Weight-Bearing and Non-Weight-Bearing Knee-Joint Reposition Sense and Functional Performance

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Abstract:

Objective: To determine the relationship between weight-bearing (WB) and nonweight-bearing (NWB) joint reposition sense ORS) and a functional hop test (FH) and to compare performance on these parameters between athletes and nonathletes**. Design:** Repeated-measures ANOVA and Pearson correlations. **Setting:** Research laboratory. **Participants:** 40 men (age = 20.8 ± 1.7 y; ht = 176.9 ± 5.8 cm; wt = 82.6 ± 9.5 kg): 20 lacrosse players and 20 nonathletes. **Main Outcome Measures:** Ability to actively reproduce 30° of knee flexion in the WB and NWB conditions and functional performance on a single-leg crossover-hop test**. Results:** No significant correlations were observed between JRS and FH in athletes and nonathletes. No significant differences were observed between athletes and nonathletes in JRS. All participants were significantly more accurate at WB than at NWB JRS. **Conclusions:** There appears to be no relationship between WB or NWB JRS and functional performance, regardless of one's physical activity level. **Key Words:** proprioception, sensorimotor, lower extremity rehabilitation, closed kinetic chain

Article:

Many physical attributes are required to perform functional activities. Individuals must possess strength, flexibility, power, speed, and muscular and cardiovascular endurance, as well as adequate sensorimotor function. Very little is known, however, regarding the relationship between currently used sensorimotor assessments, such as joint reposition sense, and functional performance. Because of difficulties in making direct measurements of afferent action potentials arising in nerve end organs, most investigations of sensorimotor function have relied on conscious perception of or subconscious reflexive responses to afferent signals. One commonly used method of assessment, which has many methodological variants, is joint position sense. Sensorimotor function is undoubtedly important for motor learning, rehabilitation, and functional performance,[1],[2] but it is not known whether information obtained using current methods to assess proprioceptive feedback provides measures related to an individual's ability to perform functional activities. If joint reposition sense were in fact a physical attribute required to perform functional activities, better performance on joint-

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repositioning assessments would be expected from active individuals possessing a high level of functional capacity.

To date, few investigations have examined the relationship between the ability to reproduce a joint angle and level of functional performance.[3-5] In individuals with an anterior-cruciate-ligament-deficient limb, joint position sense was less accurate than in age-matched controls.[4] This sensorimotor decrement did not improve after rehabilitation and was not significantly correlated with functional performance (figure-8 run, single-leg hop for distance, subjective report, and isokinetic strength testing). Joint position sense was tested in a nonfunctional, non-weight-bearing position, however. Unfortunately, the authors did not report any correlations between the uninjured control limb and performance measures. In contrast, Corrigan et al[3] observed a significant correlation between the isokinetically measured hamstring-to-quadriceps ratio in anterior-cruciate-ligament-deficient limbs and non-weight-bearing joint reposition sense (r = —.77). These correlations were not reported for the uninjured extremity or the control group, however, and strength is an indirect measure of functional performance. To date, we could find no study with the direct purpose of measuring the relationship between functional performance and joint reposition sense (JRS) in healthy individuals.

Greater accuracy in joint-repositioning tasks has been observed in individuals in the weight-bearing postion,[6,7] Higher joint-reaction forces and muscle cocontraction occur during activities performed in weight bearing than in non-weight-bearing conditions.[8],[9] Increased sensorimotor function observed during weight bearing was likely a result of greater mechanical deformation of soft tissue,"-" input from other joints,[2],[6,7] and increased muscle activity." For these reasons, an increased amount of afferent feedback should occur during functional activities such as running, jumping, and hopping. Therefore, the weight-bearing position might be more representative of afferent feedback that occurs during functional activity. In fact, the closed kinetic chain position has been promoted for improving proprioception and neuromuscular control after injury, based partly on the expected similarity in afferent and efferent activity with functional activities.[6,14-16]

The relationship between JRS and functional performance has not been established, and it is not clear whether more active individuals demonstrate a higher degree of JRS acuity. If a relationship does exist between JRS and functional performance, it might be stronger with weight-bearing JRS. Therefore, the purpose of this study was to determine the relationship between weight-bearing and non-weight-bearing active JRS and a functional hop test and to determine whether there are differences in performance on these parameters between athletes and nonathletes.

SUBJECTS

Forty healthy men (age = 20.8 ± 1.7 years, height = 176.9 ± 5.8 cm, weight = 82.6 ± 9.5 kg) free from neuromuscular dysfunction, vestibular disorders, and lower extremity injury volunteered to participate in this study. Twenty subjects were in-season Division I college lacrosse players. The other 20 were age-matched individuals with activity levels equal to those of daily living. All subjects read and signed a consent form approved by the university's institutional review board for the protection of human subjects before participating in the study.

METHODS

We assessed weight-bearing and non-weight-bearing knee JRS and functional performance using a single-leg-hop test in all participants. First, we determined whether there were differences in WB and NWB JRS for active and inactive individuals. Second, we determined whether functional performance correlated with either JRS test.

Each subject's dominant leg, defined as the leg with which the subject preferred to kick a ball, was tested. The absolute difference in degrees calculated between the criterion (30° of flexion) and active replication angles was averaged over 3 trials to represent each subject's score on both sensorimotor tests (absolute angular error). A single-leg crossover triple-hopfor-distance test assessed functional performance in all participants. Distance in centimeters was averaged over 3 trials to represent each subject's score. Subjects performed the hop test last, and we counterbalanced the 2 JRS tests. The same researcher performed all testing for each subject on the same day. To establish test—retest consistency of our JRS methods, 9 subjects returned within 1 week of their initial testing session to repeat both JRS tests.

Instrumentation

A Penny and Giles^{TM} electric goniometer (Penny and Giles, Gwent, UK), attached to the lateral aspect of the subject's dominant leg, measured knee- joint angles during JRS testing. Joint angles were measured in 1° increments by reading the LCD on the angle display unit (ADU301) provided by the manufacturer.

Participant Setup

We attached the electric goniometer to each subject's knee on an imaginary line connecting the greater trochanter and the lateral malleolus with double- sided tape and nonadhesive elastic wrap. While the subject was standing in a comfortable stance with feet shoulder-width apart and looking straight ahead, the goniometer was zeroed. This point represented anatomical zero for measurement of all knee-joint angles during all JRS testing.

TESTS

Weight-Bearing Joint Reposition Sense

The weight-bearing condition measured participants' ability to actively reproduce a target angle of 30° using methods previously described.' While in single-leg stance on a 6-in-high box, each subject was instructed to slowly squat. The researcher instructed the subject to stop and pause for 15 seconds when the knee-joint angle measured 30°. Next, the subject returned to a standing position and waited for 15 seconds. The subject was then instructed to reproduce the target angle for that trial as accurately as possible. Each subject maintained balance by leaning backward against the wall. The nontesting leg remained fully extended and non-weight-bearing off the edge of the box during the entire test. Between trials, each subject walked 20 ft to eliminate any proprioceptive memory of the test.

Non-Weight-Bearing Joint Reposition Sense

To assess JRS in the non-weight-bearing condition, each subject was seated on a chair reclined to 55°. The joint line of the dominant leg was aligned 10 cm from the edge of the seat. While seated with the test leg fully extended, the subject was instructed to slowly flex the knee. The researcher instructed the participant to stop when the knee-joint angle measured 30° and to hold the position for 15 seconds. The subject then returned the test leg to the fully extended position and paused for 15 seconds. Next, the subject was instructed to reproduce the target angle of that trial as accurately as possible. Between trials the subject performed 5 repetitions of knee flexion and extension to eliminate any proprioceptive memory.

Crossover Triple Hop for Distance

Functional performance was assessed using a crossover triple-hop-fordistance test. This test has previously been used as an assessment of lower extremity function and has produced reliable data (r = .96).[17]

The test course consisted of a 6-m-long, 15-cm-wide marking strip on the floor (Figure 1). The goal of the test was to jump forward on 1 leg as far as possible using 3 consecutive hops. While hopping as far forward as possible, participants were also required to cross over the marking strip on each hop by jumping in a medial or lateral direction. Participants started in single-leg stance on the dominant leg and made their first hop in a medial direction crossing over the marking strip. Each subject kept his hands clasped together behind his back during the test, and a 45-second rest period was given between trials.

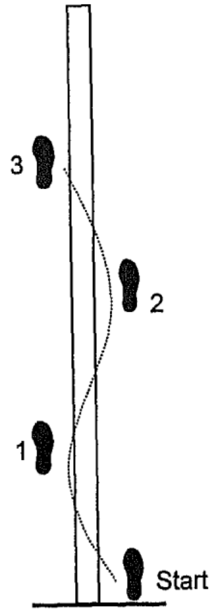


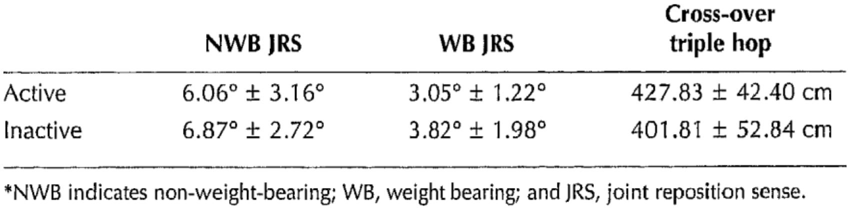
Figure 1 Crossover triple-hop-for-distance test.

STATISTICAL ANALYSIS

Absolute angular error scores were analyzed with a 2-factor repeated-measures analysis of variance (ANOVA). JRS test condition at 2 levels (weight bearing and non-weight-bearing) represented the within-subject factor, and subject grouping at 2 levels (active and inactive) represented the between- subjects factor. A Pearson product—moment correlation was calculated between crossover-hop test scores and scores on JRS testing in each condition. The a priori a level for all statistical testing was set at P = .05.

We calculated the observed power between active and inactive groups on both IRS assessments. We also calculated a model-2,k intraclass correlation coefficient (where k = 3 trials) to assess test—retest stability and a standard error of measurement (SEM) to evaluate measurement precision for both JRS test conditions.[18,19]

Table 1 Test Results of Non-Weight-Bearing and Weight-Bearing Joint Reposition Sense and Cross-Over Triple Hop for Distance (mean ± SD)*



	NWB JRS	WB JRS	Cross-over triple hop
Active	6.06° ± 3.16°	3.05° ± 1.22°	427.83 ± 42.40 cm
Inactive	6.87° ± 2.72°	3.82° ± 1.98°	401.81 ± 52.84 cm

*NWB indicates non-weight-bearing; WB, weight bearing; and JRS, joint reposition sense.

Results

Means and standard deviations of test results are presented in Table 1. No significant correlations were observed between functional-hop test scores and WB JRS (r = —.06) or NWB JRS (r = —.21). We observed no significant Group x Test interaction ($F_{1,38} = 0.002$, P .97) and no significant differences between active and inactive participants on JRS testing (F_{138} = 1.71, P = .20). Significantly less absolute angular error was observed in the WB than in the NWB test condition ($F_{1,38} = 44.79$, $P < .01$).

Our observed power for WB and NWB JRS testing demonstrated a 34% and 24% chance to find a real difference between groups (active and inactive), respectively. Using our methods, measures of JRS testing were moderately stable across testing days. Intraclass correlation coefficients and SEMs were .59 and 2.86°, respectively, for WB JRS and .57 and 1.3° for NWB JRS.

COMMENTS

We observed no relationship between weight-bearing and non-weightbearing active JRS assessments and healthy individuals' ability to perform a functional task. Mechanoreceptor feedback is important for motor learning' and dynamic joint stability,[14] both of which improve an individual's ability to perform a functional task. JRS is one method used to measure mechanoreceptor feedback[2] Single-leg-hop tests have been described as a measure of functional performance that integrates neuromuscular control and dynamic joint stabilization,[15] 2 components of the sensorimotor system that are in part a function of mechanoreceptor feedback. The absence of a significant correlation between JRS and hop-test scores in this study suggests that JRS does not assess the complex integration of peripheral feedback and subsequent efferent responses necessary for the performance of dynamic lower extremity activities.

Proprioceptive feedback, as well as all other types of feedback (inherent and augmented), is used as an error-detection mechanism while one is learning a motor skill. When attempting to improve performance on a given skill, an individual will use knowledge of previous, as well as current, outcomes to make alterations in a motor program.' The accuracy of the proprioceptive feedback will directly limit the individual's ability to detect errors and make subsequent changes. Two classes of skill exist (open and closed loop), and feedback is incorporated differently into each type of skill. This distinction is primarily a function of time delays in the transmission of afferent and efferent signals.[20] When the skill is performed slowly enough, proprioceptive feedback can be used during the execution of the task to bring about changes in immediate performance (closed loop)." If the movement is completed too quickly, proprioceptive feedback can only be used to improve the motor program for the next trial (open loop). The particular hop test used in this study might be an open-loop activity and occur too quickly for integration of proprioceptive feedback while executing the task.' Therefore, a relationship between JRS accuracy and scores on the single-leg-hop test would only be expected after a period of practice on the hop test, effectively demonstrating integration of proprioceptive feedback. Participants in this study, however, were not provided with practice trials, and only 3 trials were performed during testing.

We found no significant difference between Division-I-level athletes and inactive subjects on methods of JRS assessment. Results of several investigations using threshold to detect passive motion suggest that active individuals have greater proprioceptive acuity than do inactive individuals.[15],[21,22] College-age gymnasts[21] and ballet dancers[22] were capable of detecting smaller passive movements than were age-matched controls participating in less regular physical activity. JRS and threshold to detect passive motion are different measures that provide different information.[2] Proprioceptive feedback strictly includes afferent feedback from peripheral mechanoreceptors in muscle, tendon, and articular structures and skin." Active JRS assessments include a novel motor task, and measures obtained are not a direct representation of proprioceptive acuity. Errors committed during JRS testing could result from an inability to perceive the target angle but could also represent an inability to replicate the target joint angle. These errors could be a measure of proprioceptive acuity, motor control, or, most likely, an interaction of the 2. Regardless of the sources of error, results from this study suggest that heightened active JRS acuity is neither required for nor improved by participation in Division-I-level men's lacrosse.

Rehabilitative exercises to improve proprioceptive acuity are often used in the clinical setting after injury. The effectiveness of these "proprioceptive exercises" in increasing afferent feedback, or improving the awareness of feedback, has not been established and is an area of much-needed research.[24] It is likely that once injury or surgery damages a particular mechanoreceptor there will be no regeneration of that receptor,[25] but the athlete or patient might be able to adapt to the altered proprioceptive feedback and maintain his or her level of physical activity A sound rehabilitation protocol for improving functional performance by way of enhanced sensorimotor function should include, but not be limited to, objective assessments of progression and specificity of the functional activity (sport specificity).[14,16] Results from our study of healthy individuals agree with those of others who have investigated healthy and injured subjects [4,26] Active JRS does not appear to provide objective measurements of the neuromuscular system that are related to the ability to perform functional activities.

JRS has previously been an effective assessment for determining the presence or absence of a sensorimotor deficit after injury or surgery.[3-5] If JRS is a valid representation of the complex sensorimotor function required for functional performance, our results suggest that differences in sensorimotor function between healthy individuals with varying activity levels cannot be detected, given the reported reliability.[27],[28] Therefore, active JRS might not be an appropriate determinant for functional-activity progression during the rehabilitative process. On the point of specificity, the goal in improving functional performance by addressing the sensorimotor system is to enhance motor programs through repeated and appropriate stimulation of afferent and efferent pathways.[2,14,16] Application of specificity to the sensorimotor system appears to be most appropriately addressed with training in the closed kinetic chain.[14,16] By repeatedly stimulating appropriate neural pathways, those pathways become facilitated and can improve the accuracy and efficiency of motor programs.[1,2] Our results support those of previous research[6,7] by demonstrating an enhanced JRS in the weight-bearing as compared with the non-weight-bearing condition. Greater accuracy observed during the weight-bearing-position assessment might reflect greater stimulation of mechanoreceptors secondary to increased joint forces and muscle cocontractions.[8,9] If this increased accuracy is in fact a result of greater mechanoreceptor stimulation leading to conscious awareness of joint position, closed kinetic chain activities might provide an advantage over non-weight-bearing activities for "proprioceptive training" or enhancing motor programs through the processes of motor learning.[1]

After injury, the goal is to return the athlete or patient to an appropriate level of functional performance. Depending on the individual's desires, the level of function required for return to activity varies greatly. Before returning the athlete or patient to their chosen level of activity, clinicians must have an objective measure to determine their level of function. In Table 2 we report the means and standard deviations of scores on both IRS methods from our study, along with means and standard deviations of active knee JRS measures from 2 additional studies.[6],[7] We included participants in our study who were currently participating in Division I lacrosse and individuals not participating in regular physical activity. In 2 similar studies on active JRS in healthy individuals, one included individuals

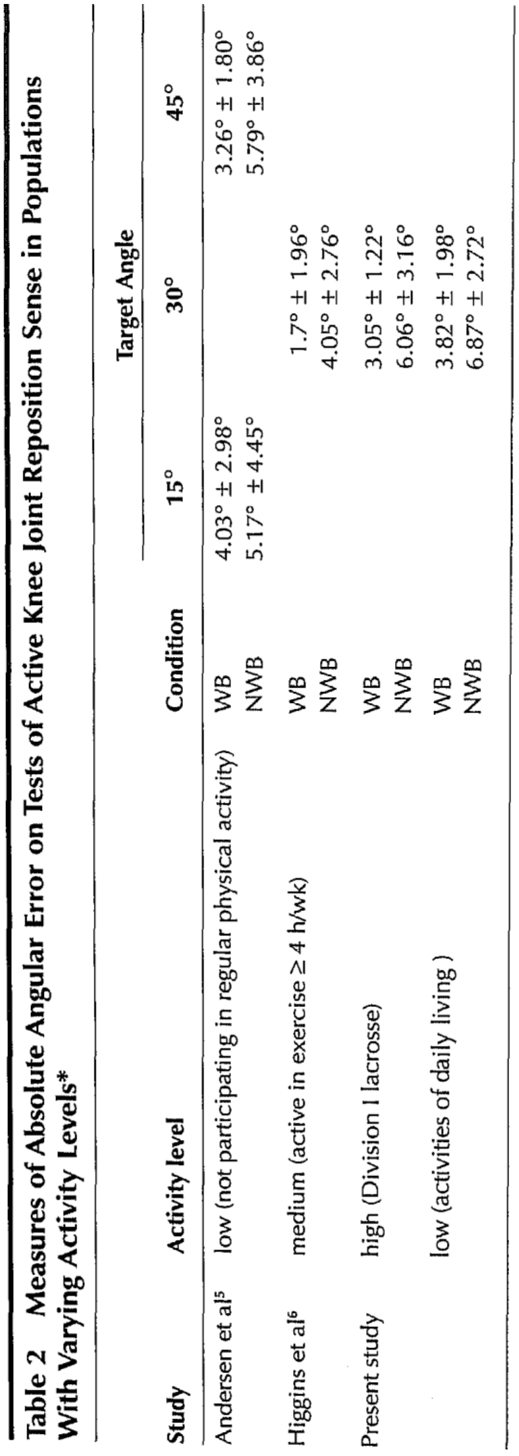


Table 2 Measures of Absolute Angular Error on Tests of Active Knee Joint Reposition Sense in Populations With Varying Activity Levels*

Study	Activity level	Condition	Target Angle		
			15°	30°	45°
Andersen et al[5]	low (not participating in regular physical activity)	WB	4.03° ± 2.98°		3.26° ± 1.80°
		NWB	5.17° ±4.45°		5.79° ± 3.86°
Higgins et al[6]	medium (active in exercise ≥ 4 h/wk)	WB		1.7° ± 1.96°	
		NWB		4.05° ± 2.76°	
Present study	high (Division I lacrosse)	WB		3.05° ± 1.22°	
		NWB		6.06° ± 3.16°	
	low (activities of daily living)	WB		3.82° ± 1.98°	
		NWB		6.87° ± 2.72°	

*WB indicates weight bearing, and NWB, non-weight-bearing.

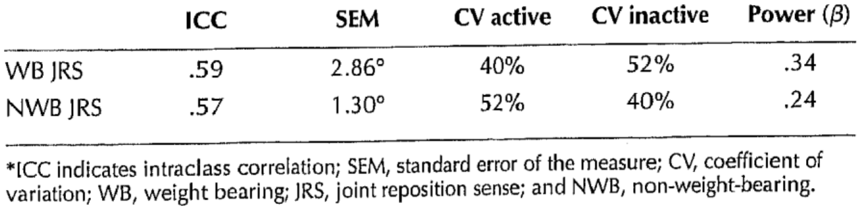
participating in exercise 4 h/ wk or more,' and the other included subjects with no regular activity schedule.' Despite the large variability in subject activity levels, there was a considerable amount. of overlap in absoluteangular-error scores across the 3 studies. For clinicians, this observation makes it difficult to use either JRS method as a prescreening or return-toplay criterion. Individuals might require increased sensorimotor function beyond JRS to perform demanding activities such as running and jumping. Current methods of JRS might lack the measurement precision or specificity to observe these differences.

Our test—retest reliability measures on both JRS assessments (Table 3) were within the range of other studies using active JRS methods (r = .40.61).[27]-[28] These correlation coefficients in the context of reliability are considered moderate at best. In addition, we observed a lack of precision in our JRS measures. The standard error of the measure calculated along with the ICCs and the coefficient of variation ([standard deviation/ mean] 3100) demonstrates a lack of precision in our JRS measures (Table 3). These factors combined point to a high variability in our testing methods and contributed to a low observed power between active and inactive subjects on JRS testing (Table 3). Our retrospective power analysis demonstrated a 24% and 34% chance of detecting a difference, if one truly existed, between the 2 groups (active and inactive) on NWB and WB JRS, respectively. Because of the large variability in this small sample of individuals, there was less chance of detecting differences between the 2 groups using our JRS-assessment methods. Improvement on the precision of JRS methods or larger sample sizes should be incorporated into future research to confirm whether there are differences between individuals with varying levels of physical activity.

CLINICAL APPLICATION

Active JRS appears to be unrelated to functional performance in healthy individuals with considerable differences in activity levels. This type of sensorimotor assessment might only detect large differences such as those occurring after injury and might not be appropriate for functional- progression or return-to-play decisions. Improving measurement precision and consistency of current testing methods might reveal a stronger relationship. To appropriately measure complicated sensorimotor function in athletes or patients in the latter stages of rehabilitation, however, assessments might need to progress beyond the paradigm of error detection. Future sensorimotor assessments might need to evaluate the ability to integrate proprioceptive feedback into functional movements. Some individuals might rely less on proprioceptive feedback regardless of their level of acuity, whereas others might adapt very well to proprioceptive deficits and therefore maintain their ability to perform functional activities.

Table 3 Calculations Demonstrating a Lack of Precision and Low Observed Power on Joint Reposition Sense Assessments*



	ICC	SEM	CV active	CV inactive	Power (β)
WB JRS	.59	2.86°	40%	52%	.34
NWB JRS	.57	1.30°	52%	40%	.24

*ICC indicates intraclass correlation; SEM, standard error of the measure; CV, coefficient of variation; WB, weight bearing; JRS, joint reposition sense; and NWB, non-weight-bearing.

CONCLUSION

Afferent feedback from cutaneous, articular, and musculotendinous mechanoreceptors clearly contributes to motor learning and functional performance. Nonetheless, the results of this study suggest that no relationship exists between weight-bearing and non-weight-bearing JRS and a healthy individual's ability to perform a novel functional task. In addition, there does not appear to be any relationship between an individual's current physical activity level and JRS acuity. Poor reliability of JRS assessments, however, might have limited the ability to detect such relationships. Future research should continue to attempt to determine whether there is a relationship between functional performance and clinical assessments of mechanoreceptor function and to determine a baseline level of sensorimotor function required to return individuals to their chosen level of activity. In addition, implications on closed kinetic chain rehabilitation of proprioception and motor learning based on increased mechanoreceptor feedback while in the weight-bearing position warrant further investigation.

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