Immediate Effect of Manual Therapy Techniques on the Limitation of Ankle Dorsiflexion: A Randomized, Controlled, Double-Blind Clinical Trial Protocol

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Research Article

Keywords: Dorsiflexion, joint mobilization, functional tests and postural control

Posted Date: July 6th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-494155/v1>

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Abstract

Background: The range of motion (RoM) of dorsiflexion (DF) plays an important role in human mobility, such as absorption of body weight during gait deceleration, jump landings, balance and eccentric movements. This limitation can generate potentially damaging movements. This way, evaluating techniques for DF RoM increase could help improve immediate performance in such functional activities. This being the case, the objective of this study will be to verify the sum effect of different joint mobilization techniques for DF gain in persons practicing physical activities and its relationship with functional performance and balance.

Methodology: This is a randomized, controlled and double-blind clinical trial. Sixty-four (64) volunteers will be recruited, aged between 18 and 40 years, who have DF limitation. After checking eligibility criteria, the participants will be submitted to a physiotherapeutic evaluation. Volunteers will be evaluated as to a DF for open kinetic chain (OKC) and closed kinetic chain (CKC), and also submitted to functional Y Balance Test under a force platform and Triple Hop Test, by a blind examiner. Another researcher, also blind, will perform the randomization of patients in groups: (A) Joint Mobilization - *Mulligan* Concept and (B) Joint Mobilization - *Maitland* Method. After the randomization, volunteers will be submitted to initial evaluation (A0) and, after 2-3 days, they will be submitted to application of the techniques, which will be randomized, and reassessed immediately (A1). After 3-4 days of the application of the techniques, the re-evaluation will be performed (A2).

Discussion: It is already known that DF RoM limitation can lead to compensatory and potentially damaging lower limb movements and that joint mobilizations are effective to treatment. However, there is no consensus whether the application of these techniques would also improve aspects of dynamic postural balance and performance in individuals practicing physical activity, and whether the sum of two joint mobilization techniques could enhance this effect. Trial registration: RBR-93xv9t, Registered 09 April 2020, <https://ensaiosclinicos.gov.br/rg/RBR-93xv9t>.

Background

Ankle dorsiflexion (DF) range of motion (RoM) plays an important role in absorbing body weight during gait deceleration, jump landings and eccentric movements [1]. The arthro-kinematic movement of DF is performed by the anterior sliding of the tibia over the talus, in closed kinetic chain (CKC) and, in open kinetic chain (OKC), the posterior sliding of the talus in relation to the tibia [2]. In this manner, the expected DF RoM for this ankle movement is 45° in CKC and 22° in OKC [3]. Some studies suggest that lower values may be considered inadequate and associated with patterns of potentially predictive movements of lower limb injury [4, 2].

These movement patterns are related to physical activities that require a wide amplitude of DF, such as jumping, step-up and step-down, since the RoM of normal DF collaborates in the load absorption imposed on the lower limb [2, 5, 6]. In conditions of CKC activities, DF limitation could difficult

progression of the tibia over the talus, limit knee flexion, decrease absorption capacity of eccentric loads and lead to compensatory knee and hip movements in the frontal plane[7].

Moreover, although the predisposing factors to injury are not totally conclusive, some studies show that DF RoM deficit perpetuates ankle instability [8, 9, 10, 11]. So, to evaluate interventions that promote this movement is of great relevance for choosing the best techniques or combination different techniques, specially of the joint mobilization to improve ankle RoM and, consequently, to reduce risk of injuries, to treat and minimize compensations and overloads in lower limbs.

Another aspect considered by Vallandingham et.al [12] is associated with DF RoM relationship and dynamic postural balance. The authors observed that DF RoM deficit reduces balance. This being so, evaluating postural control in physically active volunteers with ankle dorsiflexion deficit will bring important information for us to understand its association with functional aspects of postural balance.

Physiotherapy has tools that restore RoM such as joint mobilization, often used for this purpose [10, 13]. Specifically for gain of DF, two techniques are known and have already been studied. *Mobilization with Movement* (MWM) of the *Mulligan* Concept [11, 13, 14] is the first of them, in which the author of the technique reports that it is performed with movement close to functional in CKC [14]. According to the systematic review by Weerasekara, et.al [15], this could bring immediate benefits with its application for DF RoM. However, this same study shows that there is no consensus on immediate improvement regarding other outcomes [15].

The second technique of joint mobilization which is widely used for DF improve is the Anteroposterior Passive Mobilization (AP) of the talus in relation to the tibia of the *Maitland Method* [16, 17]. According to some authors, there is no superiority when comparing techniques for improve RoM [18, 19], but no studies were found that evaluated the additional effect on DF RoM, postural balance and functional performance when associated these two techniques of joint mobilization in same treatment.

As such, this study aims to evaluate the immediate and short-term additional effect of joint mobilization in relation to RoM, functional performance and postural balance in the physically active population.

Subjects And Methods

Study Design

This study is a randomized, controlled, double blind clinical trial with two parallel groups (**Fig. 1**). The study was approved by the Human Rights Ethics Committee under protocol number CAAE: 30660520.1.0000.5152 and registered in the Brazilian Registry of Clinical Trials (ReBEC) (Registration number: RBR-93xv9t). It is funded by the *Coordenação de Aperfeiçoamento Pessoal de Nível Superior* (CAPES- Master's Scholarship). Recruitment will begin in September 2020 with a probable end date of July 22, 2021. According to Flowchart (**Fig.1**) evaluations will be conducted pre-intervention (A0), post-intervention (A1), and 3-4 days after intervention (A2). Variables to be observed are: Amplitude of Motion

of Dorsiflexion of ankle in closed kinetic chain and open kinetic chain, postural balance and functional performance.

Participants and Evaluators

Sample calculation was performed using difference of means and standard deviation, based on closed kinetic chain range of motion, of similar works, being RoM of DF in CKC, primary outcome, performed through the Lunge Test (LT), and minimum clinically relevant difference of 3.8 degrees[20], and considering *ANOVA* statistical test of repeated measurements. Power of the test considered was 80% and alpha of 0.05, being sample size of 28 volunteers per group.

Considering possible sample losses, a total of 64 volunteers, aged between 18 and 40, who have RoM in CKC less than 40° DF ankle will be recruited. If the volunteer has bilateral ankle dorsiflexion limitation, the most affected side will be considered for analysis and intervention.

Exclusion criteria are: presenting musculoskeletal injury in lower limb, rheumatic diseases, cardiovascular diseases, or any other alteration that could harm the volunteer's health or compromise performance of tests.

These individuals will be recruited through posters on campus of the Federal University of Uberlândia (UFU) and by dissemination on social media and local media.

Research will be developed at the Laboratory of Evaluation in Biomechanics and Neurosciences (LABiN) of the Faculty of Physical Education and Physical Therapy of the Federal University of Uberlândia, Minas Gerais, Brazil.

Procedures

All participants will receive a Free and Informed Consent Term.

Volunteers will be submitted to individual physiotherapeutic evaluation containing ankle range of motion, history of injuries and previous treatments, physical activities performed, history of other diseases and, if necessary, special tests for hip, knee and ankle to exclude musculoskeletal changes in lower limbs, these being the eligibility criteria. After selection, all eligible volunteers will be randomized into two groups by a *blind* (unbiased) researcher not involved with evaluation, intervention and recruitment of volunteers. Volunteers will be informed that they will receive physiotherapeutic intervention, but will not know the difference between treatment groups or study hypothesis, and may therefore be considered blind. Randomization will be carried out by Microsoft Excell® RAND command and placed in a brown sealed envelope, listed sequentially to hide participants allocation. These will be distributed in two groups, intervention A and intervention B, and only a physiotherapist, who will not be involved in evaluations, will be responsible for applying treatment techniques and will be considered blind for evaluations.

Intervention / Control

Sixty-four volunteers will be randomly allocated in 2 groups: (A) Articular Mobilization - *Mulligan* Concept; (B) Articular Mobilization - *Mulligan* Concept + Articular Mobilization - Maitland Method. Both groups will be submitted to intervention according to techniques mentioned.

Intervention group A will be submitted to *Mulligan* mobilization technique - Mobilization with Movement (MWM) - where physiotherapist will manually stabilize with continuous pressure on the Talus in the AP direction and a belt will be passed around the distal region of the leg region of the volunteer and waist of the therapist, where pressure will be applied in the PA direction accompanying the entire range of motion that will be performed with active movements of DF with weight bearing on assessed limb performing a sinking movement and, at the end of active movement, the patient will be guided to perform a final pressure called overpressure. Intervention will be performed in 3 series of 10 repetitions. In addition, the volunteer will be guided to perform self-mobilization by performing oscillatory movements at the end of DF with weight discharge, in 3 series of 10 repetitions per day, aiming at gaining an ankle DF during 3 days [14,18].

Intervention group B will also be submitted to technique cited in group A plus Maitland method technique, which will be applied after intervention A, in grade IV, with volunteer in dorsal decubitus, and foot out of stretcher. Mobilization will occur through a passive oscillatory pressure in AP direction in talus, for 5 series of 1 minute [21,18]. All techniques will be performed by a physiotherapist trained and experienced in clinical applicability of both techniques.

Outcome Measurements

Three outcome measurements will be evaluated, 2-3 days before intervention application (A0), after immediate intervention (A1), and 3-4 days after intervention (A2).

Primary Outcome

The primary outcome corresponds to DF ankle range of motion of in CKC measured through Lunge Test (LT).

Secondary Outcome

Secondary outcome corresponds to passive ankle DF measured in OKC by means of a goniometer, Postural Control which will be evaluated through oscillation of CoP during evaluation of Y Balance Test, which will be carried out on force platform, with functional performance evaluated through Y balance test (YBT) and Triple Hop Test (THT) and, satisfaction evaluated through Medrisk satisfaction questionnaire [22].

Each result measurement is described below:

Range of Motion (RoM)

DF RoM will be measured in CKC performed by LT, this test being of high reliability for measurement of DF (ICC = 0.98) [23]. To this end, a smartphone and an application will be used for acquisition of measurements (Clinometer[®]), this application having already been validated [24].

Test will be performed with participant barefoot and with weight bearing on member evaluated (**Fig. 2**). A 50 cm line will be fixed on ground and a continuous 60 cm line will be demarcated on wall to perform test [3]. Cell phone device will be positioned 15 cm away from anterior tibial tuberosity [3]. Participants will be positioned with their feet along line on ground, and then will be asked to move maximum DF, thereby bringing knee closer to vertical line drawn on wall, without foot moving from ground (**Fig. 2**). Once maximum DF is reached, examiner will position inclinometer on reference marked on volunteer's leg. Angle (in degrees) of DF and distance (in cm) from tip of 1st toe to wall will be computed. Participant will return to initial position. Procedure will be repeated 3 times and average calculated for later analysis [4].

RoM will also be measured in OKC by means of goniometry, method validated by Petherick et.al in 1988 [26]. Participant will remain in a ventral decubitus position, knee positioned at 90° and asked to perform ankle DF movement and then evaluator will help to complete maximum DF range passively. The goniometer will be positioned on lateral malleolus with its central axis, fixed arm directed towards lateral epicondyle of knee and mobile axis will be directed towards 5th metatarsal (**Fig.3**). This procedure will be repeated 3 times and mean calculated for later analysis [26].

Postural Control

Postural control will be evaluated during execution of YBT using force platform.

Postural oscillation will be evaluated through analysis of center of pressure (CoP) displacement with data obtained during execution of YBT, performed during use of force platform (EMGSystem do Brasil® São José dos Campos, SP), with sampling frequency being 500 Hz. Force signals obtained (Fx, Fy and Fz) and the moments of these forces (Mx, My and Mz), will be used to determine CoP oscillation, with direction of CoP oscillation being considered, [+x]- anterior; [+y]- right and [+z]- upper directions will also be used.

Collecting environment will have controlled temperature and noise level minimizing interference in postural control. Participants will be previously oriented as to positions that should be performed during data collection. Volunteer must be initially positioned with face facing posterior direction of platform (-Fy).

During execution of YBT, volunteer will be tested in *unipodal* support under force platform. Participants will be positioned with foot to be evaluated at intersections of lines, formed by previous, posterior-medial and posterior-lateral directions marked on force platform. Participants will be verbally instructed to perform maximum reaches in three directions, with contralateral limb, with upper limbs positioned at waist level [27] (**Fig. 4**).

Participants will perform 3 familiarizations, followed by 3 tests for each direction. Test will be invalidated if hands do not remain at waist area, if position of support is not maintained, if heel does not remain in contact with platform during reach, if volunteer unloads body weight onto contralateral limb, or if participant loses balance during test [27].

For kinetic analysis during YBT execution, data will be filtered using Butterworth 2nd order 2.5 Hz low-pass filter applied in direct and reverse direction. Variables will be calculated: average speed (cm/s); anteroposterior peak speed (Y) (cm/s); mid-lateral peak speed (X) (cm/s); anteroposterior displacement amplitude (Y) (cm); mid-lateral displacement amplitude (X) (cm); average displacement (XY) (cm) and reliable ellipse area (cm²)⁴³ for each test displacement direction.

Functional Performance

During execution of YBT, carried out as described above, will also be computed for each direction, anterior, postero-medial and postero-lateral, displacement, in centimeters, performed with contralateral limb to supporting member [27] (**Fig. 4**). Average displacement (AD) in each direction will be normalized using length of support leg (LS) of individual [27], and composite score (CS) will be calculated.

$$CS = AD (Ant+Postero-medial+postero-lateral)/3 \times LS (*100)$$

To evaluate functional performance of THT, a demarcation will be carried out, consisting of a line 6 meters long and 15 centimetres wide, perpendicular to a starting point [29].

This test is used to measure combination of muscle strength, neuromuscular control, and ability to tolerate sports-related activities[30]. Participant must perform 3 maximum jumps with same leg following trajectory of marked line. Subsequently, the distance between starting line and tip of Hálux at site of last landing must be measured in centimeters [29] (**Fig.5**). Three (3) repetitions will be carried out for member to be tested and best result will be computed for later analysis.

Satisfaction

At the end of data collection after final reassessment (3-4 after applying technique), the Medrisk [23] satisfaction questionnaire will be presented, which is an instrument used to evaluate patient's satisfaction with physiotherapy treatment, composed of 13 questions with scores from 1 to 5 evaluating quality of service and, 1 question evaluating one's clinical perception of performance improvement.

Statistical Analysis

The normality test will be performed using the Kolmogorov Smirnov test. If null hypothesis is confirmed, comparison between groups will be performed using parametric tests, however, if null is not confirmed, non-parametric tests will be applied.

For parametric data the effect of treatment will be evaluated by ANOVA two-way test for repeated measurements, considering value of $p \leq 0.05$. Data will be evaluated by intention to treat.

Clinical relevance of results will be confirmed by calculating effect size (Cohen' d) of significant differences found between assessments. The following effects will be considered: 0.00-0.49, small; 0.50-0.79, medium and above 0.80, large (Cohen, 1988). Analysis of data will be made by intention to treat [31].

Discussion

Literature shows that the difficulty of sliding tibia over talus can limit DF in CKC, which can limit knee flexion and decrease ability to absorb eccentric loads [7]. This limitation may generate patterns of potentially predictive movements for lower limb injury [2, 25]. Some techniques and methods of joint mobilization are recognized for restoring DF RoM [10, 13]. However, there is still no consensus in literature on the addition of clinical effects on ankle DF RoM in the execution of these techniques, especially in the combination of the two best known techniques: *Mulligan* Concept and Maitland Method. In addition, no studies were found which assess maintenance of effect even if immediate or short term.

Although Vallandingham et.al [12] demonstrated an association between ankle DF RoM and dynamic postural balance, this factor is still not well established in literature. Understanding the influence of ankle RoM of DF on these variables could be an important parameter in understanding functional aspects, involvement in lower limb movement and rehabilitation process.

Trial Status

The trial registration RBR-93xv9t, Registered 09 April 2020, had as its date the first enrolled in 20 January 2021, with expected date of completion of collection in 10 September 2021.

Abbreviation

RoM - Amplitude of Movement

DF - Dorsiflection

OKC – Open Kinetic Chain

CKC - Closed Kinetic Chain

YBT - Y Balance Test

THT - Triple Hop Test

MWM - *Mobilization with Movement*

AP - anteroposterior

ReBEC - Brazilian Registry of Clinical Trials

CAPES - Coordenação de Aperfeiçoamento de Pessoal de Nível Superior

LT - Lunge Test

LABiN - Laboratório de Avaliação em Biomecânica e Neurociências

Declarations

Ethical Approval

The study was approved by the Human Rights Ethics Committee of the Federal University of Uberlândia under protocol number CAAE: 30660520.1.0000.5152.

The study was registered in the Brazilian Registry of Clinical Trials (ReBEC) (Registration number: RBR-93xv9t).

Consent for Publication

All participants will receive a consent form to be included in the study. By signing this form, the participants allow the use and publication of their data anonymously in this study. All authors of this article are consenting to acceptance for publication. All authors are also consenting to availability for publication of materials and data from this article. Volunteers consent to having their photos published where their faces will always be covered to avoid any possible identification.

Availability of Data and Materials

Not Applicable.

Competing Interests

Authors declare that they have no competing interests.

Funding

This Trial is being funded by the Coordination for Higher Level Personal Improvement (CAPES- Masters scholarship at MCS).

Recognitions

Not applicable.

Authors' contribution

All authors have read and approved the final manuscript. MCS is lead author and has developed conception of study idea and design, manuscript writing and will carry out treatment of clinical trial. RMB and CL developed conception of study idea and will participate in manuscript writing. GMA and GBBC will be blind evaluators and will contribute to manuscript writing. LRF was responsible for conception of study idea and design, project supervision and manuscript writing.

Acknowledgements

Not applicable.

References

1. Dubin JC, Comeau D, McClelland RI, Dubin RA, Ferrel E. Lateral and syndesmotric ankle sprain injuries: a narrative literature review. *J Chiropr Med*. 2011 Sep;10(3):204-19. doi: 10.1016/j.jcm.2011.02.001. Epub 2011 Jul 23.
2. Malliaras P, Cook JL, Kent P. Reduced ankle dorsiflexion range may increase the risk of patellar tendon injury among volleyball players. *J Sci Med Sport*. 2006 Aug;9(4):304-9. doi: 10.1016/j.jsams.2006.03.015.
3. Hall EA, Docherty CL. Validity of clinical outcome measures to evaluate ankle range of motion during the weight-bearing lunge test. *J Sci Med Sport*. 2017 Jul;20(7):618-621. doi: 10.1016/j.jsams.2016.11.001.
4. Rabin A, Portnoy S, Kozol Z. The Association of Ankle Dorsiflexion Range of Motion With Hip and Knee Kinematics During the Lateral Step-down Test. *J Orthop Sports Phys Ther*. 2016 Nov;46(11):1002-1009. doi: 10.2519/jospt.2016.6621.
5. Hoch MC, Farwell KE, Gaven SL, Weinhandl JT. Weight-Bearing Dorsiflexion Range of Motion and Landing Biomechanics in Individuals With Chronic Ankle Instability. *J Athl Train*. 2015 Aug;50(8):833-9. doi: 10.4085/1062-6050-50.5.07. Epub 2015 Jun 11.
6. Hoch MC, Staton GS, Medina McKeon JM, Mattacola CG, McKeon PO. Dorsiflexion and dynamic postural control deficits are present in those with chronic ankle instability. *J Sci Med Sport*. 2012 Nov;15(6):574-9. doi: 10.1016/j.jsams.2012.02.009.
7. Moore C, Donovan L, Murray AM, Armstrong C, Glaviano NR. External ankle taping does not alter lower extremity side-step cut and straight sprint biomechanics in young adult males. *Sports Biomech*. 2020 Jun;19(3):395-410. doi: 10.1080/14763141.2018.1493743.
8. Barker HB, Beynnon BD, Renström PA. Ankle injury risk factors in sports. *Sports Med*. 1997 Feb;23(2):69-74. doi: 10.2165/00007256-199723020-00001.
9. Bennell KL, Talbot RC, Wajswelner H, Techovanich W, Kelly DH, Hall AJ. Intra-rater and inter-rater reliability of a weight-bearing lunge measure of ankle dorsiflexion. *Aust J Physiother*. 1998;44(3):175-180. doi: 10.1016/s0004-9514(14)60377-9.

10. Pope R, Herbert R, Kirwan J. Effects of ankle dorsiflexion range and pre-exercise calf muscle stretching on injury risk in Army recruits. *Aust J Physiother.* 1998;44(3):165-172. doi: 10.1016/s0004-9514(14)60376-7.
11. Vicenzino B, Branjerdporn M, Teys P, Jordan K. Initial changes in posterior talar glide and dorsiflexion of the ankle after mobilization with movement in individuals with recurrent ankle sprain. *J Orthop Sports Phys Ther.* 2006 Jul;36(7):464-71. doi: 10.2519/jospt.2006.2265.
12. Vallandingham RA, Gaven SL, Powden CJ. Changes in Dorsiflexion and Dynamic Postural Control After Mobilizations in Individuals With Chronic Ankle Instability: A Systematic Review and Meta-Analysis. *J Athl Train.* 2019 Apr;54(4):403-417. doi: 10.4085/1062-6050-380-17.
13. Collins N, Teys P, Vicenzino B. The initial effects of a Mulligan's mobilization with movement technique on dorsiflexion and pain in subacute ankle sprains. *Man Ther.* 2004 May;9(2):77-82. doi: 10.1016/S1356-689X(03)00101-2.
14. MULLIGAN, B. R. *Manual therapy – 'NAGS', 'SNAGS', 'MWMS' etc.* 6.ed. Wellington: Plane View Services, 2010;
15. Weerasekara I, Deam H, Bamborough N, Brown S, Donnelly J, Thorp N, Rivett DA. Effect of Mobilisation with Movement (MWM) on clinical outcomes in lateral ankle sprains: A systematic review and meta-analysis. *Foot (Edinb).* 2020 Jun;43:101657. doi: 10.1016/j.foot.2019.101657.
16. Green T, Refshauge K, Crosbie J, Adams R. A randomized controlled trial of a passive accessory joint mobilization on acute ankle inversion sprains. *Phys Ther.* 2001 Apr;81(4):984-94.
17. de Souza MV, Venturini C, Teixeira LM, Chagas MH, de Resende MA. Force-displacement relationship during anteroposterior mobilization of the ankle joint. *J Manipulative Physiol Ther.* 2008 May;31(4):285-92. doi: 10.1016/j.jmpt.2008.03.005.
18. Rao RV, Balthillaya G, Prabhu A, Kamath A. Immediate effects of Maitland mobilization versus Mulligan Mobilization with Movement in Osteoarthritis knee- A Randomized Crossover trial. *J Bodyw Mov Ther.* 2018 Jul;22(3):572-579. doi: 10.1016/j.jbmt.2017.09.017.
19. Noten S, Meeus M, Stassijns G, Van Glabbeek F, Verborgt O, Struyf F. Efficacy of Different Types of Mobilization Techniques in Patients With Primary Adhesive Capsulitis of the Shoulder: A Systematic Review. *Arch Phys Med Rehabil.* 2016 May;97(5):815-25. doi: 10.1016/j.apmr.2015.07.025.
20. Konor MM, Morton S, Eckerson JM, Grindstaff TL. Reliability of three measures of ankle dorsiflexion range of motion. *Int J Sports Phys Ther.* 2012 Jun;7(3):279-87.
21. GD Maitland (Ed.), *Maitland's vertebral manipulation* (6th ed.), Butterworth-Heinemann, Oxford (2001), p. 171.
22. de Fátima Costa Oliveira N, Oliveira Pena Costa L, Nelson R, Maher CG, Beattie PF, de Bie R, Oliveira W, Camara Azevedo D, da Cunha Menezes Costa L. Measurement properties of the Brazilian Portuguese version of the MedRisk instrument for measuring patient satisfaction with physical therapy care. *J Orthop Sports Phys Ther.* 2014 Nov;44(11):879-89. doi: 10.2519/jospt.2014.5150.
23. Bennell KL, Talbot RC, Wajswelner H, Techovanich W, Kelly DH, Hall AJ. Intra-rater and inter-rater reliability of a weight-bearing lunge measure of ankle dorsiflexion. *Aust J Physiother.* 1998;44(3):175-

180. doi: 10.1016/s0004-9514(14)60377-9.
24. Cox RW, Martinez RE, Baker RT, Warren L. Validity of a Smartphone Application for Measuring Ankle Plantar Flexion. *J Sport Rehabil*. 2018 May 1;27(3). doi: 10.1123/jsr.2017-0143.
25. Rabin A, Portnoy S, Kozol Z. The Association of Ankle Dorsiflexion Range of Motion With Hip and Knee Kinematics During the Lateral Step-down Test. *J Orthop Sports Phys Ther*. 2016 Nov;46(11):1002-1009. doi: 10.2519/jospt.2016.6621.
26. Petherick M, Rheault W, Kimble S, Lechner C, Senear V. Concurrent validity and intertester reliability of universal and fluid-based goniometers for active elbow range of motion. *Phys Ther*. 1988 Jun;68(6):966-9. doi: 10.1093/ptj/68.6.966.
27. Gabriner ML, Houston MN, Kirby JL, Hoch MC. Contributing factors to star excursion balance test performance in individuals with chronic ankle instability. *Gait Posture*. 2015 May;41(4):912-6. doi: 10.1016/j.gaitpost.2015.03.013.
28. Duarte M, Freitas SM. Revision of posturography based on force plate for balance evaluation. *Rev Bras Fisioter*. 2010 May-Jun;14(3):183-92. English, Portuguese.
29. Hamilton RT, Shultz SJ, Schmitz RJ, Perrin DH. Triple-hop distance as a valid predictor of lower limb strength and power. *J Athl Train*. 2008 Apr-Jun;43(2):144-51. doi: 10.4085/1062-6050-43.2.144.
30. Reid A, Birmingham TB, Stratford PW, Alcock GK, Giffin JR. Hop testing provides a reliable and valid outcome measure during rehabilitation after anterior cruciate ligament reconstruction. *Phys Ther*. 2007 Mar;87(3):337-49. doi: 10.2522/ptj.20060143.
31. Elkins MR, Moseley AM. Intention-to-treat analysis. *J Physiother*. 2015 Jul;61(3):165-7. doi: 10.1016/j.jphys.2015.05.013.

Figures

Figure 1

Flowchart of screening process and allocation of volunteers.

Figure 2

Evaluation of ankle DF RoM during Lunge Test.

Figure 3

Evaluation of ankle DF RoM during Goniometry.

Figure 4

(A) YBT Previous direction. (B) YBT Postero-medial direction. (C) YBT Postero-lateral direction.

Triple hop for
distance

Figure 5

Triple hop scheme for Distance

Supplementary Files

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