are necessary to evaluate the clinical effects of heat treatment for patients with advanced knee OA or severe symptoms. In addition, for patients with advanced articular cartilage degeneration or thinning, it is possible that irreversible degeneration is present in the cartilage matrix. Whether heat treatment affects cartilage metabolism even in such patients should be determined by further evaluation.

In conclusion, after treatment with heat- and steam-generating sheets for 12 weeks, improvements in clinical symptoms and walking abilities were observed. Furthermore, effects on cartilage metabolism were suggested by the results.

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