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Abstract. [Purpose] This study sought to determine an exercise regimen that can effectively improve degenerative osteoarthritis patients’ muscle strength, proprioception, and functional performance. The regimen consisted of resistive exercises (RT) or manual therapy and resistive exercises (MT). [Subjects] The subjects were 35 elderly women who trained three times a week for eight weeks. [Methods] The 35 subjects were divided at random into RT and MT groups, according to the treatment method. [Results] Quadriceps strength significantly improved in both the RT and MT groups. Muscle strength increased to 4.35 N on the right side and to 3.55 N on the left side in the RT group, and to 10.59 N and 9.02 N, respectively, in the MT group. Only in the MT group did proprioception change significantly. The MT group showed a decrease in error from the target angle by –0.83° on the right side and –0.5° on the left side. Additionally, only in the MT group did functional performance change significantly; with the elapsed time in functional performance testing decreasing by 10.29 s. [Conclusion] According to the results, a regimen consisting of manual therapy together with resistive exercise appears to be more effective at improving muscle strength, proprioception, and functional performance than resistive exercise alone. Key words: Manual Therapy, Proprioception, Functional Performance

(INTRODUCTION

Degenerative osteoarthritis (OA) is a disease characterized by pain and disability1), and an estimated 33% of the population aged 63–94 years have degenerative OA. Degenerative OA patients have limitations in standing up from a chair, standing comfortably, walking, and using the stairs2). Treating the pain and disability resulting from degenerative OA incurs large healthcare expenses, and inadequate treatment results in long-lasting pain and disability in afflicted patients3). Compared to those without the disease, adults with degenerative OA have difficulties in maintaining an independent life and in executing physical functions such as walking, using the stairs, and lifting and carrying things; such difficulties are related to the severity of the disease4). Degenerative OA is more common in women than in men and grows worse with age; if left untreated, the disease may increase the risk of falls and decrease longevity5).

As degenerative OA affects the ligaments, articular capsules, muscles, and tendons, it generates various symptoms. Compared to healthy persons, degenerative OA patients show: degradation of proprioception; a decrease in the number of mechanical receptors; and a reduction in quadriceps strength, by as much as 50–60%6,7).
Furthermore, joint damage observed in degenerative OA lowers the excitability of motoneurons in the quadriceps femoris muscle. Low quadriceps strength and proprioception damage caused by inhibitory information and disuse atrophy in the joint result in a decrease in functional performance\textsuperscript{7,8).}

It was reported that the application of both manual therapy and resistive exercise to degenerative OA patients improved the 6-min walking distance for and the disability index after eight weeks\textsuperscript{9).} A study that applied both manual therapy and resistive exercises and compared the results with those of resistive exercises alone reported greater improvement among patients who had undergone both manual therapy and resistive exercises\textsuperscript{10).} Another study that compared manual therapy and resistive exercises for OA hip patients reported that, compared to resistive exercises alone, manual therapy brought forth greater improvements in Harris hip score, pain alleviation, and range of motion\textsuperscript{11).} Various types of research have been carried out on the treatment of pain and functional disability in degenerative arthritis patients through therapeutic exercise; however, few studies have investigated decreases in muscle strength, proprioception, and functional performance of degenerative arthritis patients. Thus, this study sought to determine an exercise regimen that can effectively improve degenerative OA patients’ muscle strength, proprioception, and functional performance. The experimental regimens consisted of resistive exercises (RT) or manual therapy and resistive exercises (MT), and we compared the results of them.

**SUBJECTS AND METHODS**

**Subjects**

Originally, the subjects of this study were 40 elderly patients who had OA of the knee on both the right and left sides. They were selected from among elderly patients who had been diagnosed with degenerative OA and had visited a hospital in Gyeonggido. We used the Lequense Index, in order to determine symptom severity of subjects\textsuperscript{12); we then selected those whose Lequense Index was between 7 and 14\textsuperscript{13).} Those who had been injected with cortisol within the previous 30 days were excluded, and five out of the 40 patients were also excluded because they had undergone an operation on the lower limbs within the previous six months. The selected subjects were allowed to continue their existing medication, but were not allowed to initiate any new drug regimen during the study. In the preliminary examination, we tested muscle strength, proprioception, and functional performance. The 35 subjects were divided at random into the RT group or the MT group, according to treatment method.

**Methods**

Quadriceps strength was measured at 90° flexion of the hip joint and 90° flexion of the knee joint. The subjects flexed their hip and knee joints by 90° and sat with their feet apart and off the floor, while the pelvis and trunk were fixed with straps. The inside, outside, and top of the ankle joint were bound with straps, and the strain gauge of a muscle strength meter (DigiMax; mechaTronic, Germany) was connected to the opposite side and fixed on the stall bar on the rear side. Quadriceps strength was measured three times for each side, and the mean value was calculated.

Proprioception was measured indirectly by assessing the joint position sense of the knee joint\textsuperscript{14).} Joint position sense was assessed using a method described previously\textsuperscript{15).} The subject was seated on a high chair and flexed the knee and hip joints by 90°, with the feet off the floor. Using an electrogoniometer (MicroFET3; Hoggan, USA), we positioned the proximal end of the electrogoniometer just below the tibial tuberosity of the proximal tibia and the distal end on the straight line along the tibia.

The difference between the performed angle and the target angle was measured three times for each of the right and left sides, and the mean proprioception value was calculated.

Inside a room, starting and finishing lines were marked on the floor. The points 1 m after the starting line and 1 m before the finishing line were also marked. We had the subjects walk a 10-m distance at a natural and comfortable speed, and measured the time that elapsed between the point 1 m after the starting line and the point 1 m before the finish line (i.e., 8 m inside the 10-m distance); The 10 m walking was performed three times and the mean value was calculated\textsuperscript{16,17).}

Using a stair exercise machine (stair case), we marked the starting point on the floor just below the first stair, and the ending point on the seventh and
final stair. We had the subjects climb up and down the seven stairs (four of which were 15 cm high and three of which were 20 cm high) at a natural and comfortable speed. This exercise was also performed three times, and the mean elapsed-time value was calculated (18).

Inside another room, a 3-m line was drawn on the floor, and the start and end points were marked. The subjects were positioned at the start point and a chair was positioned at the end point, 3 m away. The chair did not have armrests, and was 0.46 m high—approximately the height of a toilet bowl (19). We had each of the subjects walk at their own pace toward the chair, sit on the chair, stand up from the chair, and return to the starting point. This entire procedure was performed and measured three times, and the mean value was calculated. For each of the three types of functional performance (8 m walking, ascending and descending stairs, and sitting and standing), we measured the elapsed time using a stopwatch, and obtained a total elapsed time for the three activities (20).

The RT program was performed by its subjects three times per week, for eight weeks; each session was 40 min long. The RT group underwent both range-of-motion and resistive exercises (9).

The range-of-motion exercise was performed by the RT subjects twice, as follows. First, the subjects sat and stretched their legs, moved the knee from the middle of the flexion range to the end of the extension range, and maintained the extended state for 3 s; they then took a 3-s break. They repeated this exercise for 2.5 min. Then they sat and stretched the legs, moved the knee from the middle of the extension range to the end of the extension range, and maintained the extended state for 3 s; they then took a 3-s break. Finally, they performed 5 min of exercise of the lower limbs, on a stationary bicycle.

Resistive exercise was performed twice by the subjects in the RT program with a 20-s break given after each exercise. First, while the knee joint was extended, the subjects maintained static tension in the quadriceps femoris muscle for 6 s and then took a 10-s break; this process was repeated 10 times. Next, they stood with the knee joint extended to the end of the range and repeated a knee-extension exercise using an elastic band (yellow), 12 times for 1.5 min. Afterwards, they sat and repeated the leg press, using an elastic band (yellow) 12 times for 1.5 min. Then, they undertook a 1-s concentric contraction and a 2-s eccentric contraction with both legs, for 1.5 min; if they were able to, they were asked to repeat the same exercise with one leg. Finally, they performed step-ups 12 times, for 1.5 min; if they were able to, they were asked to increase the steps height. The resistance of the elastic band differs with the length of extension, and a 3.5lb (1.5876-kg) resistance is generated by extending the yellow elastic band by 67% (21). The permissible amount of exercise was defined as exercise which could be performed for more than 30 min without causing pain in the joint (25).

The MT program was performed for the subjects three times per week, for eight weeks; each session were 40 min long. The regimen was divided into manual therapy (10) and resistive exercises (19).

Manul therapy was performed, as follows, with a 30-s break given after each exercise. First, mobilization by pulling the knee joint was done twice for 30 s, at the end of the extension and flexion range. Then, mobilization by extending the knee joint (anterior gliding) was done twice for 30 s, in the range of motion and at the end of the extension range. Next, mobilization by flexing the knee joint (posterior gliding) was done twice for 30 s, in the range of motion and at the end of the flexion range. Finally, mobilization by the gliding of the patella (distal gliding) was done twice for 30 s, in the range of motion and at the end of the flexion range. The stage of mobilization for manual therapy was adjusted according to the state of the joint and the patient’s response, and the intensity was controlled by sensitively judging the range of motion, the quality of motion, and the joint end-feel.

Resistive exercise comprised one session of range-of-motion exercise and two sessions of resistive exercises (9). The permissible amount of exercise was defined as the exercise which could be performed for more than 30 min without causing pain in the joint (22).

The independent t-tests were used to compare the baseline characteristics of the two groups. The quadriceps strength, proprioception, and functional performance values of the two groups before and after the interventions were compared, using paired t-tests. Statistical significance was set at p<0.05.

RESULTS

The RT and MT groups were found to be
homogeneous; there were no significant differences between the two groups in terms of the subjects’ general characteristics, including height, weight, and disease duration.

The change in quadriceps strength was significant in both the RT and MT groups (p<0.05). Muscle strength increased to 4.35 N on the right side and to 3.55 N on the left side in the RT group, and to 10.59 N and 9.02 N, respectively, in the MT group.

The change in proprioception was not significant in the RT group, but was significant in the MT group (p<0.05). The MT group showed a decrease in error from the target angle by –0.83° on the right side and –0.5° on the left side.

The change in functional performance was not significant in the RT group, but it was significant in the MT group (p<0.05). In the MT group, the elapsed time of functional performance decreased by 10.29 s.

### DISCUSSION

The cause of degenerative OA is not clear, but in general it is believed that when there is a failing of articular cartilage, normal articular cartilage is damaged by mechanical force. That is, a single event or repeated microtraumatic injuries affect the articular cartilage, and instability caused by damage to the ligament or meniscus in the knee joint may transmit an abnormal force and cause degenerative OA. This indicates that repeated load and muscle limitations in absorbing shock resulted in OA.

Degenerative OA is an inflammatory disease characterized by the wear of articular cartilage and new bone formation on the articular surface. It invades joints loaded with weight and causes a degenerative change in articular cartilage, the enlargement of subchondral bone, and excessive inflammation.

<table>
<thead>
<tr>
<th>Table 1. Baseline characteristics of the subjects</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Illness duration (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT group (n = 17)</td>
<td>65.29 ± 2.61</td>
<td>158.76 ± 4.85</td>
<td>63.53 ± 4.14</td>
<td>5.00 ± 1.18</td>
</tr>
<tr>
<td>MT group (n = 18)</td>
<td>63.67 ± 3.19</td>
<td>159.44 ± 4.66</td>
<td>63.11 ± 2.56</td>
<td>4.94 ± 1.21</td>
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</table>

Values shown are mean ± SD. RT group, resistive exercise group; MT group, manual therapy and resistive exercise group.

<table>
<thead>
<tr>
<th>Table 2. Quadriceps strength and proprioception, at baseline and eight weeks</th>
<th>Quadriceps strength (Nm/kg)</th>
<th>Proprioception (degrees)</th>
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<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>8 Weeks</td>
</tr>
<tr>
<td>R, right side; L, left side, RT group; resistive exercise group; MT group, manual therapy and resistive exercise group.</td>
<td></td>
<td></td>
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<tr>
<td>RT group (n = 17)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>45.38 ± 5.91</td>
<td>49.74 ± 7.40*</td>
</tr>
<tr>
<td>L</td>
<td>40.18 ± 4.94</td>
<td>43.74 ± 7.17*</td>
</tr>
<tr>
<td>MT group (n = 18)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>47.15 ± 7.89</td>
<td>57.74 ± 7.57*</td>
</tr>
<tr>
<td>L</td>
<td>36.77 ± 6.56</td>
<td>45.80 ± 5.33*</td>
</tr>
</tbody>
</table>

Values shown are mean ± SD. *p<0.05

### Table 3. Functional performance, at baseline and eight weeks (second) | 8 Weeks |
<table>
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<tbody>
<tr>
<td>RT group (n = 17)</td>
<td>48.14 ± 4.60</td>
</tr>
<tr>
<td>MT group (n = 18)</td>
<td>52.02 ± 5.90</td>
</tr>
</tbody>
</table>

Values shown are mean ± SD. *p<0.05

RT group, resistive exercise group; MT group, manual therapy and resistive exercise group.
osteogenesis and pain. Consequently, degenerative OA inflicts discomfort and imposes limitations on activities of daily life.\(^{23}\) According to recent reports, there have been attempts to compare the joint effect of manual therapy and therapeutic exercise on degenerative OA.\(^{9-11,22}\)

In the current study, quadriceps strength increased significantly in both the RT and MT groups, but the increase was larger in the latter group. In one study that compared the effect of aquatic resistive exercise and ground resistive exercise in degenerative OA patients aged 50–88 years, the ground resistive exercise group showed an increase in quadriceps strength on the left and right sides, while the aquatic resistive exercise group showed an increase only on the left side.\(^{26}\) In a study that divided degenerative OA patients into isokinetic exercise, isometric exercise, isotonic exercise, and control groups, the isokinetic and isotonic groups each showed the largest increases in muscle strength at an angular velocity of 60°.\(^{27}\) In another study of degenerative OA patients older than 45 years, patients were divided into a resistive exercise group and a control group, and the former group showed greater improvement in quadriceps strength than the latter.\(^{28}\) As shown in these previous studies, resistive exercise or exercise with resistance improves muscle strength.

Mueller et al.\(^{29}\) reported that the strength of the dorsiflexor of the ankle joint highly correlates with the range of dorsiflexion of the ankle joint. It was also reported that manual therapy improves the arthrokinematics of the knee joint and increases the range of motion, and that additional resistive exercise effectively enhances improvements in muscle strength.\(^{22}\) Additionally, there has been research that has compared the joint effect of manual therapy and resistive exercise to that of resistive exercise in shoulder joint impingement syndrome patients.\(^{30}\) That research reported that muscle strength improved more in the group that had both manual therapy and resistive exercise, because pain decreased and mobility was recovered through manual therapy. In line with these findings, in order to enhance muscle strength, we hypothesized that we need to apply not only resistive exercise, but also to treat joint malfunction with manual therapy.

There was a comparative study of a control group and a group who participated in an exercise program comprising isometric, bicycle, and isotonic exercises and functional motions twice a week, for five weeks. Those who participated in the exercise program reported improvements in proprioception.\(^{31}\) When rheumatic arthritis patients were divided into a resistive exercise group and a control group, the former of which exercised twice per week for five weeks, no significant difference was observed in proprioception.\(^{32}\) However, resistive exercise performed by degenerative OA patients, resulted in a proprioception decrease of 0.47°, i.e., an improvement of 12.9%.\(^{33}\) These studies suggest that, in addition to an increase in muscle strength, there are likely other elements that effectively improve the position sense of the joint. It was reported that if the alignment and intervals of the joints are normalized, joint position sense is improved.\(^{6}\) Furthermore, when a valgus brace was applied to patients with degenerative arthritis on the inner side of the knee joint and the deformation of the varus, joint position sense improved, because the alignment of the joints improved or the excessive load on the inner side was ameliorated.\(^{34}\) These results suggest that both the normalization of body alignment and the restoration of arthrokinematics affect the function and proprioception of the joint. In the current study, the exercise group that also underwent manual therapy showed a significant difference in the measured parameters, likely because the normalization of joint motion through manual therapy affected proprioception.

It was reported that degenerative OA patients have many limitations in using the stairs, standing up from a chair, walking, standing upright, and the like, and that when arthroplasty is performed on the knee joint, pain generally disappears within two months, but functional performance tends not to improve. This suggests that pain is related to functional performance but is not proportional to it.\(^{36}\) These studies also imply that, besides pain and muscle strength, there are other factors indicating functional performance vis-à-vis the activities of daily life. It was reported that an increase in muscle strength of the elderly is a major factor for improving functional performance, and the weakening of the quadriceps femoris muscle in degenerative OA patients decreases functional performance and thus determines the severity of disability.\(^{37}\) According to previous research, the weakening of the quadriceps femoris muscle
correlates with a decrease in joint position sense and a degradation of functional performance. Furthermore, a weakening of muscle strength and degradation of proprioception both affect functional performance. In addition, improvements in functional performance that were brought about through resistive exercise have been observed in women, because muscle coordination improved proprioception and, consequently, enhanced functional performance. These previous studies’ results suggest that muscle strength and proprioception need to be improved first, in order to improve functional performance. In the current study, different from the RT group, the MT group showed improvements in both muscle strength and proprioception, probably because proprioception improved as result of improvements in muscle strength and affected functional performance. This study focused on comparison and verification of the effects of two different exercise regimens on degenerative OA patients. In future research, we will need to compare the effects in terms of severity of degenerative OA, while noting post-intervention musculoskeletal functions, medication use, patient satisfaction, socio-economic costs incurred, and the like.

REFERENCES


