Effects of Weight-Bearing Versus Nonweight-Bearing Exercise on Function, Walking Speed, and Position Sense in Participants With Knee Osteoarthritis: A Randomized Controlled Trial

Mei-Hwa Jan, MS, PT, Chien-Ho Lin, PhD, PT, Yeong-Fwu Lin, MD, PhD, Jiu-Jenq Lin, PhD, PT, Da-Hon Lin, MD


Objective: To investigate whether weight-bearing (WB) exercise enhances functional capacity to a greater extent than nonweight-bearing (NWB) exercise in participants with knee osteoarthritis.

Design: Randomized controlled trial.

Setting: Kinesiology laboratory.

Participants: Participants (N=106) were randomly assigned to WB exercise, NWB exercise, or a control group (no exercise).

Intervention: WB exercise and NWB exercise groups underwent an 8-week knee extension-flexion exercise program.

Main Outcome Measures: Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) function scale, walking speed, muscle torque, and knee reposition error were assessed before and after intervention.

Results: Equally significant improvements were apparent for all outcomes after WB exercise and NWB exercise, except for reposition error, for which improvement was greater in the WB exercise group. In contrast, there were no improvements in the control group.

Conclusions: Simple knee flexion and extension exercises (WB and NWB) performed over 8 weeks resulted in significant improvement in the WOMAC function scale and knee strength compared with the control group. NWB exercise alone may be sufficient enough to improve function and muscle strength. The additional benefit of WB exercise was improved position sense, which may enhance complex walking tasks (walking on figure of 8 route and spongy surface).

Key Words: Exercise; Kinematics; Knee; Osteoarthritis; Rehabilitation.

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THE PREVALENCE OF KNEE OA increases with advancing age.1-3 People with knee osteoarthritis are usually frustrated with knee pain, joint stiffness, decrease of muscle strength, and deficit of proprioception. Subsequently, they often have poor neuromuscular control, reduced walking speeds, decreased functional ability, and an increased susceptibility to fall.4-6 In clinical practice, rehabilitation was often intended to increase muscle strength and to enhance proprioceptive function.7,8

The benefits of WB exercises are becoming increasingly accepted and employed in the clinical setting. WB exercise of the lower extremity is typically performed with feet fixed on a stable object that generates compressive forces in the hip, knee and ankle joints. WB exercise has been shown to increase muscle strength and neuromuscular control of the lower extremity in young athletes.9,10 Giving exercise in standing or WB positions to participants with painful knee OA might aggravate symptoms such as pain, swelling, and inflammation if the knee joint is overloaded.11,12 However, conventional strength training and proprioception facilitation are usually performed in standing or in WB.

NWB exercises, where the distal extremity is free to move, have been thought to improve muscle strength rather than to improve proprioception during knee flexion and extension. The effects of NWB exercises in elderly participants with knee OA have not been well characterized. The purpose of this study was to investigate whether WB exercise is better than NWB exercise in increasing knee function in participants with knee OA. We hypothesized that the WB exercise group would have the greatest improvement in knee function, followed by the NWB exercise, and then the control group.

List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ANOVA</td>
<td>analysis of variance</td>
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<tr>
<td>ICC</td>
<td>intraclass correlation coefficient</td>
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<tr>
<td>NWB</td>
<td>nonweight-bearing</td>
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<td>OA</td>
<td>osteoarthritis</td>
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<td>RM</td>
<td>repetitions maximum</td>
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<tr>
<td>WB</td>
<td>weight-bearing</td>
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<td>WOMAC</td>
<td>Western Ontario and McMaster Universities Osteoarthritis Index</td>
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From the School and Graduate Institute of Physical Therapy, College of Medicine, National Taiwan University and the Physical Therapy Center, National Taiwan University Hospital (Jan, J.-J. Lin), Department of Orthopaedics, West Garden Hospital (Y.-F. Lin), Department of Orthopaedics, En Chu Kong Hospital (D.-H. Lin), Taipei, Taiwan; and the Department of Neurology, University of California, Los Angeles, CA (C.-H. Lin).

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METHODS

Participants

The diagnosis of knee OA was made by 2 orthopedic surgeons after clinical history and physical examination. Each participant met the American College of Rheumatology criteria for knee OA and exhibited radiographic changes (OA grade of 3 or lower; mild and moderate OA). Additional inclusion criteria were as follows: age 50 years or older, chronic knee pain for 6 months or more, willingness to cease medication, and bilateral knee OA. Participants were excluded if they had other musculoskeletal problems associated with the knee joint, such as tendon/ligament tears, or other unstable medical conditions.

One hundred eighteen participants were screened, and 106 participants were enrolled in this study. All participants gave informed consent on enrollment, and the study protocol was approved by the Ethics Committee of the National Taiwan University Hospital.

Participants were randomly divided into 3 groups using random number tables. These groups were WB exercise, NWB exercise, and a control group (no exercise) with 36, 35, and 35 participants, respectively. During follow-up, 3 participants in the WB exercise group and 2 participants in the NWB exercise group discontinued the training program because of knee pain. Four participants in the control group refused to participate in the follow-up assessment for personal reasons. Among the participants who completed the study, 4 participants in the WB exercise group and 2 participants in the NWB exercise group could not tolerate beyond 60% of 1 RM (fig 1). Participants in the control group received WB exercise or NWB exercise training at their discretion after the 8-week study period.

Weight-Bearing Exercise

Participants performed the WB exercise in a sitting position, with 1 foot fixed on the center of the pedal of an EN-Dynamic resistance device. Participants were asked to extend fully and then flex the knee joint from 90° of knee flexion at a speed of 90°/2s (fig 2A).

Nonweight-bearing Exercise

Participants were positioned with their back facing the EN-Treex and were instructed to sit comfortably in the chair and maintain the knee at 90° of flexion with a free distal extremity. For resistance training, a pad (attached to the cable of the isoton dynamometer) was placed on the anterior aspect of the distal lower leg (fig 2B). Participants were asked to extend the knee joint from 90° of knee flexion to full extension and then to flex the knee joint to the starting position with eccentric contraction of quadriceps at a speed of 90°/2s.

Fig 1. The CONSORT Flow Diagram showing the flow of participants through each stage of our randomized trial. Abbreviations: NWBE, nonweight-bearing exercise; WBE, weight-bearing exercise.
Participants in the WB exercise and NWB exercise groups underwent an 8-week program with 3 sessions a week. Each session consisted of 4 sets, with 6 repetitions a set and 1 minute of rest between each set. Before training, the 1 RM of each participant’s quadriceps was determined using the EN-Dynamic. At the first training session, resistance was set at 50% of 1 RM, and was thereafter increased by 5% every 2 weeks as tolerated. Before exercise training, participants rode a stationary bicycle at a comfortable speed with mild resistance for 10 minutes. Postexercise, cold packs were applied to each knee for 10 minutes. Both legs were exercised, with 5 minutes of rest between right and left knee training.

**WOMAC Physical Function Assessment**

The function of the most severe knee was assessed using the physical functional subscales of the WOMAC. A total of 17 tasks were included, such as walking up and down stairs, standing up, bathing, and general housework. The capacity of participants to perform a variety of tasks was scored between 0 and 4, with 4 indicating greater difficulty and 0 indicating no difficulty. Thus, the maximum overall score, which indicates severe disability, was 68 points.

**Walking Speed Over 4 Different Terrains**

To test walking speed, participants were required to walk as fast as possible along a 60-m–long level-ground hard surface, around a figure of 8 made of 2 circles (each with a 50-cm radius), and up and down a 13-step staircase (each step was 16 cm high, 30 cm long, and 80 cm wide). In addition, walking speed was tested on a 12-m–long spongy surface that was 10 cm in height and 21 shore 000 (medium) in hardness. The walking time was recorded using a stopwatch that could accurately measure to 0.01 second. The between-session (1-week interval) intrarater reliability of walking speed was examined in a preliminary study of 10 young, healthy participants and was found to be 0.81, 0.94, 0.85, and 0.88 on the level ground, up-down stairs, figure of 8, and spongy surface walking trials, respectively.

**Muscle Torque Tests**

Concentric muscle torque of bilateral knee extensors and flexors was tested at 60, 120, and 180°/s using a Cybex 6000 isokinetic dynamometer. The strength testing was carried out in the order of 120°/s, 180°/s, and then 60°/s to control for the effects of fatigue. Standard positioning was used for this assessment. Participants sat leaning against a backrest inclined 15° backward from vertical and were secured to the machine at the upper chest, pelvis, and distal femur on the tested side. The participants were instructed to extend the knee as far as possible, and then to flex as far as the device allowed. Among the records of the 3 trials at each speed, the highest values were recorded as the peak torque. All data were corrected for gravity. The between-session intrarater reliability of muscle torque was examined in a preliminary study in which 10 healthy college students performed 2 trials for each angular velocity. The ICC values were 0.81, 0.82, and 0.82 at 60, 120, and 180°/s of extension, respectively, and 0.80, 0.84, and 0.80 at 60, 120, and 180°/s of flexion, respectively.

**Reposition Error Test**

Participants were placed in a supine position and blindfolded. The tested ankle and foot were fixed with an air splint.
to eliminate any somatosensory input. Each participant placed the foot on the center of the pedal of the Shuttle Mini Clinic device. The resistance of the pedal was set at 15% of body weight. A previous study from our laboratory indicated that 15% body weight resistance, as suggested by the Birmingham guideline, was associated with high intertrial and intrater reliability. The electromyometer was attached to the lateral side of the tested leg across the knee joint with adhesive tape so that the 2 arms of the electromyometer were lined up with the axis of the thigh and the leg, respectively. The starting angle of the test was set at a knee flexion angle of 90°. Participants were then instructed to extend the knee joint to a target angle between 0° and 90° of flexion, hold that position for 5 seconds, and return to the starting angle for 10 seconds, before extending the knee again to match the target angle as well as possible. The knee reposition error was defined as the absolute difference between the reproduction angle and target angle. The same test procedure was performed twice. The mean value of the 2 absolute reposition angles was used for further statistical analysis. The between-session (1-wk interval) intrarater reliability was calculated on 10 young healthy participants. The ICC 2,2 was 0.83.

Procedure

All participants underwent an initial baseline assessment of WOMAC physical functional subscale, walking speeds on 4 different terrains, muscle torque, and knee reposition error in sequence. The walking speed test included 2 walking trials each for walking on a level hard surface, up and down stairs, a figure 8 path, and the spongy surface. Participants were instructed to walk as fast as possible except when walking on the spongy surface. When walking on the spongy surface, participants were instructed to walk at a comfortable speed to avoid falling. The mean of the 2 walking trials (measured in seconds) was used for further data analysis. For the reposition error test, the leg tested first was randomly selected to prevent a possible sequence effect.

At the completion of the 8-week intervention period, all participants received a follow-up assessment within 3 days. The procedures of assessment were as described for initial baseline assessment. The measurements of muscle torque and joint reposition error included both legs in the analysis of between-group differences because walking speed was the concomitant effort of both legs and the sampling of 1 limb for 1 person might not simulate the independent variable appropriately. All evaluations were performed by the same examiner, who was blinded to participant treatment.

Data Analysis

The distribution of participants by sex and the OA grades based on radiographs among the 3 groups were compared using the chi-square test. Baseline values for function, walking time on 4 different terrains, and muscle torque of the knee were compared among groups using a 1-way ANOVA. A 3×2 two-way ANOVA was used to compare the effects of group (NWB exercise, WB exercise, control) and timing (preintervention, postintervention). When interactions were detected, a post hoc analysis with Bonferroni adjustment (P<.008) was employed. An intention-to-treat analysis was performed that included all dropouts. Statistical significance was set at P<.05.

RESULTS

Table 1 presents the demographic information of the 3 study groups. There were no significant differences in age, sex distribution, body height or weight, or the OA grade among the 3 groups (P>.05).

Table 1: Basic Demographic Data on the Participants

<table>
<thead>
<tr>
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<th>WB N=36</th>
<th>NWB N=35</th>
<th>Control N=35</th>
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<tbody>
<tr>
<td>Age (y)</td>
<td>62.0±6.7</td>
<td>63.2±6.8</td>
<td>62.2±6.7</td>
</tr>
<tr>
<td>Sex (W:M)</td>
<td>24:12</td>
<td>25:10</td>
<td>24:11</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>160.5±7.5</td>
<td>159.2±7.3</td>
<td>156.2±8.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>63.3±10.2</td>
<td>63.7±10.3</td>
<td>62.2±10.2</td>
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</table>

NOTE. Data are presented as mean ± SD unless otherwise stated. Abbreviations: M, men; W, women.

Improvements of Functional Scale, Walking Speed, and Reposition Error

The 2-way ANOVA for repeated measures on the time factor revealed significant interaction effects for the WOMAC functional scale, walking time on 4 different terrains, and reposition error (P<.001). Post hoc analyses indicated that, compared with the preintervention values, the WOMAC function and walking times on 4 different terrains had significant improvements in both the WB and the NWB groups (P<.008). Regarding reposition error, significant improvement was found only in the WB group (P<.008). In contrast, these variables were not changed in the control group. The post hoc analyses also indicated that, after intervention, participants in both exercise groups showed improvement in the WOMAC functional scale greater than the control group (P<.008) (table 2); however, there was no difference between the WB and NWB exercise groups. Participants in the WB exercise group displayed significantly greater improvements in walking speed on the figure of 8 and spongy surface as well as reposition error compared with the NWB exercise and control groups (P<.008) (see table 2). Participants in the NWB exercise group exhibited significant improvements in walking speed up and down stairs over the control and WB exercise groups (P<.008). There were no significant differences in walking speed on level ground between the groups, and no difference in walking speed on figure 8 or spongy surface and reposition error between the NWB exercise and control groups after the intervention (P>.008).

Improvements of Knee Muscle Torque

Table 3 shows the changes in muscle torque for the 3 groups. Compared with the preintervention values, the peak torque of the knee extensors and flexors at the 3 velocities of muscle contraction was significantly greater in the NWB and WB exercise groups (P<.008). In contrast, the control group was not changed. After intervention, there was a significantly greater increase in knee extensor and flexor torque at the 3 velocities of muscle contraction in the WB exercise group compared with the control group (P<.008). The NWB exercise group showed significantly greater improvements in knee extensor torque for each angular velocity compared with the control group (P<.008). There was no significant difference in muscle torque for any angular velocity between the WB and NWB exercise groups after intervention (P>.008).

DISCUSSION

Both WB and NWB exercises were associated with significant improvements in WOMAC physical function scale compared with the control group. In contrast, the control group did
### Table 2: Improvement of Functional Score, Walking Time, and Reposition Error in the 3 Groups

<table>
<thead>
<tr>
<th></th>
<th>WB Group</th>
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<th>NWB Group</th>
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<th>Control Group</th>
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<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Effect Size</td>
<td>Pre</td>
<td>Post</td>
<td>Effect Size</td>
<td>Pre</td>
<td>Post</td>
<td>Effect Size</td>
</tr>
<tr>
<td>Functional score</td>
<td>22.6±10.1</td>
<td>12.3±9.8*</td>
<td>−10.3 (−8.5 to −12.2)†</td>
<td>27.3±9.5</td>
<td>10.1±10.3*</td>
<td>−17.2 (−14.6 to −19.8)†</td>
<td>24.8±10.7</td>
<td>25.0±11.8</td>
<td>0.2 (1.3 to −1.0)</td>
</tr>
<tr>
<td>Walking time (s)</td>
<td></td>
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<tr>
<td>Level ground</td>
<td>39.1±7.6</td>
<td>36.0±5.7*</td>
<td>−3.1 (−2.2 to −4.0) 0.47</td>
<td>38.0±7.0</td>
<td>34.6±6.0*</td>
<td>−3.4 (−2.7 to −4.2) 0.53</td>
<td>38.9±6.5</td>
<td>38.9±3.8</td>
<td>0.1 (0.5 to −0.4)</td>
</tr>
<tr>
<td>Stair</td>
<td>13.2±3.1</td>
<td>11.8±3.0*</td>
<td>−1.4 (−0.8 to −2.0) 0.45</td>
<td>14.4±4.3</td>
<td>10.0±3.1*</td>
<td>−4.4 (−3.8 to −4.9)† 0.60</td>
<td>15.2±3.6</td>
<td>15.4±4.0</td>
<td>−0.05</td>
</tr>
<tr>
<td>Figure 8</td>
<td>9.7±2.7</td>
<td>6.3±2.4*</td>
<td>−3.3 (−3.0 to −3.7)† 1.31</td>
<td>8.8±2.1</td>
<td>7.4±2.6*</td>
<td>−1.4 (−1.1 to −1.8) 0.60</td>
<td>8.9±2.8</td>
<td>8.6±2.3</td>
<td>−0.3 (2.0 to −2.5)</td>
</tr>
<tr>
<td>Sponge</td>
<td>11.2±3.3</td>
<td>5.8±2.9*</td>
<td>−5.4 (−3.7 to −7.0)† 0.8 to 1.9) 1.73</td>
<td>11.3±3.6</td>
<td>9.4±3.8*</td>
<td>−1.9 (−1.4 to −2.3) 0.51</td>
<td>11.8±3.6</td>
<td>11.7±3.7</td>
<td>−0.1 (0.6 to −0.7)</td>
</tr>
<tr>
<td>Reposition error</td>
<td>4.8±1.7</td>
<td>2.0±1.7*</td>
<td>−2.8 (−2.5 to −3.1)† 1.62</td>
<td>5.0±1.9</td>
<td>4.4±2.0</td>
<td>−0.6 (1.2 to −2.4) 0.31</td>
<td>4.3±1.7</td>
<td>5.1±1.5</td>
<td>0.8 (2.0 to −0.4)</td>
</tr>
</tbody>
</table>

Abbreviation: CI, confidence interval.
*Significant difference between pre and post training (P<.008).
†Significant difference compared with the control group (P<.008).
‡Significant difference between the WB exercise and NWB exercise groups (P<.008).

### Table 3: Improvement of Muscle Torque in the 3 Groups

<table>
<thead>
<tr>
<th></th>
<th>WB Group</th>
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<th></th>
<th>NWB Group</th>
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<th></th>
<th>Control Group</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Effect Size</td>
<td>Pre</td>
<td>Post</td>
<td>Effect Size</td>
<td>Pre</td>
<td>Post</td>
<td>Effect Size</td>
</tr>
<tr>
<td>Extensor 60°/s</td>
<td>72.3±26.5</td>
<td>83.2±24.8*</td>
<td>10.9 (8.2 to 15.5)† 0.43</td>
<td>74.2±23.6</td>
<td>89.1±27.1*</td>
<td>14.9 (10.1 to 19.6)† 0.59</td>
<td>73.2±27.3</td>
<td>73.6±24.0</td>
<td>0.4 (−1.4 to 2.1)</td>
</tr>
<tr>
<td>120°/s</td>
<td>60.6±22.8</td>
<td>68.6±20.1*</td>
<td>8.0 (3.4 to 12.6)† 0.37</td>
<td>58.7±20.3</td>
<td>70.4±21.6*</td>
<td>11.7 (7.6 to 15.7)† 0.56</td>
<td>60.3±23.9</td>
<td>60.9±22.5</td>
<td>0.6 (−0.6 to 1.9)</td>
</tr>
<tr>
<td>180°/s</td>
<td>47.0±18.8</td>
<td>53.0±19.7*</td>
<td>6.2 (2.1 to 10.3)† 0.31</td>
<td>45.3±18.4</td>
<td>55.6±18.7*</td>
<td>10.3 (6.4 to 14.3)† 0.56</td>
<td>45.4±22.9</td>
<td>46.0±20.2</td>
<td>0.6 (−0.8 to 1.9)</td>
</tr>
<tr>
<td>Flexor 60°/s</td>
<td>45.1±16.2</td>
<td>55.2±20.2*</td>
<td>10.1 (8.3 to 12.0)† 0.56</td>
<td>46.8±19.5</td>
<td>51.2±19.8*</td>
<td>4.4 (3.0 to 5.7) 0.22</td>
<td>40.6±17.2</td>
<td>41.6±18.1</td>
<td>1.0 (−0.2 to 2.3)</td>
</tr>
<tr>
<td>120°/s</td>
<td>36.6±16.6</td>
<td>44.5±17.2*</td>
<td>7.9 (6.8 to 8.9)† 0.46</td>
<td>39.7±16.3</td>
<td>43.6±17.9*</td>
<td>3.9 (2.5 to 5.2) 0.23</td>
<td>38.0±15.6</td>
<td>39.0±17.8</td>
<td>1.0 (−0.3 to 2.3)</td>
</tr>
<tr>
<td>180°/s</td>
<td>32.5±15.0</td>
<td>40.2±15.6*</td>
<td>7.7 (6.7 to 8.8)† 0.51</td>
<td>33.8±16.5</td>
<td>38.0±17.8*</td>
<td>4.2 (2.8 to 5.5) 0.24</td>
<td>33.2±14.8</td>
<td>34.4±15.3</td>
<td>1.2 (−0.0 to 2.3)</td>
</tr>
</tbody>
</table>

*Significant difference between pre and post training (P<.008).
†Significant difference compared with the control group (P<.008).
not show significant changes for any of the outcomes measured. It is noteworthy that WB exercise particularly improved the knee joint reposition sense.

In the current study, all participants showed reduced muscle torque and knee joint position sense at baseline compared with age-matched healthy controls in previous reports.²⁰,²¹ The mean knee extensor torque (180°/s) values in the current (OA knee) and previous study (healthy participants) were about 45Nm and 53Nm, respectively. The mean flexor torque values were around 33Nm and 39Nm respectively, and the mean angles of absolute reposition error were approximately 4.6° and 2.3°. Therefore, it is apparent that exercise programs emphasizing muscle strengthening and proprioception enhancement are indicated for participants with knee OA.²²

Previous investigators have reported that, by using elastic resistance devices, older adults can improve lower-extremity strength by 6% to 26% and decrease the percentage of disability by 15% to 18%.⁸⁻¹⁰,²³,²⁴ It is therefore reasonable to expect that participants with OA who undergo either WB or NWB resistance exercise training will exhibit improvements in functional capacity. Our study showed that both WB and NWB exercises improved strength by about 18% and decreased disability by 50% compared with the baseline measurement. To date, few studies have compared the effects of WB exercise and NWB exercise on functional capability (including walking speed on different terrains) in participants with knee OA.

Many researchers have concluded that knee muscle strength is closely related to knee function.²⁵⁻²⁶ In the Bristol OA knee study,²⁶ quadriceps weakness was found to be the single greatest predictor of limited lower limb function, exceeding that of knee pain. In the current study, the improvement in the WOMAC functional scale moderately correlated with extensor torque in both training groups (r=0.63–0.72). Thus, the important role of knee extensor strength in lower limb function was partially supported in our study.

Jan et al.²⁰ reported that participants with knee OA who participated in 8 weeks of a leg stretching and strengthening program significantly improved walking speed by 10%. Similarly, O’Reilly et al.²⁰ noted that resistance training exercises decreased pain during walking and stair climbing by 19% and 21%, respectively. We found that the percentage improvements in walking speed (compared with baseline) for WB and NWB exercises were as follows: level ground (8.7%, 8.9%), stairs (18.6%, 29.9%), figure 8 (38.1%, 15.9%), and spongy surface (39.3%, 16.8%), respectively. It is worth noting that the greatest improvement from baseline for NWB exercise participants was stair-walking, whereas the WB exercise group showed the greatest improvement in figure 8 and spongy surface walking.

Riener et al.²⁰ reported that knee extensor torque is most employed during walking up and down stairs, compared with traversing the other terrains. However, in our study, knee extensor torque improvement in the NWB exercise group was not significantly greater than in the WB exercise group. Thus, we hypothesized that other factors such as balance and co-contraction of knee flexor/extensor in addition to knee extensor torque should be considered in stair-walking improvement. Previous studies have shown enhanced improvements in proprioception by decreasing the base of support, decreasing the stability of the surfaces, increasing the number of repetitions, and increasing the speed and complexity of tasks.²⁸⁻²⁹ Given this, we believe that the greater improvements in walking speed on the spongy surface and figure 8 path in the WB exercise group were a result of corollary improvements in reposition sense. In addition, WB exercise might optimize neuromuscular control of the knee joint and facilitate faster walking speeds on curved paths or uneven floors. Considering the impact of falls on a person’s health and well being in the elderly population from the literature, the WB exercise training results in our study may be relatively important. Further research is warranted to investigate whether WB exercise is beneficial for better neuromuscular control and reduced risk of fall in the elderly.

In the current study, the percent improvements in knee extensor and flexor torque were 14% and 22% in the WB exercise group and 21% and 11% in the NWB exercise group, respectively. The improvement of flexor torque in the WB exercise was greater than that in the NWB exercise group. Previous studies have reported similar findings.³⁰,³¹ Shields et al.³¹ found that single-limb squatting may help simultaneously strengthen the quadriceps and facilitate coactivation of the hamstrings. In addition, the WB exercises used the ankle and hip muscles as well as the knee muscles; however, the NWB exercises mostly used the isolated knee extensor muscles, performed from 90° of knee flexion to full extension with concentric action of quadriceps, and then flexing the knee joint to the starting position with eccentric action of quadriceps. It is different from as-usual knee extension with concentric quadriceps followed by knee flexion with concentric hamstrings. This may explain why a greater improvement of knee extensor strength was observed in the NWB exercise group.

In this study, there was a greater improvement in reposition sense in the WB exercise compared with the NWB exercise participants. Previously, WB exercise has been shown to enhance proprioceptive performance in athletes and young men.³²,³³ Hurd et al.³³ and Hilberg et al.³⁵ also reported that WB exercise alters muscle activity, leading to normal quadriceps-hamstrings balance and increased joint reposition acuity. WB exercise is thought to enhance knee joint proprioception by increasing intra-articular pressure and thereby stimulating Ruffini nerve endings, which are sensitive to changes in intra-capsular fluid volume.³⁶ A review of the pertinent literature reveals that the magnitude of improvement in reposition sense varies with baseline error and the severity of disease. Improvements in reposition sense in participants with hemophilia, participants with patellofemoral pain, and young healthy participants after various resistance exercises were 5.5°, 1°, and 2.1°, respectively.³⁵,³⁷,³⁸ Lin et al.³⁸ reported that an 8-week leg press regimen (WB exercise) with resistance set at 10% to 25% of body weight improved joint reposition acuity by 2.0° in participants with knee OA. In the current study, we found that WB exercise improved reposition sense by 2.8°. The minimal detectable change with a 95% confidence interval for reposition error was 1.9° in the current study; therefore, we declared that WB exercise could significantly improve joint reposition error in our study. It is possible that the leg press exercise may help strengthen the quadriceps and hamstrings simultaneously, while also using the hip and ankle joints. This would therefore provide feedback from the entire lower extremity (rather than simply from the exercised joint in NWB exercise), and hence increase stimulation of mechanoreceptors around the joint and firing muscle spindles.³¹⁻³⁵ In addition, the reposition error test included hip, knee, and ankle motions, more closely paralleling the WB exercise than the NWB exercise pattern. In contrast, NWB exercise, consisting of either concentric 90° full knee flexion to extension or the reverse motion in an eccentric contraction, presumably results in the knee extensors being selectively strengthened. There is most likely less activation of the related sensory nerves with NWB exercises than WB exercises. This could explain why a significant improvement in reposition sense was not evident after NWB exercise intervention.

Given the vital role proprioception plays in coordinating and refining motor activity, a link between proprioceptive deficits
and functional disability might be expected. Several studies have reported poorer proprioception (as assessed by the Lequesne Index score, stair climbing time, and walking speed) in participants who are more disabled.\textsuperscript{39-41} In the current study, however, the greater improvements in joint reposition sense in the WB exercise compared with NWB exercise participants were not associated with improvements in WOMAC functional scale in either group. Other researchers have similarly found that deficits in joint position sense in participants with knee OA do not affect the severity of disability.\textsuperscript{2-4,42} The lack of an association between proprioceptive acuity and disability in knee OA may relate to the magnitude of proprioceptive deficits. Thus, we speculate that a certain proprioceptive deficit threshold must be reached before physical function is affected. On the other hand, the enhanced joint reposition sense in the WB exercise group may be related to more skillful and difficult tasks (figure 8 and spongy surface walking in our study) than the activities listed in WOMAC scale.

Study Limitations

One limitation of the study is that we evaluated participants’ knee pain with pain tolerance of functional activity instead of a visual analog scale. In the future, we should include both measurements for a comprehensive clinical picture. The resistance training was a closed kinetic chain in the WB exercise group and an open kinetic chain in the NWB exercise group, while the strength testing was an open kinetic chain. Interpretation of our results should consider the congruency between training and testing. Further, NWB exercise might be as good as WB exercise, but likely only if there is strong eccentric quadriceps overload built into the design of the NWB exercise. We also acknowledge that the measurements of joint reposition error were influenced by many factors, and the test did not use a large number of stimuli, as suggested by the principles of psychophysics. Therefore, the results should be interpreted with caution.

CONCLUSIONS

This study showed that even simple knee flexion and extension exercises performed over 8 weeks significantly improve knee strength and functional capacity in participants with knee OA. There were no significant differences in functional improvement after WB exercise and NWB exercise. Based on the results of our study, we suggest that participants with mild and moderate knee OA perform either WB exercise or proprioceptive training in addition to NWB exercise to improve gait.

References


**Suppliers**

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