Knee bracing for medial compartment osteoarthritis: effects on proprioception and postural control

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Abstract

Objective. To evaluate the effects of a functional knee brace specifically designed for patients with varus gonarthrosis on measures of proprioception and postural control.

Subjects. Fourteen men and six women (aged 59 ± 9 yr) with measurable varus alignment and osteoarthritis of the knee medial compartment.

Methods. Proprioception was assessed in the sitting position using an isokinetic dynamometer and was quantified as the ability to replicate target knee-joint angles. Postural control was assessed with a force platform using tests of single-limb standing balance performed, while the patient was standing on a stable surface and standing on foam, and was quantified as the total length of the path of the centre of pressure. All tests were performed with and without the patient’s own custom-fit valgus brace.

Results. Proprioception was significantly improved following application of the brace (mean difference = 0.7°, 95% confidence interval (CI) = 0.2 to 1.1°). Postural control was not significantly affected by the use of the brace during the stable surface test (mean difference = 2.6 cm, 95% CI = −4.3 to 9.5 cm) or the foam surface test (mean difference = 0.9 cm, 95% CI = −7.5 to 9.4 cm).

Conclusion. Although enhanced proprioception may be partially responsible for reported improvements with the use of a brace, the present findings call into question the functional importance of the small changes observed.

Key words: Knee orthosis, Valgus brace, Kinaesthesia, Joint position sense, Standing balance.

Specifically designed functional knee braces, commonly referred to as valgus braces, have been reported to decrease pain and improve measures of function and quality of life in subjects with varus gonarthrosis [1–6]. Although these braces are intended to produce a valgus-directed thrust about the knee joint for the purpose of unloading the medial compartment, the mechanisms underlying reported benefits of bracing are unclear at present. While it is possible that braces may directly alter knee joint loads, potential neuromuscular effects of bracing the arthritic knee have also been suggested [3, 7–9]. Deficits in various aspects of neuromuscular performance have recently been suggested to be important and often overlooked components of the osteoarthritis disease process [8–12]. When quantified as the ability to detect passive joint movement, or as the ability to replicate target joint angles, knee proprioception has consistently been reported to be compromised in individuals with knee osteoarthritis [7, 10, 13–16]. Given the importance of somatosensory input from the lower limb for activities such as the control of standing balance and gait [17, 18], compromised knee proprioception has been further hypothesized to affect postural control adversely. While the link between knee proprioception and postural control has not been established, the control of standing balance has also been reported to be compromised in the presence of knee osteoarthritis [10, 19].

The observed deficits in knee proprioception and postural control provide the basis for the suggestion that improvements in these specific aspects of neuromuscular performance may be mechanisms underlying the reported benefits of bracing in this patient population. Although the application of an elastic bandage has been reported to improve proprioception in subjects with knee osteoarthritis when tested in a non-weight-bearing
position [7], we are unaware of any investigation of the proprioceptive effects of bracing these individuals. Furthermore, the clinical importance and potential influence that altered knee proprioception may have on weight-bearing activities such as the control of posture remains controversial [20–22]. Therefore, the purpose of the present study was to evaluate the effects of a valgus brace on measures of knee proprioception and postural control.

Methods

Subjects

Fourteen male and six female subjects diagnosed with varus gonarthrosis by an orthopaedic surgeon at The University of Western Ontario Fowler-Kennedy Sports Medicine Clinic were studied. For each subject, the angular deformity (mechanical axis) of the lower limb was measured during single-limb stance using anteroposterior hip-to-ankle radiographs with the method described by Dugdale et al. [23]. All subjects had measurable varus alignment, complained of pain localized primarily to the medial compartment, and met the criteria suggested by Altman et al. [24] for the diagnosis of osteoarthritis.

Procedures

Each subject was fitted with a valgus brace (Unloader; Generation II Orthotics, Richmond, BC, Canada). After receiving plaster casts of the subjects’ limb, the manufacturer constructed the custom-fit braces, which consisted of polyethylene thigh and calf shells connected by a medially placed polyaxial hinge. With the use of a calibrated apparatus, the part of the brace containing the hinge was adjusted so that a 4° increase in valgus alignment of the brace resulted. Subjects completed tests of knee proprioception, followed by tests of single-limb standing balance, with and without wearing the brace, during one testing occasion of duration approximately 60 min. The order of no-brace or brace conditions was allocated randomly. Subjects wore their gym shorts and shoes for all tests.

Proprioception test

The ability to replicate target knee-joint angles was assessed using a computerized dynamometer (Kin Com 500–9; Chattecx, TN, USA) and a protocol that has been described in detail previously (Fig. 1) [20, 21]. The dynamometer sampled the angular position of the knee at a rate of 100 Hz, while controlling the angular velocity (< 5°/s) and the amount of force (1–5 newtons) required for active knee extension movements. As outlined in the articles cited, setting these specific parameters limited cutaneous input from the testing device and provided consistency between the no-brace and brace conditions. While blindfolded and seated on the dynamometer, subjects actively extended the knee (moving the dynamometer lever arm) to one of five randomly allocated target angles between 30° and 60° of knee flexion, maintaining this position for a period of 3 s. They then returned the knee to the start position and, after a rest of 5 s, attempted to reproduce the target angle attained previously, stopping when it was perceived that the angle had been replicated. Angular position was recorded continuously by the dynamometer throughout each trial, allowing the difference between target and reproduced angles to be calculated subsequent to the test session. No feedback regarding performance was provided.

Balance tests

Postural control was assessed using tests of single-limb standing balance, which were quantified using the centre of pressure signal from force platform data (model OR6-5: AMTI, Watertown, MA, USA). Testing protocols were similar to those reported previously to be valid and reliable [25, 26] and were confined to the brace-side limb. The force platform was 46 × 51 cm in size and was mounted flush with the laboratory floor (Fig. 2). During each test trial, Biomechanics Data-Acquisition and Analysis Software (AMTI, version 3.1) was used to obtain 10 s of force platform output at a sampling rate of 60 Hz.

During both the no-brace and the brace condition, following one practice trial, subjects completed three consecutive single-limb standing balance trials in two testing situations: (i) standing on the stable, level and firm surface of the force platform, and (ii) standing on

![Fig. 1. Subject wearing the brace and positioned on the isokinetic dynamometer for knee proprioception testing.](image)
a 40 × 40 cm mat of 7-cm thick medium-density polyfoam placed over the same platform. Theoretically, the viscoelastic nature of the foam makes it difficult to interpret accurately the proprioceptive input arising from the lower limb-to-ground interface [27]. Rest periods of 30–60 s were provided between trials, and at least 1 min of rest was provided between test situations.

Data analysis
For the proprioception test, the criterion measure was an error score calculated as the average absolute difference (AAD) between the target and reproduced angles, averaged over the five different target angle replication attempts. The no-brace and brace conditions were then compared using a one-way repeated measures analysis of variance (ANOVA) test. For the balance tests, the anteroposterior and mediolateral locations of the centre of pressure were derived from the force and moment profiles measured by the force platform. In keeping with recent investigations of single-limb standing balance in subjects with knee pathology [28–31], the outcome measure used during the balance assessment was the length of the path of the centre of pressure, averaged over the three trials. The no-brace and brace conditions were compared during the different test situations using a two-way ANOVA test with repeated measures on both factors (two brace conditions and two test situations). All statistical analyses were performed using Statistica (release 5.1; StatSoft, Tulsa, OK, USA). The $P < 0.05$ level was used to denote statistical significance throughout.

Results
Mean (s.d.) for age, body weight, height and degrees of varus alignment were 58.9 (9.9) yr, 87.6 (10.4) kg, 1.7 (0.1) m and 8.4 (4.3)$^\circ$ respectively for males and 58.7 (6.5) yr, 75.5 (15.6) kg, 1.6 (0.1) m, and 8.0 (4.3)$^\circ$ respectively for females. Descriptive statistics for AAD scores observed during the proprioception tests are listed in Table 1. Results of the ANOVA revealed that AAD scores with the brace were significantly lower than without the brace [$F(1,19) = 8.03, P = 0.01$]. Descriptive statistics for the lengths of the path of the centre of pressure observed during the balance tests are listed in Table 1. Results of the ANOVA revealed a significant main effect for the test situation [$F(1,19) = 25.52; P < 0.0001$], path lengths observed during the foam situation being significantly greater than without the foam. However, there was no significant main effect for the brace condition [$F(1,19) = 0.38; P = 0.54$] and there was no significant test situation × brace condition interaction [$F(1,19) = 0.13, P = 0.72$].

Discussion
Proprioception is the sense of position and movement of the limbs, and is the result of sensory inputs arising from muscle, skin and joint structures [32]. When described as

![Fig. 2. Subject completing a single-limb standing balance test on the force platform.](image)

| Table 1. Descriptive statistics for AAD scores and centre of pressure (CoP) path lengths (n = 20) |
|-----------------------------------------------|------------------------------|------------------------------|------------------------------|
|                                         | No brace      | Braces        | Difference          |
|                                         | Mean 95% CI   | Mean 95% CI   | Mean 95% CI        |
| Knee proprioception test (AAD score in degrees) | 2.9 2.4, 3.4  | 2.2 1.8, 2.7  | 0.7 0.2, 1.1*     |
| Standing balance test performed on stable surface (CoP path length in cm) | 71.9 62.2, 81.6 | 69.3 59.8, 78.8 | 2.6 $-4.3, 9.5**$ |
| Standing balance test performed on foam surface (CoP path length in cm) | 89.4 76.1, 102.8 | 88.5 73.4, 103.6 | 0.9 $-0.8, 9.4**$ |

*95% CI did not include the value 0, corresponding to a significant improvement in knee proprioception ($P=0.01$).

**95% CI included the value 0, corresponding to no significant improvement in postural control.
the conscious perception of joint position or movement, this sense may be more precisely termed kinaesthesia [32]. Using various testing procedures, different types of knee orthoses have been reported to improve kinaesthesia in healthy subjects and in those with knee pathology [7, 20–22, 33]. The present findings suggest that the Unloader knee brace also improves the perceived sense of knee-joint position in subjects with medial compartment osteoarthritis. Given the reported deficits in neuromuscular performance of subjects with knee osteoarthritis [7, 10, 13–16], the observed improvement may partially explain the reported changes in quality of life with brace use. It may also explain why simple Neoprene sleeves, which do not alter mechanical alignment, have also been reported to improve measures of function and quality of life in patients with varus gonarthrosis [3].

However, although statistically significant, the mean improvement in the perceived sense of knee-joint position observed with the brace was quite small (0.7; Table 1), and the clinical importance of this difference is unclear at present. The lack of improvement in postural control observed in the present study (Table 1) further questions the functional importance of minor changes in knee proprioception, and is consistent with previous reports suggesting that similar changes may not affect weight-bearing activities substantially [20, 21]. For the present stable surface balance test situation, post hoc analysis indicated that, when using a two-sided alpha value set at 0.05 and the observed standard deviation of the difference between the no-brace and brace conditions, 20 subjects provided 80% statistical power to detect a difference of 9 cm between these two conditions [34]. This corresponded to a difference of 12%. Similarly, during the foam balance test situation, there was 80% power to detect a difference of 11 cm, or 13%. As a result, we are confident that if any effects of bracing on postural control were present, they were very small.

We suggest that although braces may provide subtle knee proprioceptive cues, this contribution may be minor compared with the somatosensory information already available during weight-bearing tasks. Similarly, since postural control involves the integration of visual and vestibular systems in addition to somatosensory input [27], small changes in knee proprioception may have very little effect on the control of standing balance. Hurley et al. [10] also questioned the relationship between their measures of joint position sense and standing balance in subjects with knee osteoarthritis, and suggested that other factors are important for postural control in this patient population.

It is possible that valgus bracing for prolonged periods involves the combination of several underlying mechanisms, including changes in various neuromuscular factors, such as proprioception, muscular strength and atrophy, along with mechanical factors such as altered moments about the knee and compressive joint loads [4, 5, 35]. As a result, future research should attempt to investigate the relative clinical importance of these mechanisms.

Conclusions
Although there is increasing evidence suggesting that braces improve knee proprioception when tested under conditions of relatively limited somatosensory input (i.e. sitting), the present results suggest that the control of single-limb standing balance (characterized by additional sensory input) is not similarly improved. Although enhanced knee proprioception may be partially responsible for the reported improvements in function and quality of life with the use of a brace, the present findings call into question the clinical importance of the minor changes in neuromuscular performance observed. We suggest that the mechanisms underlying the use of a valgus brace probably involve minor neuromuscular effects working in combination with more substantial mechanical effects. Since knee bracing appears to involve several mechanisms, future research should attempt to determine the relative clinical importance of these postulated processes.

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References