Artículo original

Measurement of ankle dorsiflexion: comparison between two different positions

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doi: 10.18176/archmeddeporte.00108

Recibido: 01/05/2020
Aceptado: 18/01/2021

Summary

Background: Several closed-chain activities, including walking, running, squatting or jumping, require normal flexibility of the ankle joint. Reduced ankle dorsiflexion range of motion will limit the forward progression of the tibia over the talus during these skills. A restriction ankle dorsiflexion range of motion has been associated with several clinical conditions in the lower extremities. Weight bearing dorsiflexion measurements has been shown to be more reliable than non-weight bearing and are more clinically relevant. In clinical practice and research, multiple protocols and positions have been utilized when measuring weight bearing ankle dorsiflexion range of motion, although the differences among have not been studied.
Objective: The purpose of this study was to come ankle dorsiflexion range of motion in two different positions: standing and kneeling.
Material and method: Sixty physically active participants (51 men, 9 women; average age 21.6 ± 1.2 years) participated in this study. Weight bearing ankle dorsiflexion range of motion was evaluated, in random order, in two positions: a standard position of the weight-bearing lunge test (WBL-Nor) and with the modified weight-bearing lunge test, one knee on the floor (WBL-Mod).
Results: Statistically significant differences were found ($p < 0.001$; $\eta^2=0.513$) between the values recorded during the WBL-Nor (12.5 ± 3.2 cm) vs. WBL-Mod (10.9 ± 3.5 cm).
Conclusion: The standing and kneeling tests of ankle dorsiflexion range of motion cannot be used interchangeably, if the objective is to measure peak ankle dorsiflexion range of motion. It is recommended that this test is performed in standing if the patient/research participant is capable.

Key words:
Foot. Weight-bearing. Range of motion. Articular.

Medición de la dorsiflexión del tobillo: comparación entre dos posiciones diferentes

Resumen

Antecedentes: Varias actividades en cadena cerrada, como caminar, correr, ponerse de cuclillas o saltar, requieren un rango de movimiento normal de la articulación del tobillo. La reducción del rango de movimiento de la dorsiflexión del tobillo limitará la progresión hacia adelante de la tibia sobre el astrágalo durante estas acciones. Una restricción de la dorsiflexión del tobillo se ha asociado con varias disfunciones clínicas en las extremidades inferiores. Se ha demostrado que las mediciones de dorsiflexión en carga son más fiables que las que no soportan carga y son más relevantes clínicamente. En la práctica clínica y en la investigación, se han utilizado múltiples protocolos y posiciones al medir el rango de movimiento de la dorsiflexión del tobillo en carga, aunque las diferencias entre ellas no se han estudiado.
Objetivo: El objetivo de este estudio fue obtener el rango de movimiento de la dorsiflexión del tobillo en dos posiciones diferentes: de pie y arrodillado.
Material y método: Sesenta participantes físicamente activos (51 hombres, 9 mujeres; edad promedio 21,6 ± 1,2 años) participaron en este estudio. Se evaluó el rango de movimiento de la dorsiflexión del tobillo en carga, en orden aleatorio, en dos posiciones: una posición estándar (WBL-Nor) y otra modificada, con una rodilla en el suelo (WBL -Modificación).
Resultados: Se encontraron diferencias estadísticamente significativas ($p <0{,}001$; $\eta^2 = 0{,}513$) entre los valores registrados durante el WBL-Nor (12,5 ± 3,2 cm) vs. WBL-Mod (10,9 ± 3,5 cm).
Conclusión: La posición de medición condicionan los valores de la dorsiflexión del tobillo. Si el objetivo es medir el rango de movimiento máximo de la dorsiflexión del tobillo, se recomienda que esta prueba se realice en WBL-Nor.

Palabras clave:
Pie. Carga. Rango de movimiento. Articular.

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Introduction

The knee and ankle are a complex joint that are mobile, flexible, stable, strong, and resistant, responsible to support the body mass, that allows to be engaged in a wide range of movements and activities of daily living[1,2].

Several closed-chain activities, including walking, running, squatting, landing or jumping, require normal flexibility of the ankle joint[3,4]. A restriction of ankle dorsiflexion range of motion (DF ROM) has been linked to lower extremity (LE) biomechanical faults and clinical conditions[5-9]. Restrictions in ankle DF ROM may be due to tightness of the triceps surae[5] or arthrokinematics restrictions in the posterior glide of the talus on the ankle mortise[10]. Reduced ankle DROM will limit the forward progression of the tibia over the talus during activities that require simultaneous knee flexion and ankle dorsiflexion[7]. During closed-chain activities, restricted DF ROM is often accompanied by decreased sagittal plane motion of the knee, hip, and trunk, as well as increased frontal plane motion of the LE[11]. For example, during a squat, restricted DF ROM may result in excessive subtalar joint pronation and midtarsal dorsiflexion[12], tibial and femoral internal rotation, medial knee displacement, and knee valgus[8,13]. Decreased DF ROM was also associated with reduced quadriceps activation and increased soleus activity during the descent portion of a squat[8].

Because of these biomechanical compensations, reduced ankle DF ROM has been associated with increased risk of several clinical conditions, including anterior cruciate ligament (ACL) injury[12], stress fractures[14], plantar fasciopathy[15], Achilles tendinopathy[16] patellar tendinopathy[17], patellofemoral pain syndrome[18] and iliotibial band syndrome[19]. Thus, physical therapists must recognize the importance of accurate assessment of DF ROM during pre-season screening for LE injury risk factors[20,21], as well as when evaluating and treating a variety of lower extremity clinical conditions[22,23].

Historically, DF ROM has been assessed in the clinic using a goniometer or inclinometer in a non-weight bearing position. Intra-rater reliability of measurements of non-weight bearing ankle DF ROM are moderate to good with a goniometer (ICC=0.65-0.89) and good with a digital inclinometer (ICC=0.84-0.95)[20]. However, inter-rater reliability of goniometric measurements has ranged from poor to moderate[24].

Recently, weight bearing tests have increased popularity[25], as this measurement is assumed to more precisely reflect ankle range of motion during functional activities[26]. The weight bearing lunge test (WBLT), as described by Bennell in 1998 measures ankle dorsiflexion isolated to the tibio-talar joint proportional to the patient's body weight[25]. The original WBLT aligned the subject perpendicular to wall and instructed the subject to bend the knee while keeping the heel on the ground. The subjects was repositioned further/closer to the wall until maximal dorsiflexion was achieved, defined as the maximal distance from the wall to the toe while maintaining contact with the wall and keeping the heel on the ground[27]. According to Bennell[26] (1998), 1.0 cm distance from the wall was equivalent to 3.6˚ of DF ROM.

Variations of the WBLT include using an inclinometer to measure the relative angle of the tibia to the ground. The weight-bearing lunge test has demonstrated good to excellent intra-rater (ICC= 0.88 and 0.97) and inter-rater reliability (ICC=0.82 and 0.97), both when measuring distance from the wall or tibial angle[21,26,27]. Along of the time, mobile applications that measure ankle dorsiflexion such as Tiltmeter[28], iHandy, and Dorsiflex iPhone app[29] have become more accessible and clinically useful. The Leg Motion® system (CheckyourMOtion®, Albacete, Spain) is a new, portable device designed to measure WB ankle DROM in a manner similar to the weight-bearing lunge test[3,30]. The Leg Motion® system has been demonstrated to be a reliable and valid measurement of WB ankle DF ROM in healthy participants and allows for test in virtually any location[3,31]. However, there is scarce information about different positions.

Multiple techniques have been utilized in the literature when measuring WB ankle DF ROM, including distance from the wall, digital inclinometry and goniometry[32]. Variations in the position of the contralateral lower extremity are seen as well. Bennell described the position of the untested limb as resting freely in a comfortable position on the floor[26]. The two most common positions utilize a tandem stance, one measuring the front ankle with the knee flexed and the other measuring the rear ankle with the knee extended[32]. While the majority studies perform the WBLT in standing, Balsalobre-Fernandez[29] took measurements with the subject kneeling on the opposite limb. Stanek[33] described the kneeling ankle dorsiflexion although the stepping distance was not standardized across participants.

The hypothesis of this study establishes the existence of significant differences in the result of the WBLT between the standard WBLT position (WBL-Nor) and a modified position of kneeling (WBL-Mod).

To date, no published studies have compared WB DF ROM in a kneeling position with a standing position. The purpose of the present work was to compare ankle DF ROM measurements between the standard WBLT position (WBL-Nor) and a modified position of kneeling (WBL-Mod). A secondary purpose of the investigation was to compare DF ROM measurements between right and left lower extremities in both conditions.

Material and method

Subjects

A priori sample size tests (G* Power 3.1.9.7) revealed that a total of 55 participants would be required to detect an effect side of 0.5, a statistical power of 0.8 and an alpha of 0.05. Therefore, 60 volunteers were recruited to avoid critical data loss.

Participants were recruited from a student population at a University. Sixty healthy, physically active adults (51 males and 9 females, age 21.6 ± 1.2 years, height 175.6 ± 0.3 cm, body mass 74.2 ± 7.3 kg) volunteered to participate in the study. Participants were excluded if they had any joint pathology in the hip, knee or ankle that a caused pain or restricted movement, neuromuscular disease, recent heel or knee pain; or a history of recent lower extremity trauma or elective surgery (in the last six months). The present study was approved by the institutional research ethics committee, and conformed to the recommendations of the Declaration of Helsinki. All participants read and signed an approved, written informed consent document before data collection.

Procedures

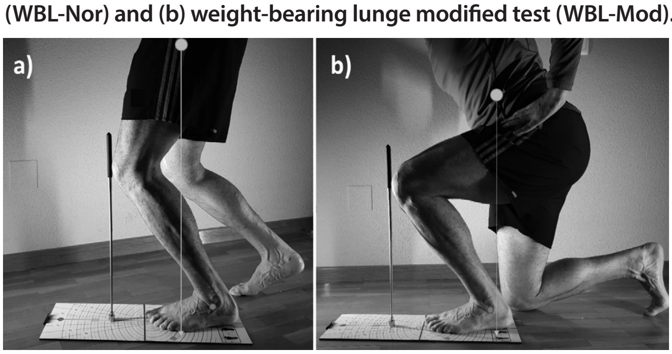
Ankle dorsiflexion ROM was evaluated using the LegMotion® system (CheckyourMOtion®, Albacete, Spain) in two positions: a standard position of the weight-bearing lunge test (WBL-Nor) and with the weight-bearing lunge modified test, one knee on the floor (WBL-Mod). The order of testing was determined by coin flip. All tests were conducted at the same time of the day (9:00 to 14:00) with 2 days (48 hours) between sessions.

For both tests (WBL-Nor and WBL-Mod), all subjects started with their hands on the hips and placed the assigned foot on the middle of the longitudinal line just behind the transverse line on the platform. During WBL-Nor the contralateral foot was placed lateral to the platform, with toes even with the posterior edge of the platform (Figure 1a). During WBL-Mod test the contralateral knee was placed posterolateral to platform, with the femur starting perpendicular to the ground, and the tested foot flat on the platform (Figure 1b). In both positions, the second toe and the center of the heel were placed directly over LegMotion® system (CheckyourMOtion®, Albacete, Spain), in order to attempt to reduce the subtalar joint pronation during the measurement procedure. While maintaining each position, subjects were instructed to perform a lunge in which the knee was flexed with the goal of making contact between the anterior knee and the metal stick. When the subjects were able to maintain heel and knee contact, the metal stick was moved away from the knee (Figure 1). The maximal distance achieved was recorded in centimeters. Three trials were performed for each ankle with ten seconds rest between trials. The third value in each ankle was selected for subsequent analysis of weight-bearing DF ROM[3,31,34].

Data analysis

Data were analyzed using PASW/SPSS Statistics 23 (SPSS Inc, Chicago, IL). After comparing the normality of the data by means of the Kolmogorov-Smirnov test, the Student t test for related samples was applied, establishing the level of significance at $p \leq 0.05$. All the measures were normally distributed, as determined by the Kolmogorov-Smirnov test. Sphericity was tested by the Greenhouse-Geisser method. The dependent variable (DF ROM) was evaluated with a two-way repeated measures analysis of variance (ANOVA) of test x leg. Where significant F values were achieved, pairwise comparisons were performed using the Bonferroni post hoc procedure. Effect size statistic, η^2, was analyzed to determine the magnitude of the effect independent of sample size. Values are presented as mean ± standard deviation (SD).

Figure 1. Leg Motion procedure (a) weight-bearing lunge test (WBL-Nor) and (b) weight-bearing lunge modified test (WBL-Mod).



Results

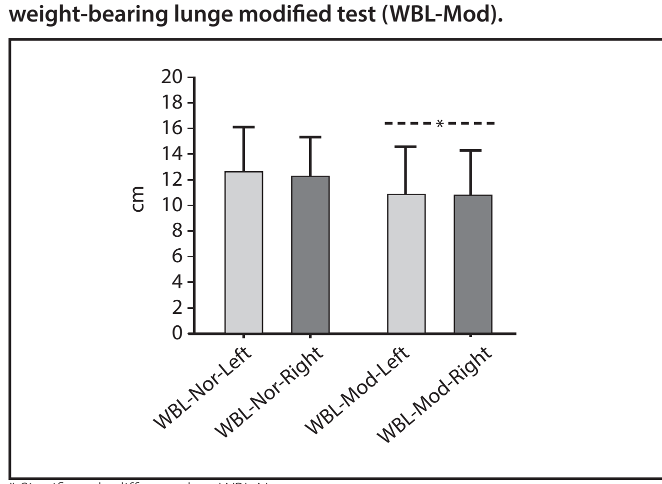
On average, participants in standing (WBL-Nor) achieved greater DF ROM (12.5 ± 3.2 cm) compared to kneeling (WBL-Mod) (10.9 ± 3.5 cm) (Figure 2). This difference, -1.6 cm, 95% CI [1.29, 1.94] was significant ($p < 0.001$), and represented a medium effect size, η^2=0.513.

There was no significant difference between right and left legs ($p > 0.05$; η^2=0.017). ANOVA showed no significant interaction effects between test procedure and legs ($p > 0.05$; η^2=0.014).

Discussion

This was the first investigation to compared the DF ROM between two versions of the weight bearing lunge test: standing (WBL-Nor) and kneeling (WBL-Mod). Significant differences in DF ROM were found between the two positions, with greater DF ROM recorded in the standing position. Several studies have demonstrated greater ankle DF ROM in weight bearing compared to non-weight bearing in healthy subjects. Most authors attribute these differences to the greater moments applied to the ankle joint during weight-bearing[24,32,35,36]. The present method did not allow us to quantify the contribution of the moment applied to the ankle, but some assumptions can be made, based on biomechanical principles. The WBL-Nor position allows a greater anterior excursion of the body's center of mass (COM), approximated just anterior to S2, than the WBL-Mod position (Figure 1). A more anterior center of mass increases the distance from the ankle joint to the body weight vector, this increasing the torque at the ankle joint. Additionally, in the kneeling position, a larger percentage of the individual's body weight is presumably accepted through the non-tested LE. Thus, the force of the body weight vector in the WBL-Mod position is less than in

Figure 2. DF ROM of weight-bearing lunge test (WBL-Nor) and weight-bearing lunge modified test (WBL-Mod).



* Significantly different than WBL-Nor.ms

the standing position. The combination of a greater moment arm and greater force through the body weight vector in the WBL-Nor position results in a much larger moment dorsiflexion moment about the ankle in standing. Thus, these findings of greater DF ROM in the standing WBL position are consistent with other studies demonstrating increased DF ROM with increased DF moment through the ankle[24,35,36].

Subjects in this study demonstrated a statistically significant difference in DF ROM between the WBL-Nor and WBL-Mod positions ($p < 0.001$). The mean WBL-Nor DF ROM in this study was 12.9 ± 3.2 cm, compared to 10.9 ± 3.5 cm in the WBL-Mod position. The WBL-Nor data is consistent with other studies that have utilized the tape measure or LegMotion system ® with healthy young adults, with mean distances ranging from 10.3 to 12.0 cm and standard deviations of 2.7-3.0 cm[3,21,30,37-39]. This difference is clinically relevant based previous publications that have determined the minimal detectable change of the WBL-Nor to be 1.1 - 1.6 cm[21,36,40].

This data did not show any differences between the right or left ankles for either the WBL-Nor or WBL-Mod positions. This is consistent with previous works that have found minimal differences between limbs in the WBLT[3,29,30,39]. Hoch and McKeon[38] noted that the majority of healthy subjects exhibited asymmetry of DF ROM of 1.5 cm or less, but there was not limb bias observed in the asymmetries. Reid[41] has suggested using a cutoff of 2.0 cm or greater of asymmetry as a clinically relative impairment.

A limitation to this investigation was the sample of participants used in this study took part physically active and therefore, the results cannot be generalized to a non-sporting population. Another limitation that there was no measurement to the the nature of the restriction in ankle DF-ROM[42].

There are two benefits of this study. First, the test can be performed on patients for whom weight-bearing is contraindicated in a standard position of the weight-bearing lunge test (WBL-Nor). Second, it isn´t difficult for a single observer to measure dorsiflexion with flexed knee. It is simple to administer, that allows health professional directly assess the ankle dorsiflexion range of motion while adopting a comfortable testing position.

Conclusion

Healthy subjects demonstrated greater DF ROM during the WBLT when performed in the standing position compared to a kneeling position. Given the results of the current study, if the objective of the test is to measure peak passive ankle dorsiflexion, it is recommended that this test is performed in standing if the patient/research participant is capable. Not only was there an effect of position on peak passive dorsiflexion where greater values were achieved in standing, but the difference was clinically relevant based on the published minimal detectable change (MDC)[21,32].

Declaration of interest statement

The last author declared potential conflicts of interest. He has patented the LegMotion® system (CheckyourMOtion®, Albacete, Spain).

Acknowledgments

The authors thank all the participants which, without their help, we were not able to conduct the study.

Conflict of interest

The authors do not declare a conflict of interest.

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