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Reliability Study of Diagnostic Tests for Functional Hallux Limitus

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Abstract

Background: Functional hallux limitus (FHL) refers to dorsiflexion hallux mobility limitation when the first metatarsal head is under loading conditions but not in the unloaded state. The goal of the study was to evaluate 3 common manual tests (Buell, Dananberg, and Jack tests) for assessing first metatarsophalangeal joint (MPJ) mobility and determining the normal values needed to detect FHL, and clarify the signs and symptoms associated with this pathology.
Methods: Forty-four subjects were included in this reliability study. Subjects were divided into healthy control (non-FHL) and FHL groups according to the Buell first MPJ limitation values in addition to signs and symptoms derived from the literature. In both groups, we measured the mobility in the Buell, Dananberg, and Jack tests using a goniometer; their intraclass correlation coefficients (ICCs), sensitivities, and specificity indexes were also calculated.
Results: All techniques showed high reliability across measurement trials with ICCs ranging from 0.928 to 0.999. The optimal mobility grades for predicting FHL were 68.6 ± 3.7 degrees, 21 ± 5.9 degrees, and 25.5 ± 6.5 degrees (mean±SD) ($P < .05$) for the Buell, Dananberg, and Jack tests, respectively.
Conclusion: Normal and limited mobility values were established for assessing FHL using each technique. The sensitivity and specificity data were perfect for the Dananberg and Jack tests, thus identifying these tests as specific and valid tools for use in FHL diagnosis. Pinch callus was the sign most associated with FHL.
Level of Evidence: Level II, comparative series.

Keywords: hallux limitus, reliability analysis, first metatarsophalangeal joint

Introduction

Functional hallux limitus (FHL) refers to dorsiflexion hallux mobility limitation when the first metatarsal head is extended during the final phase of gait,[18] and normal mobility is available throughout unloading[6,7,18,22] in contrast with hallux rigidus, in which this limitation is present during all phases.[7] FHL has been implicated in the development of first metatarsophalangeal joint (MPJ) osteoarthritis[7] and has a detrimental effect on the smooth transference of the body load in the heel-off phase of gait.[22] According to the sagittal plane facilitation theory proposed by Dananberg,[6] dynamic restriction of the first MPJ during gait induces a lack of stability, forcing the body to compensate for this biomechanical disturbance. FHL can go unrecognized in nonweightbearing examinations.[6] Therefore, correct diagnosis of FHL

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is important for preventing and treating other foot conditions.[15]

FHL signs most frequently described in the literature are hyperkeratotic skin lesions over the plantar/plantar-medial interphalangeal joint of the hallux[3,7,13] (termed pinch callus),[32] hyperkeratotic transfer lesions under the second metatarsal head with or without metatarsalgia,[10,14] hallux interphalangeal joint angle,[1] and hallux extensus.[20] We did not include other radiologic signs, such as first metatarsal head alterations, dorsal or lateral spurs, and bunion formation[21] or pain,[10] in this classification because these signs are more relevant to hallux rigidus, which was not evaluated in this study.[5,12,28]

FHL has been categorized as mild or severe based on the Foot Posture Index.[26] Opinions vary widely about the degree of dorsiflexion limitation in the first MPJ that should be considered hallux limitus, and there is no consensus about how to assess FHL.[2,8,24,30] There are 2 basic approaches to evaluating hallux dorsiflexion mobility: (1) weightbearing and (2) nonweightbearing assessments.[6,8,23] In 1953, Jack[16] described one of the first methods to evaluate the first MPJ in a weightbearing position, and this method is still commonly used today.[23] This procedure involves dorsiflexion of the hallux. Normal dorsal joint mobility values are between 37 degrees[23] and 40 degrees.[13] There are 2 representative techniques for nonweightbearing assessments. The Dananberg test[6] consists of a clinician grasping the proximal phalanx of the hallux (PPH) and moving it over the first MH while applying pressure passively under it to prevent plantarflexion until the clinician feels this first metatarsal plantarflexion. Some authors have noted the need to reach 60 to 65 degrees[11] or 65 to 75 degrees[27] during the gait propulsion phase, but they did not specify their measurement methods. Buell et al[2] used a second kind of nonweightbearing assessment that involves examining the first MPJ without immobilizing the first metatarsal head. Rather, the clinician grasps the PPH and moves it around the first metatarsal head until maximal dorsiflexion of the hallux has been achieved. The normal value is 82 degrees. These passive manual tests do not show a standard lock pressure value until the clinician has to push or stop the movement around the first metatarsal head. In addition, it is unclear which test is most reliable in assessing the first MPJ.[8] Therefore, in this reliability case-control study, our principal goal was to determine normal and limited values to determine if FHL exists. The specific objectives of this study were (1) to calculate the mean grade values for each technique in participants with and without FHL (cases and controls, respectively); (2) to measure the reliabilities of the 3 techniques in diagnosing FHL; and (3) to identify the signs most strongly associated with FHL.

Methods

Participants

The Institutional Review Board approved the present case-control study. All subjects gave their written informed consent before participation in the study. Participants for this reliability study were recruited from the same private clinic over a 4-year period (December 2014 to March 2017); cases and control participants were matched according to age. The clinical characteristics associated with FHL were recorded. Several inclusion criteria were applied to the case group: (1) no previous trauma or actual/chronic dysfunction in the lower limbs and feet; (2) normal dorsiflexion of the ankle of at least 10 degrees with the knee fully extended; (3) normal range of motion in the subtalar joint of 30 degrees; (4) normal range of motion in nonweightbearing in the first metatarsocuneiform joint with 4 mm of both dorsiflexion and plantarflexion of the first metatarsal; (5) normal unrestricted motion along the longitudinal axis of the midtarsal joint of 15 degrees; (6) participant age >18 years and <60 years; (7) no stiffness in other foot joint; (8) no evidence of a nonfixed deformity at the first MPJ and first metatarsocuneiform joints; and (9) <82 degrees in first MPJ mobility according to the Buell[2] technique. Exclusion criteria were: (1) under the influence of any drug; (2) a foot or lower limb deformity; (3) any metabolic, congenital, vascular, functional, and/or structural disease involving either lower extremity during the 6 months before study enrollment; (4) <40 degrees of available first MPJ dorsiflexion based on the Buell technique in order to discriminate it from a structural limitation at the joint[13,23,24,28] related to hallux rigidus, which was not evaluated in this study; and (5) absence of dorsal osteophytes above the first MPJ and/or lack of pain within the joint consistent with hallux rigidus.[28]

Out of 122 volunteered subjects who participated in the study, 37 subjects met the inclusion criteria, but 15 participants refused to participate in the study for unknown reasons. A total of 22 participants (10 males and 12 females) were included in the case group. Twenty-two healthy participants (11 males and 11 females) with no foot problems were included in the control group.

Procedures

We used a classical goniometer to assess manually the mobility grades for each test for each group of subjects.

We assessed the 3 techniques in an individually randomized order with 6 measurement trials for each technique on each foot. For the Buell[2] technique (Figure 1), the examiner moved the proximal phalanx of the hallux (PPH) into dorsiflexion by pushing it with his finger to reach the maximal amount of movement; for the Dananberg test[6] (Figure 2), the clinician pushed the PPH until plantarflexion of the first

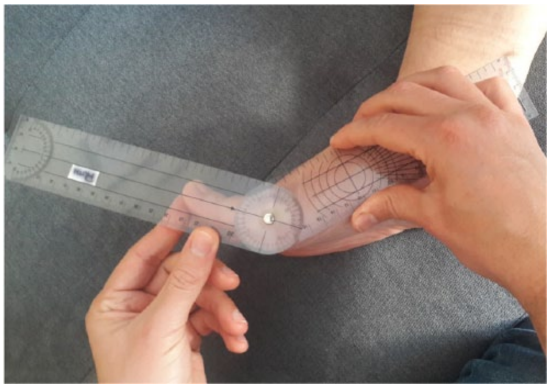

Figure 1. Buell technique performed with a classical goniometer. The clinician pushed the proximal phalanx of the hallux with his finger while using the goniometer to assess to achieve maximum dorsiflexion.

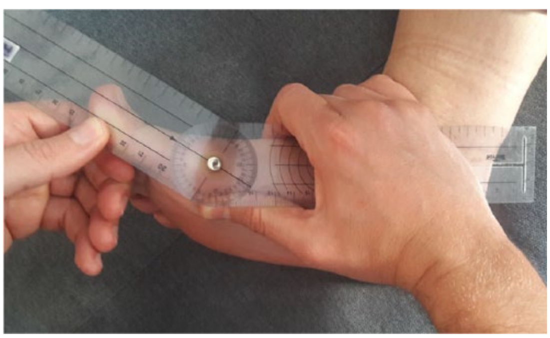

Figure 2. Dananberg technique performed with a classical goniometer. The clinician pushed the proximal phalanx of the hallux with his finger while the first metatarsal head was stabilized, avoiding plantarflexion, when using the goniometer to achieve maximum dorsiflexion.

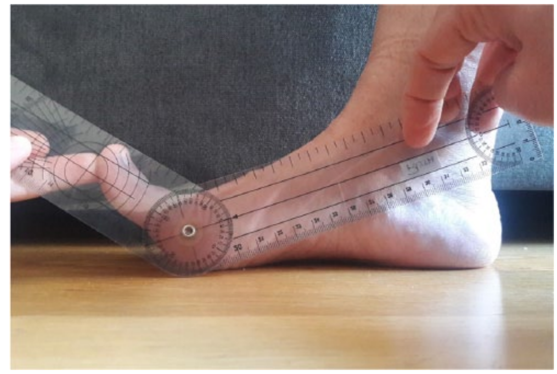

Figure 3. Jack technique performed with a classical goniometer. The clinician pushed the proximal phalanx of the hallux with his finger with the subject in weightbearing position while using the goniometer to achieve maximum dorsiflexion.

metatarsal head was detected. For the Jack technique[16] (Figure 3), the examiner pulled the PPH to dorsiflexion with his hand until the maximal amount of mobility was reached with the subject standing; for all techniques, the static arm of the goniometer was placed along the first metatarsal longitudinal axis while the free movable arm followed the PPH axes.

Statistical analysis

To assess the reliability of each technique across measurement trials, we computed intraclass correlation coefficients (ICCs).[19] Landis and Koch[19] proposed that coefficients <0.20 indicate slight agreement, between 0.20 and 0.40 indicate fair reliability, between 0.41 and 0.60 indicate moderate reliability, between 0.61 and 0.80 indicate substantial reliability, and between 0.81 and 1.00 indicate almost perfect reliability. We considered coefficients of ≥ 0.90 as indicative of a sufficient magnitude of reliability given that reliability coefficients >0.90 increase the likelihood that a measurement is also reasonably valid.[25] We conducted all analyses related to the mobility variables at the level of individual feet.

All continuous data were examined for normality using the Kolmogorov-Smirnov test, and data were considered normally distributed if the test returned $P > .05$. For each continuous variable, we calculated the mean ± standard deviation (SD) and a 95% confidence interval (CI). To compare demographic and biometric variables between male and female participants, we computed independent sample t tests. We calculated standard errors of the mean (SEMs) to measure the range of error for each assessment technique, from the ICCs and SDs: $SEM = SD \times \sqrt{(1 - ICC)}$.

We present descriptive summaries as mean ± SD. For all analyses, we considered $P < .05$ (within a 95% CI) as statistically significant. We conducted data analysis with SPSS software, version 19.0 (SPSS Science, Chicago, IL).

Results

Data were not normally distributed ($P < .05$). Sociodemographic data and its relationship between signs-symptoms and cases (FHL)–control subjects are shown in Table 1. Pinch callus (Figure 4) was identified as the most prevalent sign associated with FHL. Table 2 summarizes the reliability of grades mean values for the measurements of the dorsiflexion techniques for first MPJ.

The reliability of the variables measured showed a near perfect ICC reliability ranging from 0.97 to 0.999 with a small SEM ranging from 0.167 to 0.644. For the case and

Table 1. Descriptive Sociodemographic Data and Clinical Characteristics of the Case and Control Healthy Group Subjects.

Variable	Total Population, Mean % ± SD (95% CI) (N = 44)	Cases Group, Mean % ± SD (95% CI) (n = 22)	Control Group, Mean % ± SD (95% CI) (n = 22)	*P* Value
Age, y	35.8±0.3 (35.8-35.9)	36.2±5.1 (34.0-38.3)	35.5±5.2 (33.4-37.72)	.922
Height, cm	169.0±4.3 (167.7-170.3)	164.7±2.1 (163.8-165.6)	173.3±4.2 (173.2-173.5)	<.001
Weight, kg	61.9±10.3 (58.8-64.9)	51.5±4.3 (49.7-53.3)	72.1±2.7 (71-73.3)	<.001
Foot size, Es	40.2±1.9 (39.6-40.8)	38.2±2.1 (37.3-39.1)	42.1±1.3 (41.5-42.7)	<.001
BMI	21.5±1.5 (21.0-21.9)	20.2±1.7 (19.5-20.9)	23.0±2.6 (21.9-24.0)	<.001
Hallux extensus, n (%)	7 of 44 (15.9)	7 of 22 (31.8)	0.0	<.001
Hallux IP, n (%)	3 of 44 (6.8)	3 of 22 (13.6)	0.0	<.001
Pinch callus, n (%)	14 of 44 (31.8)	14 of 22 (63.6)	0.0	<.05
Hyperkeratosis under head of II MTT bone, n (%)	10 of 44 (22.7)	5 of 22 (22.7)	5 of 22 (22.7)	<.05
Medial I MPJ hyperkeratosis, n (%)	8 of 44 (18.2)	8 of 22 (36.4)	0.0	<.001
Swelling I MPJ, n (%)	8 of 44 (18.2)	8 of 22 (36.4)	0.0	<.05

Abbreviations: BMI, body mass index; CI, confidence interval; Es, number according to European mode size; II MTT, second metatarsal bone; I MPJ, first metatarsophalangeal joint; IP, interphalangeus.
[a]Participants with functional hallux limitus.
[b]Healthy participants, without functional hallux limitus.
[c]Level of significance; *P* <.05 (with a 95% CI) was considered statistically significant.

Figure 4. Pinch callus. Hyperkeratotic skin lesion placed on the medial aspect of the interphalangeal joint of the hallux.

control groups, we detected a statistically significant difference ($P < .001$) between each grade measurement, except for the Buell test assessment ($P < .05$). Using the Buell test, grade measurements showed the highest values of first MPJ mobility for both the case and control groups (68.6 ± 3.7 degrees and 82.1 ± 9.3 degrees , respectively) whereas the Dananberg maneuver had the lowest grades of I MPJ mobility in the case group (Table 2).

Discussion

Limitations on weightbearing first MPJ dorsiflexion might contribute to some overload pathologies of the foot[9] even when normal nonweightbearing movements are present. Therefore, detecting this condition, termed FHL, through restricted movement is crucial for preventing foot-related pathologies, regardless of muscular etiology as a possible cause of that lack of mobility.[31] The Buell, Dananberg, and Jack tests are the most frequently used tests for assessing first MPJ movement[23]; however, similar to other manual clinical techniques that have been reported in the literature,[2,6,16] there is a lack of consensus[8] about manual mobility assessments, which underlines the need for objective measurements in diagnosing FHL. Therefore, the focus of the present investigation was to determine the normal physiological and pathologic values for each of the 3 selected tests.

We found that each of the 3 techniques had high reliability, with either the Dananberg or Jack yielding the best quality scores and ICC results, thus providing data to support their use. Also, there were no systematic errors between the 2 measurements for any variable.

Our passive range of first MPJ motion measurement with the subject in nonweightbearing situation under the Buell technique[2] reached 81.1 ± 9.2 degrees and 68.6 ± 3.7 degrees in the control and FHL case groups, which were similar to values obtained by the author (82 and 55 degrees, respectively). In relation to the first MPJ motion, Dananberg[6] himself did not provide data about this; other authors subsequently set these values as <12 degrees of dorsiflexion during weightbearing[18,29] or around 60 to 65 degrees[11] or 65 to 75 degrees[17] with a simulated load on the first MPJ. In agreement with the latter values, in this study we found dorsiflexion during weightbearing values of 67.6 ± 11 degrees and 21 ± 5.9 degrees for the control and case group, respectively.

Table 2. Mean Values and Reliabilities of Grades for the Measurements of the Dorsiflexion Techniques of the First Metatarsophalangeal Joint.

Technique Variable	Case Group[a] (n = 22)			Control Group[b] (n = 22)			
	Mean (degrees) ± SD (95% CI)	ICC (95% CI)	SEM	Mean (degrees) ± SD (95% CI)	ICC (95% CI)	SEM	*P* Value[c] (Means)
Buell	68.6±3.7 (66.9-70.4)	0.97 (0.94-0.987)	0.644	82.1±9.2 (77.7-84.6)	0.997 (0.995-0.99)	0.500	<.05
Dananberg	21.0±6.0 (18.2-23.9)	0.996 (0.992-0.998)	0.377	67.6±11.0 (63.5-71.8)	0.999 (0.998-1.00)	0.349	<.001
Jack	25.5±6.6 (22.4-28.7)	0.997 (0.995-0.999)	0.359	48.5±5.3 (46.5-50.5)	0.999 (0.998-0.999)	0.167	<.001

Abbreviations: CI, confidence interval; ICC, intraclass correlation coefficient; SEM, standard error of the mean.
[a]Participants with functional hallux limitus.
[b]Healthy participants, without functional hallux limitus.
[c]Level of significance of means; *P* <.05 (with a 95% confidence interval) was considered statistically significant.

Typical normal value assessments of the MPJ in the weightbearing situation under the Jack test have been established as between 37 ± 2.8 degrees[24] and 40 degrees,[14] which are close to our results in which the control group mean value was 48.5 ± 5.3 degrees.

Finally, consistent with prior reports and hypotheses, we detected several signs and symptoms associated with FHL, including pinch callus,[2,3,7,13] a hyperkeratotic skin lesions on the medial first metatarsal,[10,14] and swelling in the first MPJ.[1]

Although our results showed a very small SEM and almost perfect reliability with no systematic error between measurements, these techniques could still vary with clinician experience and human error.

All measurements were performed in a Caucasian population, which might limit the generalizability of the results.

Conclusions

Accurate procedures for diagnosing FHL have not yet been established. There are multiple techniques for assessing FHL, and there is no consensus about normal and pathologic values of MPJ dorsiflexion. The range of motion values of the IMPJ performing Buell, Dananberg, and Jack test were 68.6 ± 3.7 degrees, 21± 5.9 degrees, and 25.5 ± 6.5 degrees for the case group, and 82.1 ± 9.3 degrees, 67.6 ± 11 degrees, and 48.5 ± 5.3 degrees for the control group. The latter 2 techniques displayed perfect reliability and lower level of measurement error. The pinch callus was the most typical sign associated with FHL. These results can be used as the basis for future studies and determination of a priori sample sizes for future investigations.

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Declaration of Conflicting Interests

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Data availability statement

All the data analyzed in the present study are available for checking when it will be required.

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