JMSCR Vol||05||Issue||02||Pages 17484-17492||February 2017

www.jmscr.igmpublication.org
Impact Factor 5.84
Index Copernicus Value: 83.27
ISSN (e)-2347-176x ISSN (p) 2455-0450
crossref DOI: https://dx.doi.org/10.18535/jmscr/v5i2.45

IGM Publication
Journal Of Medical Science And Clinical Research
An Official Publication Of IGM Publication

Weight-Bearing and Non-Weight Bearing Proprioception Assessment of Dominant and Non-Dominant Lower Limbs in Adult Females

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Abstract
Background: *Weight-bearing (WB) assessment has long been reported to be more accurate and functionally related than non-weight-bearing (NWB) assessment. Yet, there is lack of knowledge that supports its relation with proprioception accuracy and functional performance.*
Purpose: *This study examined the relationship between WB and NWB active joint reposition sense (JRS) and a functional hop test. In addition to determining whether there are differences of these parameters between the dominant and non-dominant extremities.*
Methods: *Thirty adult females with mean age 20.3± 1.46 years and BMI 32.56 ± 3.26 kg/m^2 participated in the study. They were tested under two conditions for both lower limbs that were tested randomly; WB and NWB.*
Results: *Two-Way ANOVA revealed that the absolute errors of the JRS testing were significantly high during NWB testing compared with WB testing of both lower extremities (p<0.05). Moreover, the ANOVA revealed a significant reduction in the absolute error values of JRS with the dominant limbs compared with the non-dominant limbs (P<0.05) during both testing procedures. Additionally, the Pearson Product Moment Correlation Coefficient (r) showed moderate significant negative correlations between the hopping distances and absolute JRS testing errors of both NWB and WB testing of only the dominant lower limbs (r= -0.50, P= 0.034) and (r= -0.511, P= 0.030) respectively.*
Conclusion: *The findings indicate that WB proprioception assessment produced more accurate and functionally related results than NWB assessment especially for the dominant lower extremities in healthy adult females.*
Keywords: *Proprioception, weight-bearing, non-weight-bearing, closed kinetic chain, functional performance.*

Introduction

Proprioception is an important factor for safe and adequate performance of physical activities. Proprioception is the ability to detect changes in a specific joint position and being able to adapt to these changes [1]. It is a key component for body coordination and muscle control during the performance of movement [2]. Inputs from mechanoreceptors within the joint, ligaments, tendons and skin are all combined to give the sense of change of position [1]. Proprioception was first defined as the travelling of afferent information to the central nervous system (CNS). It encompasses a wide variety of different components including kinesthesia, somatosens-ation, balance, reflexive joint stability, and Joint Position Sense (JPS) [2].

Proprioceptive acuity has been defined as the ability of a person to feel his joint position, recognize joint movement, identify different forces falling on the joints, and discriminate movements between his limbs [3]. It has also been defined as the awareness of one's own body segments orientation and position [4]. Determining the specific receptors involved in proprioception is very difficult, as the body has the ability to use many sensory inputs to determine the joint's position and movement [5].

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 (JPS). In recent years, increasing numbers of authors have recommended weight- bearing (WB) tests of joint position or movement sense. They argue that WB tests are more functional, and involve all of the cutaneous, articular and muscular proprioceptors that act together during normal everyday activities [6,7]. They also argue that standing WB assessm-ents have more clinical relevance when evaluating proprioception in relation to falls [8], chronic sprained ankles [9] and other WB- specific pathologies.

Various studies conducted previously for comparing non-weight-bearing (NWB) with WB knee joint position or movement sense [6,10,11,12,13]. Because of the limitations in those trials (inconsistent results, different assessment proced-ures, different amount of weight bearing), the differences between the two assessment methods cannot be documented. Additionally, the relationship between JRS and functional performance has not been established.

Hence, there is limited knowledge about the effects of WB on proprioception accuracy and functional performance in adults. The purposes of this study were to determine the relationship between WB and NWB active JRS and a functional hop test. In addition to determining whether there are differences of these parameters between dominant and non-dominant extremities. As many previous studies used the other extremities as a reference after rehabilitation.

Single hop test was used to assess the functional performance. This functional test proved to have good intra-rater reliability and were related to changes in lower limbs' function [14]. By investigating the difference between WB and NWB proprioception assessment and their relations to functional performance, this study can recommend an accurate, cheap and non-invasive assessment tool for proprioception deficits. Proper assessment and follow up for proprioception and functional performance may limit future injuries, which has both positive health and economic impacts.

Materials and methods

Participants

A total of 30 healthy females free from neuromuscular dysfunction, vestibular disorders, and lower extremity injury participated in this study. Their mean (SD) age, weight and height were 20.3± 1.46 years, 75.6± 3.08kg, 1.76 ± 0.03 respectively. Participants were excluded if they were previously diagnosed with osteoarthritis or patellar tendinitis, had a previous history of surgery, fracture, patellar dislocation/subluxation, or ligamentous or other so tissue injury; or had any medical condition that precludes safe testing. An informed written consent was taken from the participants involved in the study. In the current study, bothlower limbs were tested. The institutional review board for research at the institution approved the procedures used in this study.

Instrumentation

A plastic standard goniometer was used to measure the knee- joint angles during JRS testing. It is formed of clear plastic that permit observation of joint's axis of motion and its range of motion. Joint angles were measured in 1° increments. Five-meters tape was used to measure the distance of single leg hopping test trials. The level of functional performance was assessed using the single hop test. This test has previously been used for assessing the lower extremity function and has produced reliable data (r = .96) [14].

Procedures

In the current study, WB and NWB knee joint reposition sense (JRS) were assessed in addition to the functional performance which is assessed using a single-leg-hop test in all participants. First, we determined whether there were differences between WB and NWB-JRS for dominant and non-dominant lower extremities. Then, we determined whether the functional performance correlated with either JRS tests. Each participant was allowed to randomly select one from two folded papers located in a container. These papers represented the dominant and non-dominant limbs. Then, each participant was asked to randomly select one from another two folded papers located in another container. These papers represented the WB and NWB proprioception assessment techniques. Each participant was tested according to these random selections.

Participant's dominant leg was defined as the leg with which the participant preferred to kick a ball. The absolute difference in degrees calculated between the target angle (30° of flexion) and active replication angles was averaged over three trials to represent each participant's score on both tests (absolute angular error). The same researcher performed all testing for each participant on the same day.

Prior to data collection, the plastic goniometer was attached to each participant's knee on the lateral aspect (along an imaginary line connecting the greater trochanter and the lateral malleolus) with non-adhesive elastic wrap. While the participant 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.

For the weight-bearing (WB) testing condition, which assessed the participants' ability to actively reproduce a target angle of 30°, the participant was instructed to stand on the tested limbwith eye closed. Then each participant was instructed to slowly squat. The researcher instructed the participant to stop and pause for 15 seconds when the knee-joint angle measured 30°. Next, the participant returned to a standing position and waited for 15 seconds. The participant was then instructed to reproduce the target angle for that trial as accurately as possible. Each participant maintained balance by leaning backward against the wall. The non-testing leg remained flexed and away from the ground during the entire test. Between trials, each participant walked five steps to eliminate any proprioceptive memory of the test.

For the non- weight-bearing (NWB) testing condition, participants were lying prone with their knees extended and trunk supported (figure 1), the participant 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 participant then returned the tested leg to the fully extended position and paused for 15 seconds. Next, the participant was instructed to reproduce the target angle of that trial as accurately as possible by active contraction at slow angular velocity and stopped when she perceived that the target angle had been reached. The participant was instructed to hold the knee in the test position for four seconds and to concentrate on (sensing) the knee position. Between trials the participant performed five repetitions of knee flexion and extension to eliminate any proprioceptive memory.

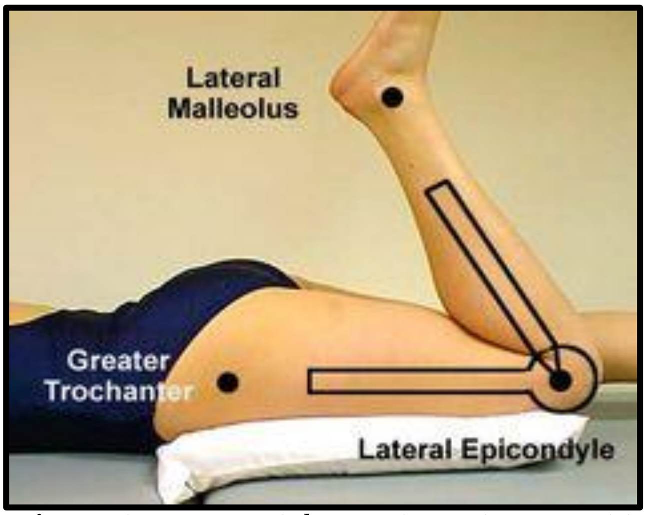

Figure 1: Non- Weight-Bearing Joint Reposition Sense testing from prone

After 5-minute rest period, the participant was asked to stand on the tested limb with the toes lined at the tape measure's zero mark. Then she was instructed to jump forward on one leg as far as possible using three consecutive hops. The recorded measure was the distance from the zero mark to the place where the back of the participant's heel hit the ground upon completing the single hop on the tested limb (Figure 2). Distance in centimeters was averaged over the three trials to represent each participant's score. Each participant kept his hands clasped together behind his back during the test, and a 45-second rest period was given between trials [15].

The same whole procedure was repeated again for the other limb after 5-min rest period. This rest period was given to minimize the carry- over effect of the sensation as indicated by Bell-Krotoski et al. [16].

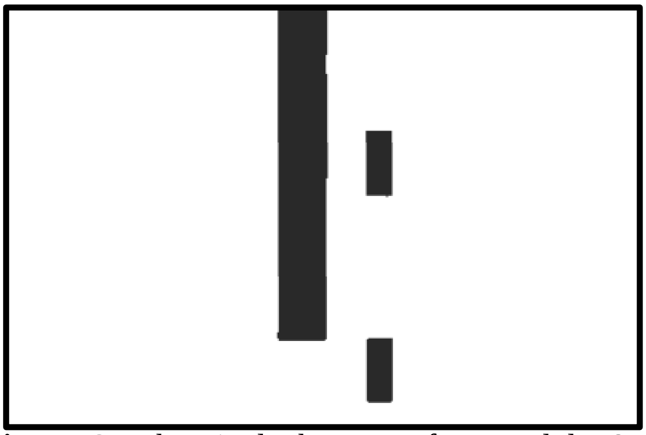

Figure 2: The single hop test from Bolgla & Keskula [14]

Statistical analysis

All statistical measures were performed through the Statistical Package for Social Science (SPSS) version 20 for windows. Initially, data were screened through conducting Kolmogorov-Smirnov and Shapiro-Wilks normality tests for normality assumption as a prerequisite for parametric analysis. This was done also through assessing for the presence of significant skewness and kurtosis in addition to the presence of extreme scores. Once data were found not to violate the normality assumptions, parametric analysis was used.

Two-way Analysis of Variance (ANOVA) within-subject design was used to differentiate between the different testing conditions for the absolute error of JRS of both lower extremities. Additionally, the paired t-test was used to compare between the dominant and non-dominant extremities for the SLH distance. Finally, the Pearson Product Moment Correlation Coefficient (r) was used to study the bivariate correlations of the absolute JRS testing error and the hopping distance of both lower limbs. The level of significance was set at an alpha level of 0.05.

Results

The Two-Way ANOVA showed that the magnitude of absolute errorsof the JRS testing were significantly high during NWB testing compared with WB testing of both lower extremities ($p<0.05$) (figure 3). Regarding the effect of dominancy, the ANOVA revealed a significant reduction in the absolute error values of JRS with the dominant limbs compared with the non-dominant limbs ($P<0.05$) during both testing procedures (figure 4). Additionally, the Paired t-test revealed that the SLH distance scores of the dominant lower limbs were significantly greater than the SLH distance scores of the non-dominant limbs (figure 5).

Moreover, a moderate significant negative correlations were detected between the hopping distances and absolute JRS testing errors of both NWB and WB testing of only the dominant lower limbs ($r= -0.50$, $P= 0.034$) and ($r= -0.511$, P=

0.030) respectively. While a weak non-significant correlations were detected between the hopping distances and absolute JRS testing errors of both NWB and WB testing of the non-dominant lower limbs (r= 0.1, P= 0.48) and (r= -0.03, P= 0.48) respectively.

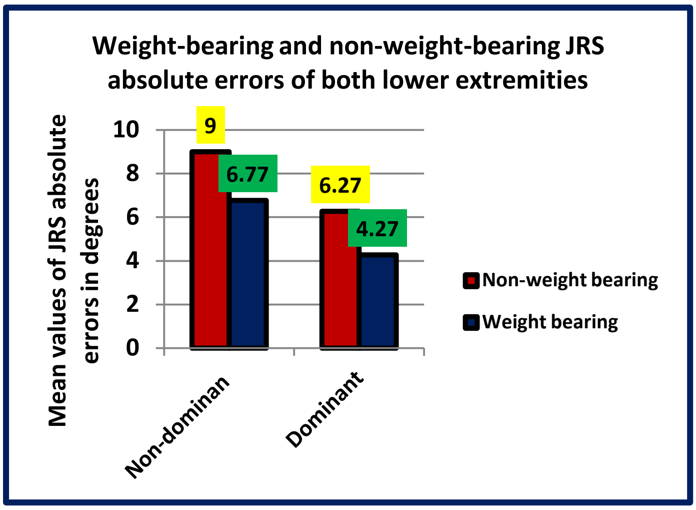

Figure (3): Absolute JRS testing errors during weight-bearing (WB) and non-weight bearing (NWB) testing of both lower extremities in healthy adult females

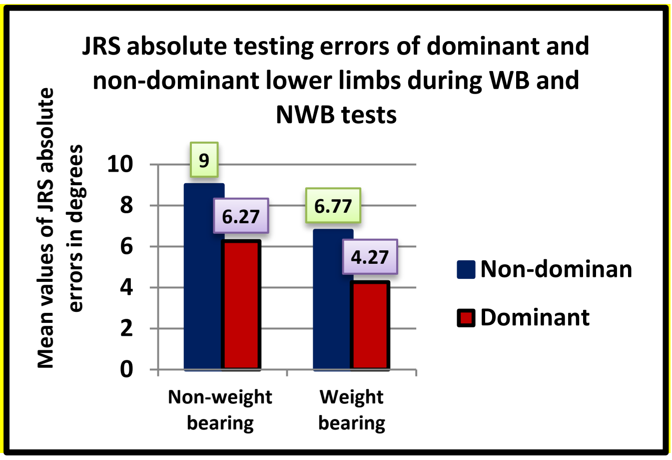

Figure (4): Absolute JRS testing errors of dominant and non-dominant lower extremities during WB and NWB testing in healthy adult females

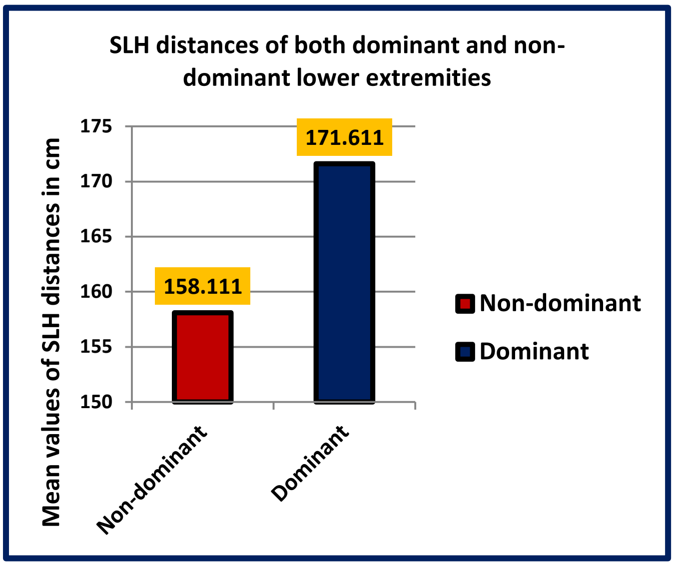

Figure (5): Single leg hop (SLH) distance scores of both lower extremities in healthy adult females

Discussion

The findings of the present study showed a significant reduction in the JRS errors with weight-bearing compared with non-weight bearing conditions. Despite the fact that it is not well known how WB diminishes JRS errors, it is suggested that the NWB knee repositioning procedure had the greatest potential for assessing the proprioception of the tested joint only,while whole limb positioning (WB) provides the chance for proprioceptive feedback from adjacent joints. Possibly, the sensory areas of the brain may use this information in detecting the location of the knee [17,18]. A similar explanation to locating the knee joint position during WB-JRS testing may arise from the skin of the tested foot [19]. WB may enhance the afferent signals from compressed mechanoreceptors in the connective tissue structures of the WB joints.

Another possible explanation is that foot dorsifl-exion and the resulting calf muscle lengthening which occurs during WB assessment procedures may also play an important rule. As it was concluded by Refshauge and Fitzpatrick [20] that the foot and knee postures, including calf stretch, were the major determinants of the WB (and NWB) test results. Also, it was previously documented that even aminimum resistance increases the afferent output from muscle spindles

[21], So the greater resistance applied to muscles through weight bearing may affect the magnitude of muscle contractions that may affect the proprioceptive acuity [22].

The difference between WB and NWB-JRS testing has been previously studied with controversial findings. The results of the current study are similar to those reported by Ghiasi and Akbari [23], Stillman and McMeeken [24], Hyouk Bang et al. [25]. These authors found significant reduction in the JRS errors during WB testing. The results of the current study are consistent also with those of Andersen et al. [6], who reported that knee joint angles are more accurately repositioned in the closed chain condition. Additionally, this study is also in agreement with the results found by Bunton et al. [26]. Those authors reported that proprioception is improved by WB because of the proprioceptive input produced by Golgi tendon organs, Golgi ligament endings, Ruffini endings, Pacinian corpuscles, and muscle spindles. which may be another explanation for the greater accuracy of WB testing found in this study.

On the other hand, the reported findings are contradicted with those reported by Kramer et al. [27] and Lokhande et al. [28]. These researchers did not find any significant difference between the two testing conditions. Additionally, Lokhande et al. [28] found a significant increase in the JRS testing errors during WB. These contradictions might be attributed to the different testing procedures of proprioception, and /or small sample sizes which might have resulted in low statistical power, and finally the different measured variables (absolute error or relative errors).

Regarding the effect of dominancy, the statistical analysis revealed a significant reduction in the absolute error values of JRS with the dominant limbs compared with the non-dominant limbs. Additionally, the Paired t-test revealed that the SLH distance scores of the dominant lower limbs were significantly greater than the SLH distance scores of the non-dominant side. These results are suggested to have resulted fromwhat is called dynamic neuromuscular imbalance that was observed in females by Hewett et al [29]. Those authors observed three neuromuscular imbalances presented in females. One of these imbalances is the dominant-leg dominance.

Dominant-leg dominance is the imbalance between muscular strength and recruitment on opposite limbs, with the non-dominant limb often having weaker and less coordinated musculature. The authors also stated that during single-leg landing, pivoting or deceleration, the female may have a lack of dynamic muscular control of the non-dominant knee, which may predispose the knee to injury [29]. The findings of the current study may support this view as all our participants were females.

The results of the current study are consistent with those of Hewett et al. [30]. Those authors concluded that when assessing proprioception and neuromuscular control, the contral ateral limb may not be a suitable control because of the bilateral deficits. While, the current results are contradicted with those obtained by Sekir et al. [31] who didn't found any difference between the two limbs. This contradiction may be attributed to different sample; as they assessed the proprioception in male subjects while in this study all the participants were females.

Regarding the relation between the JRS and functional performance, a moderate significant negative correlations were detected between the hopping distance and absolute JRS testing error of both NWB and WB conditions of the dominant lower limbs. While a very weak non-significant correlations were detected between the hopping distance and absolute JRS testing error of both NWB and WB testing of the non-dominant lower limbs. These relations may be attributed to the effect of dominant leg dominance on the functional performance that may occur via its significant effect on muscle strength and coordination that were just reported.

The results of the current study are consistent with those of Riskowski et al. [32]. Those authors found that dominant lower limbs are responsible for greater loading forces and greater propulsive forces than the non-dominant. They also recommended the presence of functional asymmetry in gait relate to balance, fall risk and ADL activities

Few previous studies found significant relation between the Functional performance and balance scores of non-dominant leg [33,34]. These contradictions may be due to the use of different samples, as all these articles assessed athlete participants (football, volleyball).These athletes use their non-dominant leg for support during kicking, while in this study the sample consisted of non-athlete females.

The current study is limited by the inability of generalizing the findings on the male population as the study being conducted on females. Females were examined as they constitute higher incidence of knee injury than males [35] and the fact that the measured variables are affected by sex [30]. On the other hand, this study has the privilege of being stringently designed through randomization of testing conditions rendered it more controlled than much of the previously conducted research in this area. Furthermore, examining one group of participant in a repeated-measures design enabled minimizing the extraneous effects that might affect the relationship between independent and the measured variables. Hence, the internal validity of the study was improved.

Conclusion

Weight-bearing proprioception assessment produced more accurate and functionally related results than non-weight-bearing assessment especially for the dominant lower extremities.

Acknowledgment

The author would like to thank all the participants who kindly participated in the study.

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