
Objective: To understand the mechanical and sensorimotor adaptations that may occur with ankle osteoarthritis (OA).

Design: Case-control.

Setting: Biodynamics research laboratory.

Participants: Subjects with ankle OA (n=8; 4 males, 4 females) were matched to healthy controls (n=8; 4 males, 4 females).

Interventions: Not applicable.

Main Outcome Measures: Mechanical joint stability was assessed with an instrumented ankle arthrometer. Static balance was measured using a force platform during a double-legged stance. Isometric ankle/foot complex strength in the sagittal and frontal plane was assessed with a handheld dynamometer. Last, subjective level of function was assessed using the foot and ankle disability index.

Results: There were significant group × side interactions for anterior displacement, inversion rotation, eversion rotation, ankle isometric strength, and the foot and ankle disability index (P<.05). The affected ankle of the OA group demonstrated significantly more mechanical stiffness, more impairments in ankle/foot isometric strength, and less subjective level of function than the matched controls. Additionally, the ankle OA group exhibited significantly more center of pressure displacement, total velocity, and mediolateral velocity (P<.05).

Conclusions: These limitations observed in joint laxity, postural control, muscle strength, and perceived function provide evidence that patients with ankle OA display a number of characteristics that affect joint stability and overall function. These identified impairments necessitate the need for rehabilitation and exercise programs to be developed to help improve joint stability and function in patients with ankle OA.

Key Words: Ankle joint; Osteoarthritis; Rehabilitation.

OSTEOARTHRITIS IS THE MOST common form of arthritis and is a major cause of morbidity and disability.1 Specifically, OA affects approximately 60% of the population in the United States over the age of 65 years. Although the prevalence of ankle OA is not well known compared with that of the hip and knee joint, recent research has identified that a larger number of patients are being diagnosed with ankle OA.2

There are several reported causes of ankle OA.2-7 These include primary osteoarthritis, systematic osteoarthritis (rheumatoid arthritis and other systemic diseases), and posttraumatic osteoarthritis. Posttraumatic OA is the most common form, accounting for more than 70% of all ankle OA cases.2-8 It has been surmised that fractures of the malleoli, tibial plafond, and the talus can lead to posttraumatic OA.2,5 Additionally, research has reported ligament lesions to be a significant cause of posttraumatic OA.3,4,6,8 Inadequate ligament healing after the initial ankle sprain likely leads to the development of development of CAI,9 which then progresses to ankle OA. Previous research3,4,6 has reported that a high percentage (66%-78%) of patients with CAI develop ankle OA. There appears to be a relationship among previous ligament damage, CAI, and the development of ankle OA.

Previous research has demonstrated mechanical9-11 and sensorimotor12-15 impairment in subjects with CAI. Decreased mechanical stability and sensorimotor impairment can lead to decreased function and potentially lead to further degeneration of the articular surfaces, accelerating the development of posttraumatic OA. However, the magnitude of these effects has not been quantified in patients with ankle OA. It is known, however, that OA can affect load-bearing function and range of motion observed at the ankle joint complex.16,17 Subjects with ankle OA have reported severe limitations in mobility, fine motor skills, housework, leisure activities, and relationships with family.5,15,16,18 These functional limitations can also impact the subjects cognitively and emotionally. It is speculated that these impairments in subjective level of function could be a result of deficits in the mechanical and sensorimotor system.

Ankle replacement surgeries are expected to increase approximately 5% a year19; this anticipated increase necessitates examination into the prevalence, causes, effects, and treatment of ankle OA. Specifically, the need to examine the mechanical and sensorimotor changes in patients with ankle OA has now emerged. By understanding the changes that may occur with
ankle OA, better rehabilitation and nonsurgical treatment paradigms can be further developed to address the specific mechanical and sensorimotor changes. By designing more effective treatments, functional limitations reported by patients with ankle OA could be significantly decreased, which could potentially decrease the need for joint replacement surgery. Therefore, the purpose of this study is to examine a selection of mechanical and sensorimotor measures in patients with ankle OA compared with healthy controls matched for age, weight, height, and sex. We hypothesized that we would see decreased mechanical laxity, impaired static balance, and decreased isometric strength in those with ankle OA.

METHODS

Subjects

Eight subjects with unilateral ankle osteoarthritis (4 males, 4 females; age, 51.8±11.41y; mass, 88.2±21.16kg; height, 175.6±9.5cm) and 8 healthy controls matched for sex, age, weight, and height (4 males, 4 females; age, 51.5±11.2y; mass, 85.3±20.1kg; height, 172.2±10.5cm), participated in this study. All patients with ankle OA were diagnosed with unilateral secondary ankle OA via radiographic evidence by an orthopedic surgeon. The cause of the subject’s ankle OA was a previous history of ligamentous injury at the ankle. All subjects reported a previous history of repetitive ankle sprains and giving way at the ankle. None of the subjects had sustained an ankle sprain within at least a year of inclusion in the study. The severity of ankle OA was not controlled in this study (although all subjects had early-onset, grade 1 or 2 ankle OA). All subjects with OA reported pain to be mild or moderate during ankle testing. No subjects reported their current pain at the time of testing to be severe or unbearable. Subjects in both groups were excluded if they had a previous history of lower-extremity fracture, history of ankle surgery, significant axial alignment asymmetry, rheumatoid arthritis, diabetes, neuropathies, vestibular, proprioceptive or eye disorders, chronic narcotic use, and gout. Healthy control subjects could have no significant history of lower-extremity injury or history of injury to either ankle within the previous 2 years. All subjects gave written informed consent prior to participating, approved by institutional review boards at the university and the medical center.

Procedures

Data collection took place in the Biodynamics Research Laboratory at our university, where measures of mechanical stability, static balance, isometric strength, and subjective level of function were taken on all subjects. The examiners collecting these data were blind to the subjects’ ankle injury history. All measures were taken according to a counterbalanced Latin square design to avoid any potential order effects of testing. All measurements were taken on both lower extremities of each subject.

Mechanical stability measurement. Instrumented measurement of ankle-subtalar joint stability was performed using a portable ankle arthrometer. Measurements from the ankle arthrometer have been reported to be highly reliable and valid for assessing ankle ligamentous stability. The methods we used for subject positioning and the testing procedures in this study were identical to those previously reported. In brief, subjects were positioned supine on the treatment table with the hip and knees in extension. The ankle was kept in a neutral position (0° of flexion) throughout testing. To measure AP laxity, the ankles were loaded with 125N in each direction. Starting at the neutral position, an anterior load was applied initially, followed by a posterior load. For inversion-eversion laxity, the ankles were loaded to 4000N per mm of inversion and eversion torque. Starting at the neutral position, inversion loading was applied first, followed by eversion loading. There was 1 trial performed for each direction. Dependent measures were the amount of anterior and posterior laxity in millimeters and the inversion and eversion laxity in degrees.

Static balance measurement. A nonconductive force platform interfaced to a multipurpose data acquisition system was used for measurement of COP variables. Three translational forces (Fx, Fy, Fz) and 3 moments of force (Mx, My, Mz) were sampled at 500Hz (gain set to 1.0) and digitally filtered using a second-order low-pass Butterworth digital filter with the cut-off frequency set at 6Hz. The force platform was calibrated before the data collection period for each subject.

Subjects were instructed to step onto the force platform with the right leg on one side and the left leg on the other side of the center of the force platform. They were instructed to assume a double-legged stance with hands resting at their sides and were asked to stand as motionless as possible while looking straight ahead at a designated mark on the wall. Data sampling was initiated 3 seconds after the subject was properly positioned on the force platform. Subjects were required to successfully maintain the stance position for 20 seconds a trial for a total of 5 trials, with a 45-second rest period between trials.

The dependent variables measured included total COP displacement (mm), total velocity (mm/s), ML displacement (mm), AP displacement (mm), ML velocity (mm/s), and AP velocity (mm/s). Total COP displacement was measured as the sum of the instantaneous displacement in the ML and AP directions. Total velocity was measured as the rate of change of displacement (mm/s). Displacement (mm) in the ML (or AP) direction was calculated as the distance of the final position from the original position.

Isometric ankle/foot strength measurement. Isometric strength was measured using a MicroFet 2 handheld dynamometer. The subject was positioned on a treatment table with their hips and knees extended at 0°. The dynamometer was placed on the hand of the investigator. The subject’s ankles were placed in mid plantar flexion, dorsiflexion, inversion, and eversion for testing. Subjects were then instructed to push as hard as they could against the investigator for 5 seconds. Three maximal repetitions were performed in each direction. The mean peak force/body weight for each direction was recorded. Each limb was measured separately. Before data collection began, 10 healthy subjects not participating in the study were used for reliability analysis. Intratester reliability for strength was evaluated by calculating ICC3,1. The SE of measurement was calculated as an additional measure of precision. Inter-strength reliability was high for all strength variables.

Subjective level of function. All subjects filled out the FADI. The main section of the FADI assesses activities of daily living, while the sports scale assesses more difficult tasks that are essential to exercise/activity. A 104-point scale is used for the FADI, and a 32-point scale is used for the FADI Sport. The scores range from 4 (no difficulty at all) to 0 (unable to do) for each activity rated. Reliability and sensitivity of both components have been previously reported in subjects with and without ankle injury. ICC3,1 over a 1-week period for the FADI and FADI Sport was .91 and .82, respectively. Over a 6-week period, the ICC values were .98 for the FADI and .91 for the FADI Sport.

Statistical Analysis

Separate group (ankle OA, control) × side (involved, uninvolved) mixed model analyses of variance were calculated to
assess the effect of each factor and the interaction of these factors on each dependent variable within the 3 constructs studied (mechanical stability, isometric strength, subjective level of function). For the static balance construct, a series of independent t tests were run to determine the effect of group (ankle OA, healthy control) on each dependent variable. The level of significance was established a priori using the Bonferroni correction procedure (level of significance was established a priori using the Bonferroni correction procedure (P≤.001), and ML velocity (P=.014) in the ankle OA group compared with the matched limb of the control group. The ankle OA group also significantly less inversion (F=13.091; df=1; P=.003) and eversion rotation (F=8.740; df=1; P=.010). There were no significant differences for posterior displacement.

Static Balance

The means, SDs, and 95% CIs for each dependent variable by group are presented in table 2. The results of the independent t tests demonstrated significant differences for several static balance variables. There was significantly more COP total displacement (t=2.810; df=14; P=.014) in the ankle OA group compared with the healthy group. Additionally, COP total velocity (t=4.353; df=14; P=.001), and ML velocity (t=2.494; df=14; P=.026) in the subjects with ankle OA was significantly faster compared with the control group. There were no significant differences for COP ML displacement, AP displacement, and AP velocity. Effect sizes for each dependent variable are also presented in table 3.

Isometric Ankle Strength

The means, SDs, and 95% CIs for each dependent variable by group and side are presented in tables 1 and 2. There were significant group by side interactions (P≤.05) for the following variables: plantar flexion, dorsiflexion, inversion, and eversion strength. There was significantly less isometric strength for ankle plantar flexion (F=6.180; df=1; P=.026), dorsiflexion (F=6.957; df=1; P=.019), inversion (F=26.17; df=1; P=.001), and eversion (F=14.515; df=1; P=.002) in the involved ankle of the OA group compared with the opposite ankle and the matched limb of the control group.

Subjective Level of Function

The means, SDs, and 95% CIs for each dependent variable by group and side are presented in tables 1 and 2. Overall, there were significant group by side interactions (P≤.05) for the FADI and FADI Sport. The subjects with ankle OA scored significantly less on both the main FADI (F=36.570; df=1; P=.001) and the FADI Sport (F=48.507; df=1; P=.001).

DISCUSSION

The current study reported significant impairments in mechanical and sensorimotor function in patients with ankle OA compared with healthy controls matched for age, height, weight, and sex. These impairments are likely the cause of the significantly decreased subjective level of function also reported. All subjects reported their ankle pain to be mild or moderate during ankle testing. No subjects reported their pain at the time of testing to be severe or unbearable. So although pain could decrease function, the other measures also play a big role in decreasing function. This work represents the first investigation of its kind examining changes in joint mechanics and sensorimotor control in subjects with ankle OA. Previous studies have reported deficits in gait, subjective function, and participation in sports and activities. However, these studies did not examine the specific mechanisms that may contribute to the impairments in walking gait and subjective function. It is expected that impairments in ankle motion, balance, and joint strength will impair activities of daily living and ability to exercise.

Table 1: Mechanical Stability, Strength, and Subjective Level of Function by Group and Side

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Ankle OA Involved</th>
<th>Ankle OA Uninvolved</th>
<th>Control Matched</th>
<th>P (Group by Side)</th>
<th>P (Group)</th>
<th>P (Side)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior displacement (mm)</td>
<td>7.1±1.9</td>
<td>10.6±1.5</td>
<td>11.2±1.8</td>
<td>.001*</td>
<td>.023*</td>
<td>.001*</td>
</tr>
<tr>
<td>Posterior displacement (mm)</td>
<td>4.8±1.3</td>
<td>5.0±1.3</td>
<td>4.9±0.58</td>
<td>.093</td>
<td>.091*</td>
<td>.722</td>
</tr>
<tr>
<td>Inversion rotation (°)</td>
<td>21.6±6.4</td>
<td>31.3±4.5</td>
<td>32.0±2.1</td>
<td>.003*</td>
<td>.001*</td>
<td>.004*</td>
</tr>
<tr>
<td>Eversion rotation (°)</td>
<td>9.4±2.8</td>
<td>15.2±5.1</td>
<td>21.3±5.6</td>
<td>.010*</td>
<td>.001*</td>
<td>.008*</td>
</tr>
<tr>
<td>Isometric plantar flexion strength (PT/BW)</td>
<td>0.18±0.09</td>
<td>0.22±0.07</td>
<td>0.39±0.10</td>
<td>.026*</td>
<td>.001*</td>
<td>.033*</td>
</tr>
<tr>
<td>Isometric dorsiflexion strength (PT/BW)</td>
<td>0.16±0.05</td>
<td>0.20±0.06</td>
<td>0.36±0.10</td>
<td>.019*</td>
<td>.001*</td>
<td>.014*</td>
</tr>
<tr>
<td>Isometric inversion strength (PT/BW)</td>
<td>0.09±0.03</td>
<td>0.14±0.04</td>
<td>0.22±0.04</td>
<td>.001*</td>
<td>.001*</td>
<td>.008*</td>
</tr>
<tr>
<td>Isometric eversion strength (PT/BW)</td>
<td>0.10±0.03</td>
<td>0.14±0.03</td>
<td>0.22±0.04</td>
<td>.002*</td>
<td>.001*</td>
<td>.001*</td>
</tr>
<tr>
<td>FADI (%)</td>
<td>65.3±18.3</td>
<td>88.1±11.2</td>
<td>98.8±3.5</td>
<td>.001*</td>
<td>.001*</td>
<td>.001*</td>
</tr>
<tr>
<td>FADI Sport (%)</td>
<td>34.4±19.3</td>
<td>79.2±26.9</td>
<td>97.6±6.7</td>
<td>.001*</td>
<td>.001*</td>
<td>.001*</td>
</tr>
</tbody>
</table>

Values are mean ± SD unless otherwise noted.
Abbreviations: BW, body weight; PT, peak torque.
*Significant.

Table 2: Static Balance Variables by Group

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Ankle OA Group</th>
<th>Control Group</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>COP total displacement (mm)</td>
<td>219.5±193.6</td>
<td>27.0±6.6</td>
<td>.014*</td>
</tr>
<tr>
<td>COP total velocity (mm/s)</td>
<td>36.8±16.4</td>
<td>11.4±2.1</td>
<td>.001*</td>
</tr>
<tr>
<td>COP ML displacement (mm)</td>
<td>2.8±4.5</td>
<td>0.88±0.55</td>
<td>.238</td>
</tr>
<tr>
<td>COP AP displacement (mm)</td>
<td>1.9±2.2</td>
<td>0.35±0.40</td>
<td>.074</td>
</tr>
<tr>
<td>COP ML velocity (mm/s)</td>
<td>0.53±0.61</td>
<td>0.01±0.09</td>
<td>.026*</td>
</tr>
<tr>
<td>COP AP velocity (mm/s)</td>
<td>0.68±0.83</td>
<td>0.15±0.13</td>
<td>.092</td>
</tr>
</tbody>
</table>

Values are mean ± SD unless otherwise noted.
*Significant.
Mechanical Stability

There were significant decreases in anterior displacement, inversion rotation, and eversion rotation in the subjects with ankle OA compared with the opposite ankle and the matched ankle of the control group. Collectively, these results confirm anecdotal evidence that those who have ankle OA do possess a significantly stiffer joint. To our knowledge, no other study has reported mechanical stability in patients with ankle OA. Previous research has reported mechanical stability to average 11.9 mm for anterior displacement, and 34° for inversion rotation in healthy ankles. These values are very similar to those values seen in the uninvolved ankle of the OA group (anterior displacement = 10.6 mm; inversion rotation = 31.1°) and the matched ankle of the healthy group (anterior displacement = 11.2 mm; inversion rotation = 33°) tested in this study. It was not surprising that we observed decreased ankle joint arthrokinematics in the subjects with ankle OA. As OA progresses, significant deformity and malalignment of the joints of the ankle/foot complex may develop. Patients with ankle OA typically report the ankle becoming progressively stiffer. This decreased arthrokinematic motion is likely a result of the development of osteophyte growth and soft tissue contractures.

Interestingly, all subjects with ankle OA had a history of ligament injury to the lateral ligament complex. They all reported a previous history of ligament laxity and the ankle giving way. Over time, this increased laxity could have led to the damage associated with ankle OA. As OA progresses, osteophytic changes in the periarticular region occur that mechanically interfere with a normal range of motion. Further damage to joint surfaces results in pain, limiting motion, which could lead to soft tissue contractures. This loss of joint mobility is a vicious cycle which, if not treated, could impede function.

Normal motion of the bones of the ankle is necessary for normal function. In order to have full physiologic joint motion, there has to be full arthrokinematic motion. Impaired arthrokinematics typically displays itself clinically as decreased physiologic motion. Previous research has shown decreased physiologic range of motion in patients with ankle OA. The impaired arthrokinematic motion measured in the current study is most likely the reason subjects reported decreased motion and function in the involved ankle.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Ankle OA Involved</th>
<th>Control-Matched</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior displacement (mm)</td>
<td>7.1 ± 1.9 (5.64–8.52)</td>
<td>11.2 ± 1.8 (9.7–12.65)</td>
<td>2.16</td>
</tr>
<tr>
<td>Posterior displacement (mm)</td>
<td>4.6 ± 1.3 (3.89–5.49)</td>
<td>4.9 ± 0.58 (4.11–5.71)</td>
<td>0.23</td>
</tr>
<tr>
<td>Inversion rotation (°)</td>
<td>21.6 ± 6.4 (17.97–25.78)</td>
<td>33.0 ± 2.1 (29.37–36.68)</td>
<td>1.78</td>
</tr>
<tr>
<td>Eversion rotation (°)</td>
<td>9.4 ± 2.8 (6.04–12.82)</td>
<td>21.3 ± 5.6 (18.14–24.92)</td>
<td>2.13</td>
</tr>
<tr>
<td>Isometric plantar flexion strength (PT/BW)</td>
<td>0.16 ± 0.05 (0.09–0.22)</td>
<td>0.16 ± 0.05 (0.09–0.22)</td>
<td>2.0</td>
</tr>
<tr>
<td>Isometric dorsiflexion strength (PT/BW)</td>
<td>0.09 ± 0.03 (0.07–0.12)</td>
<td>0.22 ± 0.04 (0.20–0.25)</td>
<td>3.25</td>
</tr>
<tr>
<td>Isometric inversion strength (PT/BW)</td>
<td>0.10 ± 0.03 (0.07–0.13)</td>
<td>0.22 ± 0.04 (0.19–0.24)</td>
<td>3.0</td>
</tr>
<tr>
<td>FADI (%)</td>
<td>65.3 ± 18.3 (55.28–75.22)</td>
<td>98.8 ± 3.5 (88.78–108.72)</td>
<td>1.83</td>
</tr>
<tr>
<td>FADI Sport (%)</td>
<td>34.4 ± 19.3 (23.44–45.44)</td>
<td>97.6 ± 6.7 (86.63–108.62)</td>
<td>3.27</td>
</tr>
<tr>
<td>COP total displacement (mm)</td>
<td>219.5 ± 193.6 (57.62–381.29)</td>
<td>270.0 ± 6.8 (215.52–32.51)</td>
<td>0.99</td>
</tr>
<tr>
<td>COP total velocity (mm/s)</td>
<td>36.8 ± 16.4 (23.09–50.52)</td>
<td>11.4 ± 2.1 (9.65–13.08)</td>
<td>1.55</td>
</tr>
<tr>
<td>COP ML displacement (mm)</td>
<td>2.8 ± 4.5 (0.88–6.55)</td>
<td>0.88 ± 0.55 (0.41–1.34)</td>
<td>0.43</td>
</tr>
<tr>
<td>COP AP displacement (mm)</td>
<td>1.9 ± 2.2 (0.02–3.85)</td>
<td>0.35 ± 0.40 (0.01–0.689)</td>
<td>0.70</td>
</tr>
<tr>
<td>COP ML velocity (mm/s)</td>
<td>0.53 ± 0.61 (0.01–1.04)</td>
<td>0.01 ± 0.09 (–0.09–0.06)</td>
<td>0.85</td>
</tr>
<tr>
<td>COP AP velocity (mm/s)</td>
<td>0.68 ± 0.83 (–0.01–1.38)</td>
<td>0.15 ± 0.13 (0.04–26)</td>
<td>0.64</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD (95% CI) or as otherwise indicated. Abbreviations: BW, body weight; PT, peak torque.

Static Balance

Static balance was significantly impaired in the ankle OA group compared with the control group. There was significantly more COP total displacement, COP total velocity, and ML velocity in the subjects with ankle OA. Initially, we had planned to test single leg stance in order to compare the involved ankle of the OA group with the opposite uninvolved ankle. However, none of the 8 subjects with ankle OA could maintain a single-leg stance, so double-leg stance was tested. Static balance impairments have been demonstrated in patients after an acute ankle sprain and in subjects with chronic ankle instability.

Postural control deficits could have been caused by previous damage to the lateral ligaments of the ankle. With injury to ligaments, mechanoreceptors may be damaged as well. If damaged, the proprioceptive input from ligamentous mechanoreceptors may be altered and further disrupt the axis of joint rotation. This may lead to altered proprioceptive input from tissues that are abnormally stressed and force the athlete to compensate if function is to be maintained. Altered postural control can result from a transfer of load from the affected joint to the surrounding joints as the foot tries to accommodate to the limited range of motion in the affected joint. Postural control deficits are likely a result of a combination of impaired proprioception and neuromuscular control. We did not directly measure proprioception or neuromuscular control, so we do not know which system may have led to the impairment in postural control. We did ensure subjects had no vestibular or vision impairments. Further research should examine all components of the sensorimotor system to understand fully where deficits exist.

Isometric Ankle Strength

Unlike what has been reported in patients with knee OA who have quadriceps weakness, to date ankle isometric strength has not been reported in subjects with ankle OA. This is significant in that the musculature controlling the ankle/foot complex contributes substantially to dynamic joint stabilization and postural control. In the current investigation, subjects with ankle OA demonstrated significant weakness in all strength variables. The involved ankle of the OA group was signifi-

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cantly weaker than the opposite ankle and the matched ankle of the control group for ankle plantar flexion, dorsiflexion, inversion, and eversion strength. Previous research has produced conflicting evidence on the role of strength deficits and ankle instability.\textsuperscript{14} The decreased strength demonstrated may be in part a result of the limited motion available at the joint. It is unknown whether the weakness present leads to decreased function, or whether decreased function leads to isometric weakness in subjects with ankle OA. Load-bearing dysfunction can result in an apparent loss of motor control and instability. Although we did not measure reflex inhibition, inhibition of the controlling muscles may lead to that loss in motor control and stability secondary to pain. Similar to the knee, the lack of strength measured in the ankle could lead to decreased stability and control of the ankle joint, both of which could limit function.

**Subjective Level of Function**

The ankle OA group also reported significant impairments in subjective level of function. The main FADI assesses activities of daily living, whereas the FADI Sport examines activities common to participation in sports (running, jumping, cutting). The decreased subjective level of function reported in this group was not surprising. Previous research has reported decreased subjective level of function in subjects with ankle OA.\textsuperscript{15} This decreased function could be a result of pain, weakness, balance deficits, or decreased motion, all of which were reported in the present study.

**Clinical Implications**

All 8 subjects were not currently participating in a formal rehabilitation program. The deficits in arthrokinematics, balance, strength, and subjective level of function are concerning. These impairments in mechanical and sensorimotor control likely contribute to the gait limitations reported in previous research. A recent study by Valderrabano et al\textsuperscript{17} reported significant differences in spatiotemporal gait variables in subjects with ankle OA.\textsuperscript{16} This decreased function could be a result of pain, weakness, balance deficits, or decreased motion, all of which were reported in the present study.

Several previous projects have demonstrated improvements in balance after balance training. Wester et al\textsuperscript{24} examined 15 minutes of progressive balance training in patients diagnosed with a lateral ankle sprain. Only 25% of the training group had recurrent sprains over an 8-month follow-up compared with a 54% recurrence rate in the control group. Similar results were reported by Holme et al,\textsuperscript{25} who at 1 year of follow-up showed that 29% of their control group and just 6% of their balance training group had a recurrent sprain. Although these studies did not specifically examine patients with ankle OA, they provide evidence that balance can be improved with exercise. Research examining the effect of rehabilitation or exercise on improving range of motion and strength is more limited. Studies have reported a positive effect of stretching and range of motion exercises on physiologic motion as well as joint mobilizations on arthrokinematic motion.\textsuperscript{10,26,27} Additionally, strengthening exercises have been shown to improve strength at the ankle.\textsuperscript{12,22,23,26} Further research is needed to examine the effect of rehabilitation and exercise on mechanical and sensorimotor changes in patients with ankle OA. From there, the role on more functional activities such as gait and stair climbing can be examined.

**CONCLUSIONS**

Mechanical and sensorimotor impairments occur in subjects with beginning-stage ankle OA. These changes may continue to worsen, which may lead to worsening of ankle OA. Additionally, these changes may lead to altered gait, activities of daily living, and participation in exercise/leisure activities. The role rehabilitation and exercise play in the improvement of these impairments needs to be examined.

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**References**


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b. 4060-NC; Bertec Corp, 6171 Huntley Rd, Ste J, Columbus, OH 43229.
c. Motion Monitor; Innovative Sports Training, 3711 N Ravenswood Ave #150, Chicago, IL 60613.
d. Hoggan Health Industries, 12411 S 265, Draper, UT 84820.