Comparison of Weight-Bearing and Non-Weight-Bearing Conditions on Knee Joint Reposition Sense

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Higgins, M.J., Perrin, D.H. (1997). Comparison of weight bearing and non-weight bearing conditions on knee joint reposition sense. *Journal of Sport Rehabilitation*, *6*(4): 327-334.

Abstract:

In this study, joint reposition sense of the knee in a non-weight-bearing (NWB) state and that in a weight-bearing (WB) state were compared, and it was determined whether a significant relationship existed between knee displacement (KD) and joint reposition sense. The dominant knees of 8 male and 12 female subjects (age 19-26 years, M ± SD = 21.5 ± 2.06) who had no previous history of knee dysfunction were tested for accuracy of angular reproduction in the WB and NWB states. There was a significant difference in the accuracy of angular repositioning between the two conditions, with the WB test having less deviation from the predetermined angle. There was a weak relationship between KD and the ability to reproduce specific angles of the knee. These results suggest that the WB or closed chain state of the knee was more accurate in the determination of joint position sense than the NWB or open chain condition.

Article:

Many researchers have examined the role of mechanoreceptors in the joint position sense of knee movement (1-4, 6-9, 11-13, 15, 18, 20, 24). It has been shown that joint position sense may be a function of joint receptors and/or muscle receptors (1-13, 15, 20, 24). In almost all of these studies, joint position sense has been measured with the limb in a non-weight-bearing position (2-8, 10, 12, 15, 18, 20, 24). Andersen et al. did measure joint reposition sense in a weight-bearing position (1), while others created tension around the joint to determine if this affected joint position sense (10, 11). Joint position sense is an essential component of weight-bearing and non-weight-bearing conditions, because it provides us with the ability to sense body position and movement. This is accomplished through the stimulation of sensory nerve terminals found in muscles, joints, and tendons.

Joint positioning and joint motion are two closely related proprioceptive sensations that are mediated by mechanoreceptors such as the Ruffini ending, the Golgi tendon organ, and the Pacinian corpuscle (11-13), which originate in the tendons, ligaments, and joint capsule (3, 11, 13). Sensory receptors in muscle and tendon are thought primarily to mediate subcortical reflexes (1), and as such, these receptors are not stimulated by changes in joint position. Dvir et al. (11) concluded, however, that static position sense is the function likely to be controlled entirely by knee musculature. Barrack et al. (5) reported that muscle and tendon receptors play a significant role in the sensation of joint motion and position.

Very limited joint position sense testing has been done with the knee in a weight-bearing position. Since the knee normally bears weight during athletic activity, its proprioceptive acuity in a weight-bearing position should be tested.

The purpose of this study was to compare joint reposition sense of the knee when assessed from weight-bearing (WB) and non-weight-bearing (NWB) positions. A secondary purpose of this study was to determine if a significant relationship existed between the amount of anterior tibial displacement and joint reposition sense.

Materials and Methods

Subjects

Twenty college-age male and female subjects with no history of knee pathology (age 21.5 ± 2.1 years, height 66.7 ± 3.6 in., weight 155 ± 25.3 lb) volunteered to participate in this study. All subjects were recreational athletes who participated in formalized or regular exercise ≥ 4 hr per week. Each subject read and signed a form giving his or her consent to participate in the study.

Experimental Design

We tested knee joint reposition sense under two conditions: weight-bearing and non-weight-bearing. The order of test condition was assigned for each subject in a counterbalanced fashion. Each subject was measured for the amount of anterior tibial displacement in the knee by KT-1000 (MEDmetric Corp., San Diego, CA) measurement. Each subject was then tested in the non-weight-bearing condition, which consisted of repositioning the knee to a 30° angle while the subject was seated on a Cybex. The weight-bearing test consisted of repositioning the knee to a 30° angle while the subject performed a one-leg wall squat. Measurement for accuracy of joint reposition sense was recorded in each condition.

Instrumentation. We used the KT-1000 knee arthrometer (MEDmetric Corp., San Diego, CA) to determine anterior displacement of the tibia in each subject. A Cybex II Dual Channel System with a Cybex Data Reduction Computer (CDRC; Lumex Corp., Ronkonkoma, NY) was used to measure the joint angle at the knee in the NWB test. A Leighton Flexometer (17) was used to measure the joint angle at the knee in the WB test.

Non-Weight-Bearing Test. The Cybex II and the CDRC were calibrated prior to testing to ensure accuracy of the system's goniometer. Also prior to testing, we determined the dominant extremity by asking the subjects which foot they would use to kick a ball. For the test, each subject was seated on the dynamometer (Figure 1) with the popliteal fossa positioned at least 10 cm off the edge of the dynamometer seat to eliminate cutaneous cues. We aligned the movement arm so that its center of rotation was equal to the lateral joint line. We placed the shin pad approximately 2 cm above the medial malleolus. Each subject was blindfolded to eliminate visual cueing. We placed the tested (dominant) knee at a predetermined angle (30° of flexion) for 15 s and then placed the knee at the dynamometer's reference starting angle of 0° (180° extension) for 15 s. We asked each subject to reposition his or her knee al the predetermined angle, and we measured this angle. Each subject performed three tests.

Weight-Bearing Test. The weight-bearing test consisted of a wall squat; each subject stood on the dominant extremity on a 6—in. box with his or her back against a wall (Figure 2). Each subject placed the nondominant extremity in a nonweight-bearing position. We fitted each subject with a Leighton Flexometer on the dominant extremity's distal thigh approximately 1 in. above the lateral joint line. Each subject was then blindfolded to eliminate visual cues. The subject began the test with the knee at the reference starting angle of 0° (180° extension) as measured by the Flexometer. Each subject squatted to 30° of knee flexion as measured by the Flexometer and held this angle for 15 s. The subject then returned to the starting position (knee in 0° of extension) for 15 s. Following this rest period, the subjects tried to reposition themselves at the predetermined angle, and we measured this angle. We conducted three tests on the dominant extremity and took the average of the three trials. One warm-up test was conducted for both the nonweight-bearing and weight-bearing tests. Also, the order of test condition was assigned for each subject in a counterbalanced fashion.

KT-1000 Measurement. We attached the KT-1000 to the subject's leg with two Velcro calf straps after appropriate alignment, according to manufacturer's guidelines. We tested the subjects according to the procedure manual, and the data were recorded on the Patient Evaluation Form designed by the manufacturer (19). We measured anterior tibial displacement of the knee by applying a 30-lb passive force.

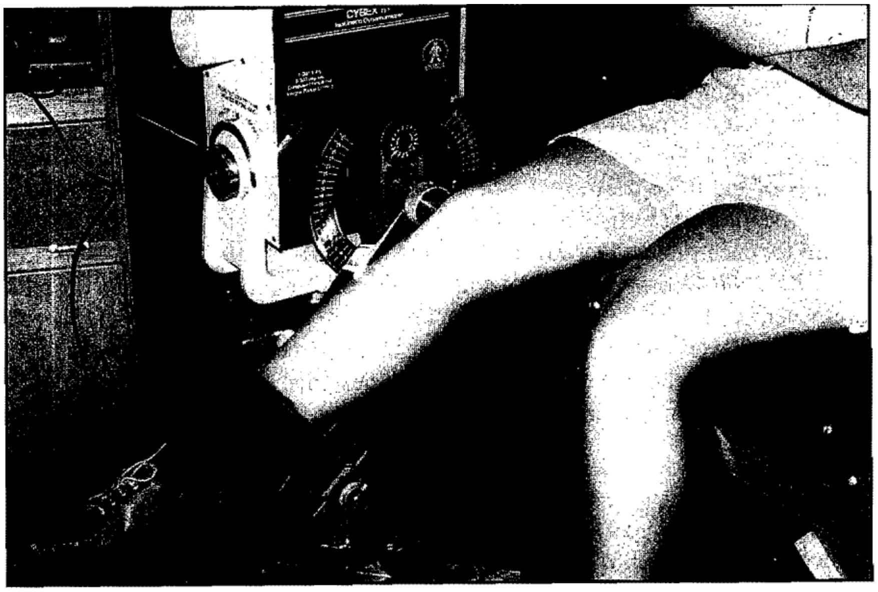

Figure 1 — Positioning of the subject for measurement of joint reposition sense of the knee in the non-weight-bearing test.

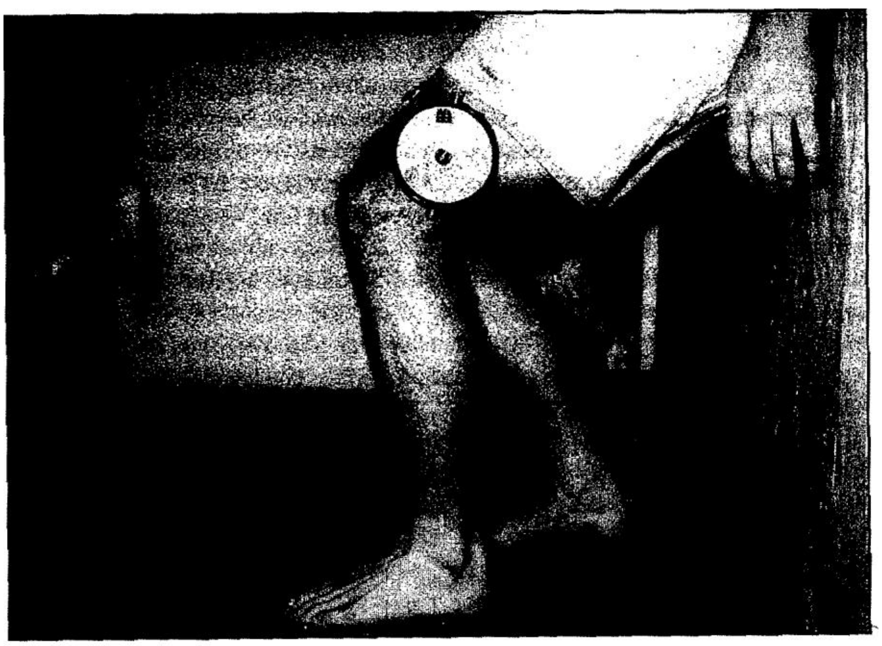

Figure 2 — Positioning of the subject for measurement of joint reposition sense of the knee in the weight-bearing test.

Statistical Analysis

Student's *t* tests ($p < .05$) were computed to determine if significant mean differences existed between the weight-bearing and non-weight-bearing conditions. To determine the relationship between anterior tibial displacement and joint position sense, a correlation matrix was computed from each of these measurements. The reliability of measurement for the WB and NWB conditions was analyzed using a repeated-measures analysis of variance (ANOVA). An interclass correlation coefficient (ICC[2,1]) (23) and a standard error of measurement (SEM) were calculated for 60 repeated measures.

Results

The WB condition was significantly different in accuracy of angular repositioning of the knee compared to the NWB condition. The WB condition revealed less deviation from the predetermined angle than the NWB position, $t(19) = 2.81$, $p < .05$. The WB mean deviated 1.7 ± 1.96° from the predetermined angle, whereas the

NWB mean deviated 4.05 ± 2.76° from the predetermined angle. The ICCs and associated SEMs for the WB and NWB measurements were R =.97 (*SEM* = 0.94°) and R = .93 (*SEM* = .90°), respectively.

Anterior displacement as measured by the KT-1000 arthrometer ranged from 4 to 12 mm of displacement with a mean displacement of 4.96 ± 1.86 mm. A weak relationship was found between knee displacement (KD) and the ability to reposition the knee at a predetermined angle in either the WB or NWB conditions (KD and WB $r = .04$, $p > .05$; KD and NWB $r = .17$, $p > .05$).

Discussion

The major finding of this study was that accuracy of angular repositioning of the knee was more precise in the WB position compared to the NWB position, which is in agreement with other studies (1, 9). This may be due to the functional position of the subject's knee in the WB condition, since Burton et al. (9) reported that developing proprioception and incorporating intricate timing with muscular force are essential for accurately performed functional activities. We found in this study that neither knee displacement nor anterior laxity was related to accuracy of angular reproduction in nonpathological knees.

Proprioception is the sense of balance, position, and movement of the limbs (16). Vision, vestibular function, and somatic pathways all play a role in proprioception. Vision was eliminated as a factor in this study because all of the subjects were blindfolded, so they could not use this sense to target the appropriate angle. The specialized receptors of the vestibular apparatus are largely responsible for controlling balance (16). The receptors of the vestibular apparatus did not play a major role in this study because this study concentrated on sense of joint position of the limbs and the sense of limb movement (kinesthesia). Three main types of peripheral receptors may signal the stationary position of the limb and the speed and direction of limb movement: mechanoreceptors located in joint capsules, cutaneous mechanoreceptors, and mechanoreceptors in muscle that are specialized to transduce muscle stretch (16).

We designed the WB test to more accurately replicate the weight-bearing state of the knee during activities such as walking and running. The limitation of this test was that it was impossible to eliminate muscular, capsular, and cutaneous cues from the secondary joints such as the hip and ankle. Since the closed chain system is a more functional position, meaning that it simulates everyday lower extremity activity, the ankle, knee, and hip should be tested both individually and together to detect angular repositioning at one or all of the joints. The subjects kept their tibias perpendicular to the ground to minimize movement at the ankle in the WB position. Hip movement, however, was not controlled in the WB position, which may have led to the more accurate repositioning of the knee as compared to the NWB condition. Moreover, the WB position involved use of the main muscle, tendon, and capsular receptors responsible for joint repositioning and proprioception both in and around the knee joint (1, 3, 4, 9, 11, 13, 14). These receptors are stimulated by muscle contraction, joint movement, and approximation, which were all part of the WB condition (2, 8, 10, 11).

Our results support previous research by indicating that all of these receptors have a role in the ability of the knee to reproduce specific angles (1, 4-10, 11). Our results are consistent with those of Andersen et al. (1), who reported that knee joint angles are more accurately repositioned in the closed chain or WB condition., Our study is also in agreement with that of Bunton et al. (9), who reported that proprioception is improved by WB or with closed kinetic chain exercises because of the proprioceptive input by Golgi tendon organs, Golgi ligament endings, Ruffini endings, Pacinian corpuscles, and muscle spindles. These same receptors are also thought to be responsible for postural and protective reflexes (4), which may be another reason why the WB condition was more accurate in this study. The use of knee, ankle, and hip musculature in the WB condition most likely played a major role in the subjects' ability to reposition their knees at the predetermined angle. The subjects may also have received cutaneous cues as their backs slid against the wall. However, this was necessary to help keep the tibia perpendicular to the ground, which enabled the subjects to concentrate on movement at the knee.

The use and effectiveness of closed chain exercises have been well documented in the literature (9, 22, 25). Since repositioning in the WB or closed chain position was more precise than in the NWB or open chain position, our study seems to support the integration of closed chain exercises into the rehabilitation program to help increase proprioceptive feedback to the injured athlete. This increased proprioceptive feedback helps protect the joint and decrease ligament strain by approximating the joint and stimulating Golgi ligament endings and muscle spindles. It also allows the athlete to perform rehabilitative exercises with the knee in a more functional position that will simulate activities of sport and daily living.

It has been shown in previous studies that joint laxity decreases the ability of the joint to detect the accuracy of angular repositioning and knee displacement (3, 5, 7, 11). Lephart et al. (18) found that subjects with ACL-deficient knees had decreased proprioception in the deficient knees compared to ACL-intact knees.
The use of subjects with nonpathological knees and intact anterior cruciate ligaments is probably the reason why we found no significant difference between knee displacement and joint reposition sense. Knee displacement may not have been related to joint reposition sense in this study because a nonpathological knee, no matter how much displacement is present, is "normal" to that subject. A learning process may have occurred in those subjects with the most knee displacement, enabling them to accurately reposition their knees.

Conclusion

Angular repositioning in healthy subjects was more accurate when the knee was in the WB or closed chain position compared to the NWB or open chain position. This was likely due to the use of joint approximation and muscular contraction around the knee, hip, and ankle as well as capsular receptors and cutaneous receptors at the three joints. The functional position of the knee during the test may also have influenced reposition sense. This study revealed a poor relationship between knee displacement in nonpathological knees and the ability to reproduce angular position.

Knee proprioception should be tested in the most functional positions possible. Future research should compare closed and open chain proprioceptive testing under conditions of active and passive movement in both healthy and pathological knees.

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