Original article

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Reliability and Reference norms of heel-to-toe walking, lateral walking, and step-over walking among young adults: A Cross-Sectional Study

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Abstract

Introduction: Clinimetric properties play an essential part in clinical practice in order to select the appropriate measurement instrument and reference value aid in the evaluation of intervention efficacy and precision of tool. This study aims to establish inter-rater and intra-rater reliability as well as normative reference values of heel-to-toe walking, lateral walking, and step-over walking among young adults.

Material and methods: In this cross-sectional study, 400 young adults in the age group between 18 and 25 years were recruited according to the eligibility criteria. All the tests were recorded 3 times with the help of a stopwatch to calculate inter-rater and intra-rater reliability. The mean values were statistically analysed. Kolmogorov Smirnov test was used for the normality of the data. The descriptive statistics are reported as geometric mean (GM) with a 95% confidence interval (CI).

Results: Heel-to-toe (ICC = 0.99, Cronbach's α – 0.994), lateral (ICC = 0.96, Cronbach's α – 0.988), and step-over walking (ICC = 0.96, Cronbach's α – 0.987) demonstrated excellent intra-rater reliability. Inter-rater reliability was excellent for heel-to-toe walking (ICC = 0.92, Cronbach's α – 0.923), lateral walking (ICC = 0.84, Cronbach's α – 0.846), and step-over walking (ICC = 0.92, Cronbach's α – 0.929). Reference norms for step-over, heel-to-toe walking, and lateral walking came out to be 24.71s, 35.02s, and 20.09s, respectively.

Conclusions: Findings indicate that heel-to-toe walking, lateral walking, and step-over walking are reliable tests and can be further recommended to measure coordination among young adults.

Keywords: adolescent, cross-sectional study, equilibrium

Introduction

Coordination is the ability to execute proper movements of body segments at an appropriate time with the correct amount of force necessary for balance and mobility. The ability to perform smooth, precisely controlled motor responses relates to coordination and balance [1]. An approach to maintaining walking balance and coordination is needed to execute stable walking patterns in adults [2]. Appropriate coordination tests are required to identify balance and mobility deficits in young individuals to promote early dynamic balance and mobility techniques [3–5]. Coordination tests are classified as either non-equilibrium or equilibrium tests,

and there are approximately 25 equilibrium coordination tests that can test the static or dynamic balance of the body during perturbations [6].

To assure the quality of results, the researcher must select an appropriate and accurate test, which depends entirely on their clinimetric properties [7]. These clinimetric properties determine the aptness of a test. Measurements should be reliable and valid for diagnosing, selecting and evaluating functions that reflect everyday balance functioning and mobility [8]. The interpretation of the measurement tool's findings must be reliable and precise prior to being implemented for further assessment purposes, and the normative reference value helps tool detection or measurement, as well as the efficacy of the intervention [8]. Reference norms of an instrument or a test aids in improvement in responsiveness and helps to investigate the normal characteristics of particular region of people compared with the reference data of a usual person [9].

Reliability and validity are the main elements of the clinimetric properties which assess the effectiveness of the test [8-10]. The reliability of an instrument can be measured within and between raters, and between two different measurements [8]. When developing a new test, it is necessary to determine the reliability of the test compared to the clinical population in which the test is intended to be used [8,11]. Inter-rater reliability explains the consistency of an instrument after multiple trials by different raters, whereas the accuracy of a test is explained by the intra-rater reliability when the same rater measures the test or instrument multiple times [12]. Reliability between the two raters and an individual rater establishes an instrument's capacity to produce accurate findings that are free of measurement error when repeated by different assessors [13].

Previous studies show good-to-satisfactory internal consistency with excellent intra-rater of heel-to-toe walking and lateral walking among the older population [3,11]. Few studies show the high reliability of single- and dual-task tandem gait among healthy and uninjured young athletes [14]. However, there is a lack of evidence available that determines the clinimetric properties of heel-to-toe walking, lateral walking, and step-over walking among the population of young adults. Hence, the clinimetric properties of these parameters in relation to a coordination test like heel-to-toe walking, lateral walking and step-over walking has not been explored yet among a young population. The study objective is to evaluate the inter and intra-reliability of heel-to-toe walking, sideways walking, and step-over walking among healthy young adults aged 18 to 25 years. The secondary objective is to estimate the normative reference values of heel-to-toe walking, sideways walking, and step-over walking among healthy young adults aged 18 to 25 years.

Materials and methods

Participants

A cross-sectional study was conducted in a multispecialty tertiary care hospital. A total of 400 participants between 18 and 25 years old were recruited, 50 for each age group. Ethical approval was obtained from the Institutional Ethics Committee with the registration number MMDU/IEC-2306. The trial was registered under the number CTRI/2022/11/047332. Inclusion criteria include young adults aged 18–25 years, able to walk independently without any assistance**,** both male and female, those who follow verbal commands, and having a Montreal Cognitive Assessment ≥ 26 points. The exclusion criteria comprised any untreated symptomatic illness, any neurological disorder, any musculoskeletal disorder or injury that could affect lower extremity, any cardiovascular or pulmonary disease, any lower limb surgery within the past 6 months, and significant hearing or vision loss.

Procedure

Participants were recruited in accordance with the selection criteria. An informed sheet along with informed consent was completed by all participants. Age, sex, height, weight, body mass index (BMI), and limb length were noted as demographic details. Prior assessment was based on the eligibility criteria for the recruitment of participants. All participants received a detailed explanation of the procedure for each test. They were asked to perform heel-to-toe walking, lateral walking and step-over walking without footwear. Young adults who had visual impairments were recommended to use corrective glasses.

Outcome variables

Heel-to-toe: Participants were asked to complete a 10-meter walk in a straight line, barefoot, using an alternate heel-to-toe gait pattern along a 10-meter-long coloured tape with the hands at anterior iliac spines. They were also asked to perform one practice trial and three timed trials to walk beyond the 10-meter line and turn 180 degrees to return to the starting position [6,15,16]. Time was recorded from the command "START" up until completion of the task.

Lateral walking: The researcher gave clear instructions along with a demonstration of the procedure of lateral walking. Participants were asked to stand on the inner side of their bare feet by placing both hands at the anterior superior iliac spines and then walk laterally in a straight line along the 10-meter-long measuring tape, keeping their head up and without crossing the feet [5,6,17]. Each subject was asked to perform one practice trial and three timed trials. Trials were recorded after the command "START" until completion of the task.

Step-over walking: Step-over walking was demonstrated to the participant by instructing them to lift the dominant leg and step over it in front of the non-dominant leg. The non-dominant leg bears the whole weight and the hands were placed at the anterior superior iliac spines. The non-dominant leg was brought back in contact with the dominant with bare feet. The same procedures were repeated by completing the task along a 10-meter measuring tape [6]. The participants performed one practice trial and three timed trials. Trials were recorded by using an inbuilt smartphone stopwatch, Android version (Honor JSN-L42) and (Honor) from the command "START" until the task was completed.

Inter-rater reliability: Inter-rater reliability was evaluated by recording the time of each test with the help of two independent raters simultaneously. Both the raters were physiotherapists. Firstly, the first rater recorded the time of each outcome measure performed by the participants with the help of a stopwatch built into a smartphone, Android version (Honor JSN-L42). Then, the second rater simultaneously recorded the time of each outcome measure independently from the other rater with the same smartphone stopwatch, Android version (Honor JSN-L42) [8,18].

Intra-rater reliability: Intra-rater reliability was evaluated by a single rater instructing the participant to perform each test three times, with a 2-min rest in between each trial. The time of each of the 3 tests was recorded with the help of smartphone stopwatch, Android version (Honor JSN-L42). The recorded values were analysed to evaluate the intra-rater reliability of each test [8].

Normative reference value: Normative reference value was evaluated by giving the instruction to the participants to perform three trials of all the outcome measures i.e., heel-to-toe walking, lateral walking, and step-over walking. The average value of the recorded three trials was estimated. The calculated average values were considered to be the normative values of the outcome measure [6,19].

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) software (IBM) version 16 was used to analyse the data. The demographic data was found to be not normally distributed by the Kolmogorov-Smirnov test with a level of significance at >0.05 [20]. The mean value of each test was estimated and descriptive statistics were evaluated and expressed as geometric mean with a 95% confidence interval, as all the tests were not normally distributed [21]. The geometric mean was considered to be the reference values of each test. Inter-rater and intra-rater reliability was estimated by means of the interclass correlation coefficient. Interpretation of ICC suggests <0.40 poor reliability, 0.40 to 0.75 fair to good reliability, and >0.75 excellent reliability [22,23,24]. Cronbach's α was used to estimate the internal consistency. Internal consistency with an $\alpha \leq 0.5$ was considered as unacceptable, > 0.6–0.7 as questionable, > 0.7–0.8 as acceptable, >0.8–0.9 as good, and >0.9 was considered as excellent [3]. No missing data was noted, as this was a one-time study.

Results

The participants' demographic characteristics were found to be not normally distributed and represented as mean and standard deviation in Table 1.

Table 2 depicts the normative reference value of heel-to-toe, lateral, and step-over walking. Reference norms for step-over, heel-to-toe walking, and lateral walking came out to be 24.71s, 35.02s, and 20.09s, respectively.

Tab. 1. Demographic characteristics of the participants

Demographic characteristics	Mean ± SD	SEM	p-value
Age [year]	21.50 ± 2.29	0.11	0.001*
Weight [kg]	56.78 ± 13.33	0.66	0.001*
Height [cm]	162.78 ± 8.24	0.41	0.001*
BMI [kg/m^2]	21.35 ± 4.40	0.22	0.001*

SD – standard deviation, SEM – standard error mean, *p-value is statistically significant (>0.05).

Tab. 2. Normative Reference Value of the Outcome measures

Outcome variables (in seconds)	Geometric Mean (95% CI)	Range (Min.–Max.)
Heel-to-toe walking	35.02 (35.25–36.86)	45.96 (13.27–59.22)
Lateral walking	20.09 (20.26–21.45)	45.31 (10.54–44.66)
Step-over walking	24.71 (24.97–26.46)	34.11 (10.34–45.31)

CI – Confidence Interval.

Tab. 3. Inter and Intra-rater reliability of equilibrium coordination tests

Tests	Inter-rater reliability		Intra – rater reliability	
	ICC	Cronbach's α	ICC	Cronbach's α
Heel-to-toe walking	0.92	0.92	0.99	0.994
Lateral walking	0.73	0.85	0.98	0.988
Step-over walking	0.86	0.92	0.97	0.997

ICC – Intraclass Correlation Coefficient.

The inter-rater reliability and intra-rater reliability ICC and Cronbach's α value of heel-to-toe, lateral, and step-over walking tests are presented in Table 3. Heel-to-toe (ICC = 0.99, Cronbach's α – 0.994), lateral (ICC = 0.96, Cronbach's α – 0.988), and step-over walking (ICC = 0.96, Cronbach's α – 0.987) demonstrated excellent intra-rater reliability. Inter-rater reliability was excellent for heel-to-toe walking (ICC = 0.92, Cronbach's α – 0.923), lateral walking (ICC = 0.84, Cronbach's α – 0.846), and step-over walking (ICC = 0.92, Cronbach's α – 0.929).

Figure 1 ((a) to (i)) represents a Bland-Altman graph to show the level of agreement between the trials of heel-to-toe walking, lateral walking, and step-over walking for Intra-rater reliability.

Discussion

The reliability of a tool is assured the medical professionals with regard to the measurement tool and its applications in clinical practice. Inter-rater reliability and intra-rater reliability help clinicians choose with confidence the measurement tool corresponding to the patient's ability and function [25]. Appropriate conclusions and comparisons can be deduced from the results based

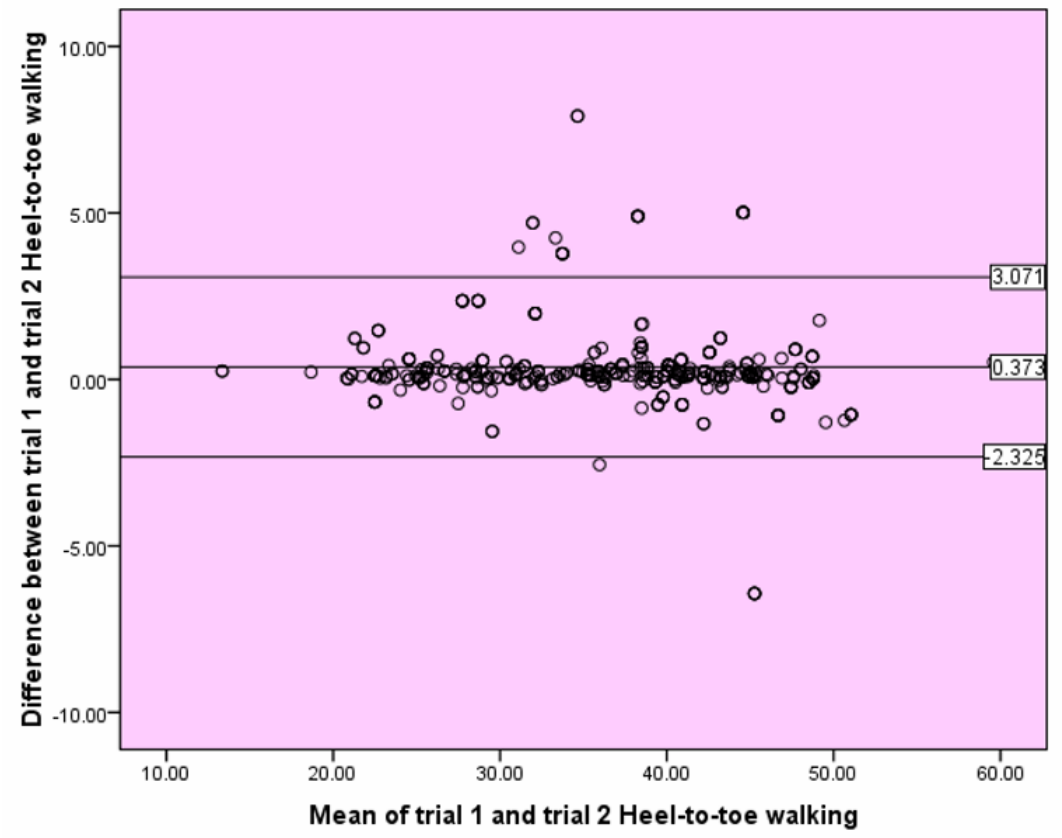

Fig. 1(a). Level of agreement between trial 1 and trial 2 of Heel-to-toe walking

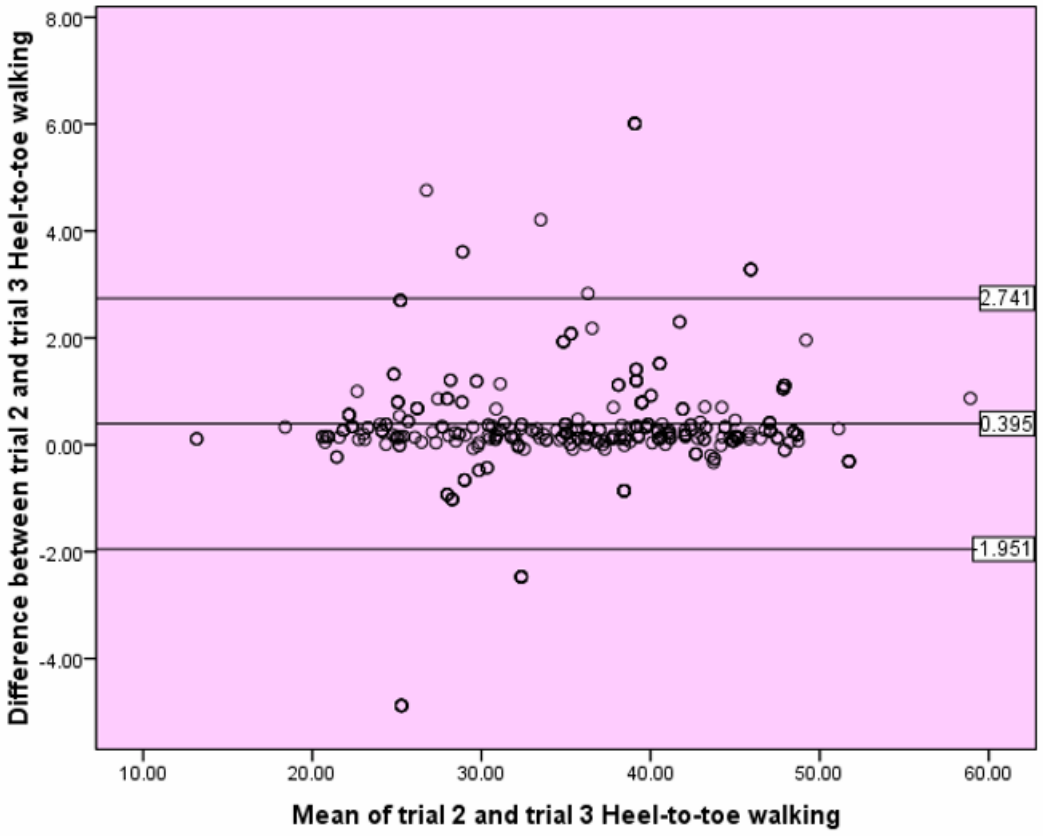

Fig. 1(b). Level of agreement between trial 2 and trial 3 of Heel-to-toe walking

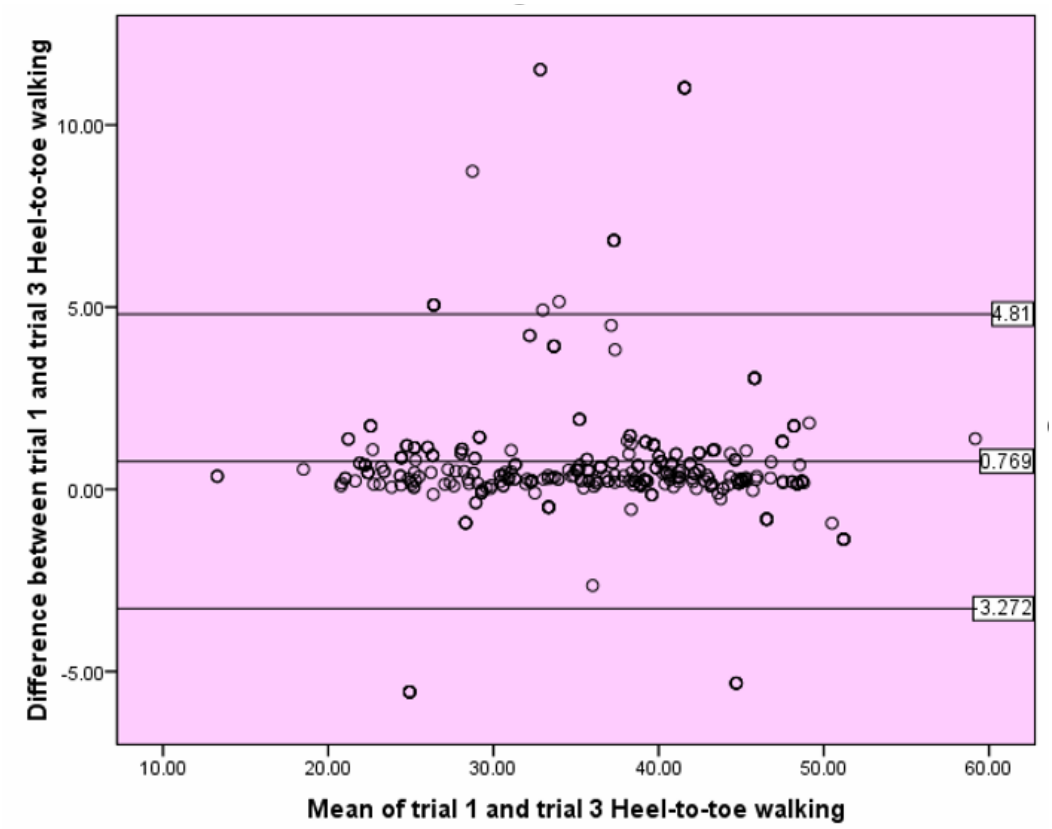

Fig. 1(c). Level of agreement between trial 1 and trial 3 of Heel-to-toe walking

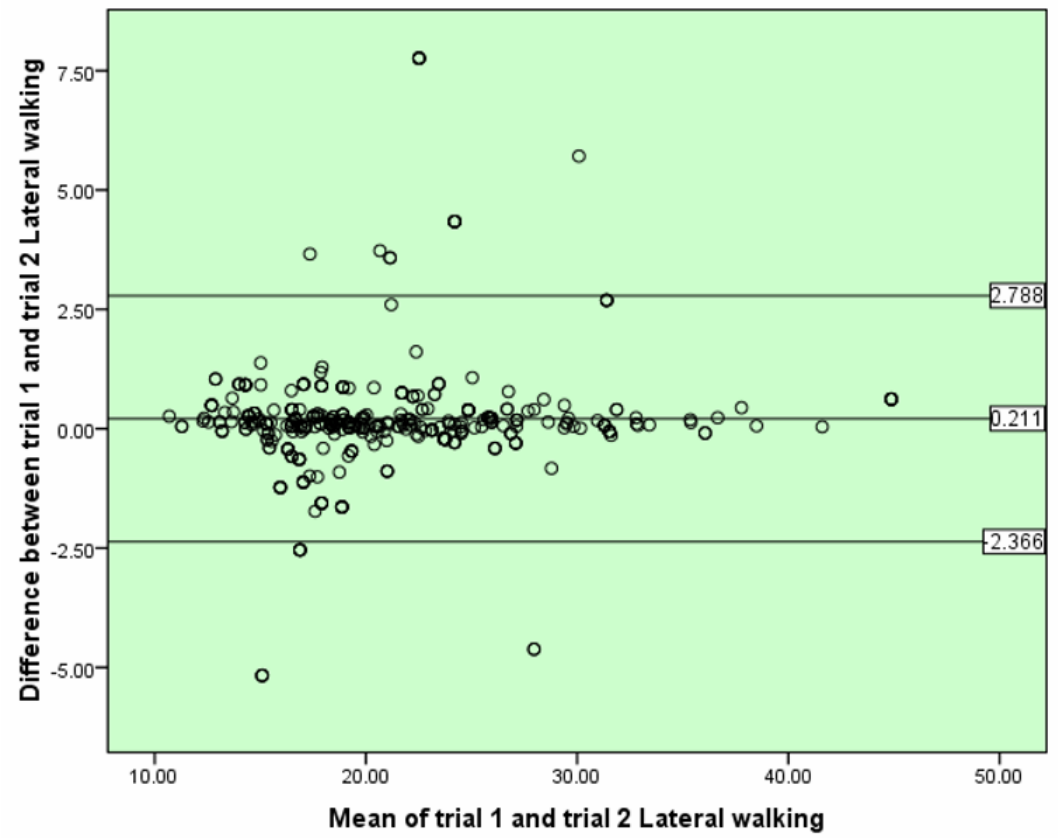

Fig. 1(d). Level of agreement between trial 1 and trial 2 of Lateral walking

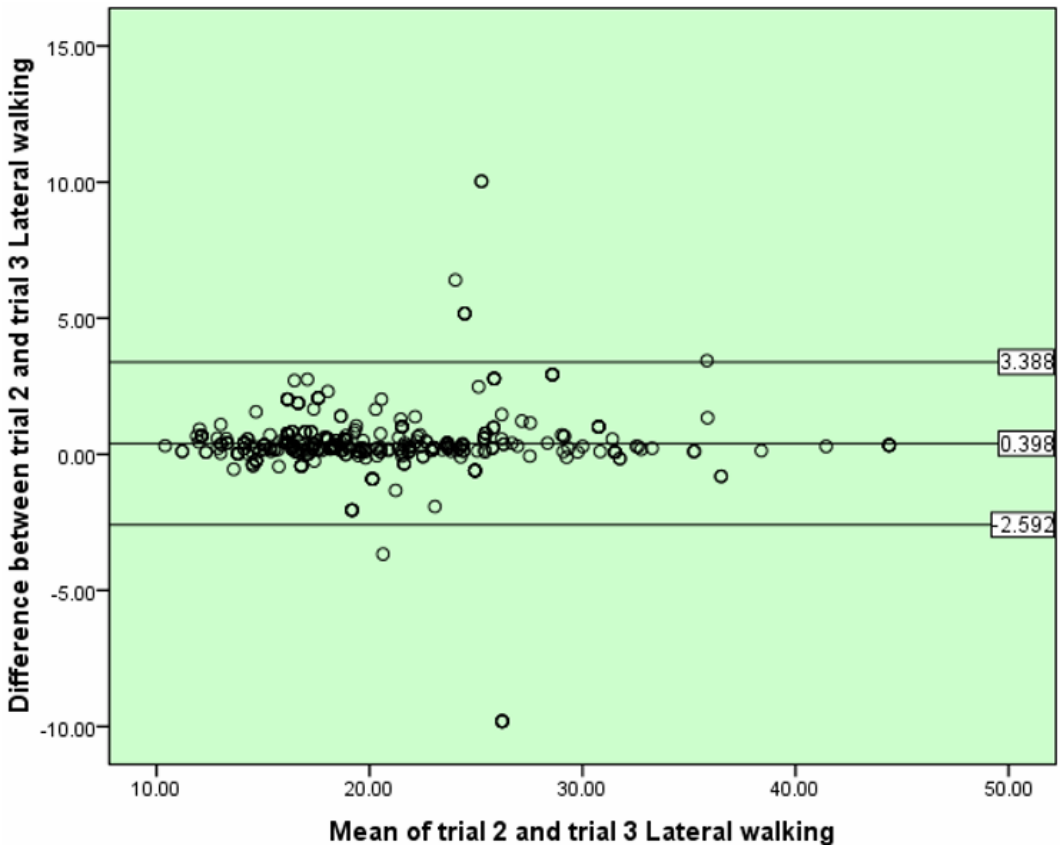

Fig. 1(e). Level of agreement between trial 2 and trial 3 of Lateral walking

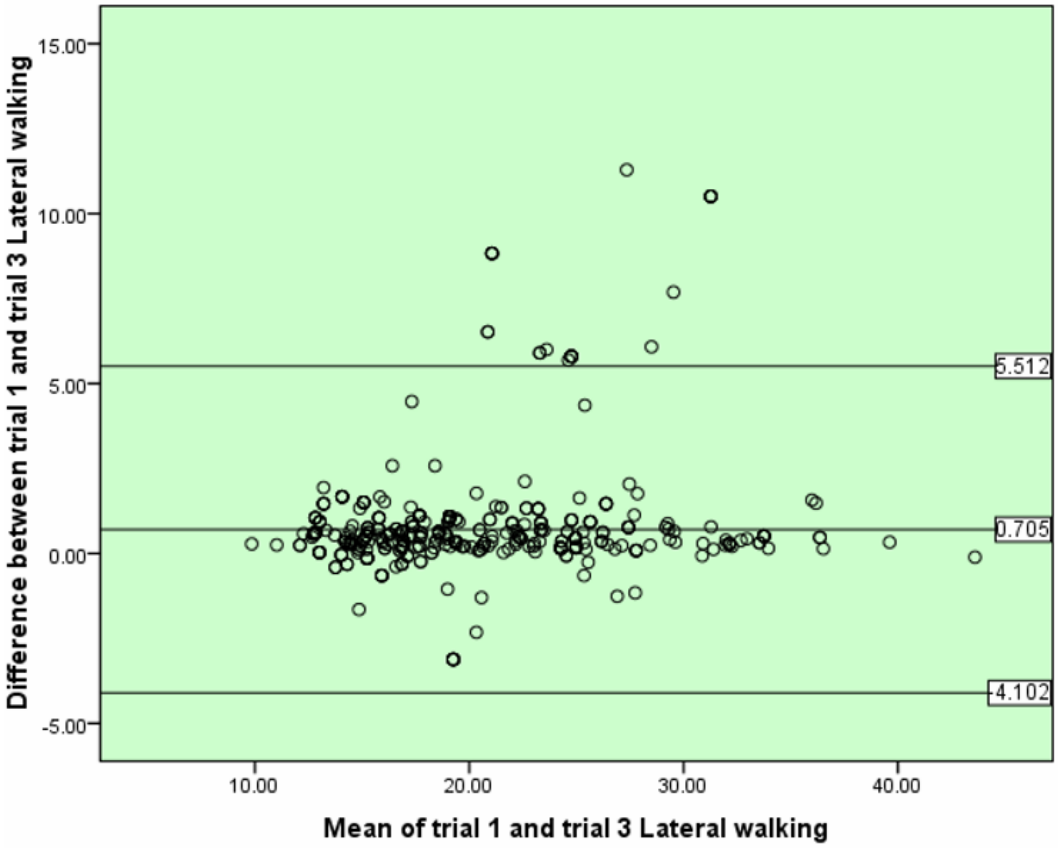

Fig. 1(f). Level of agreement between trial 1 and trial 3 of Lateral walking

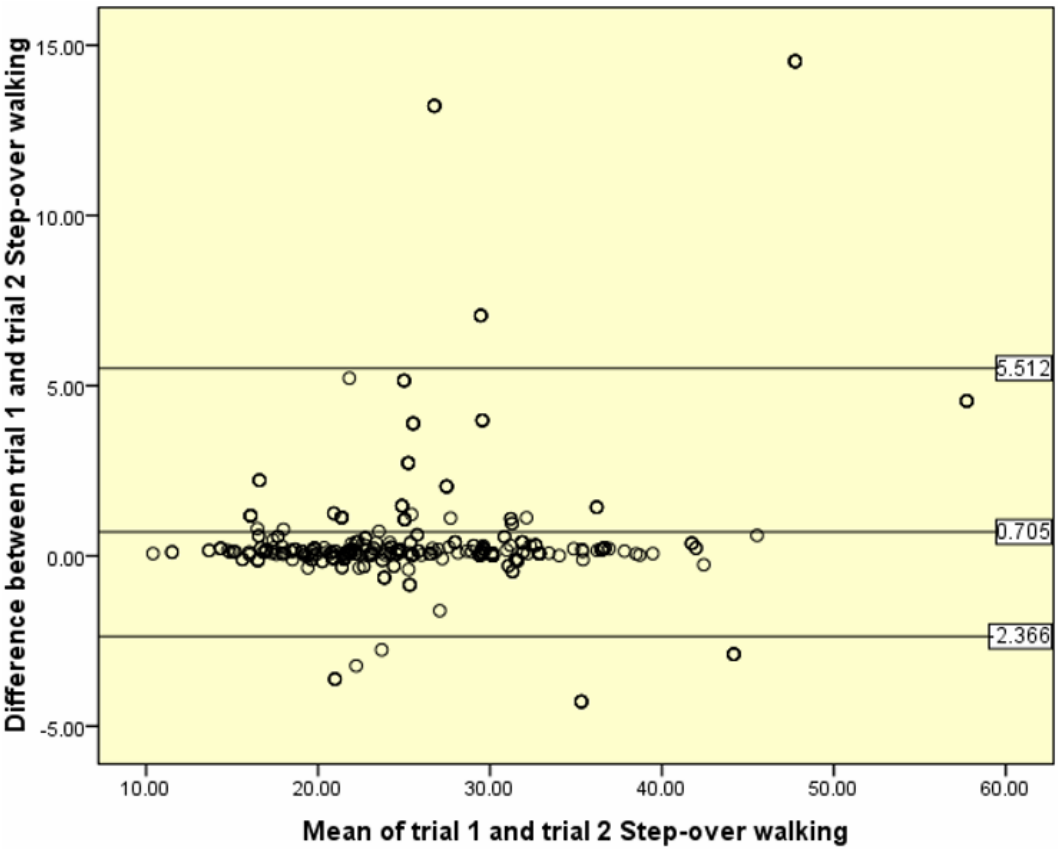

Fig. 1(g). Level of agreement between trial 1 and trial 2 of Step-over walking

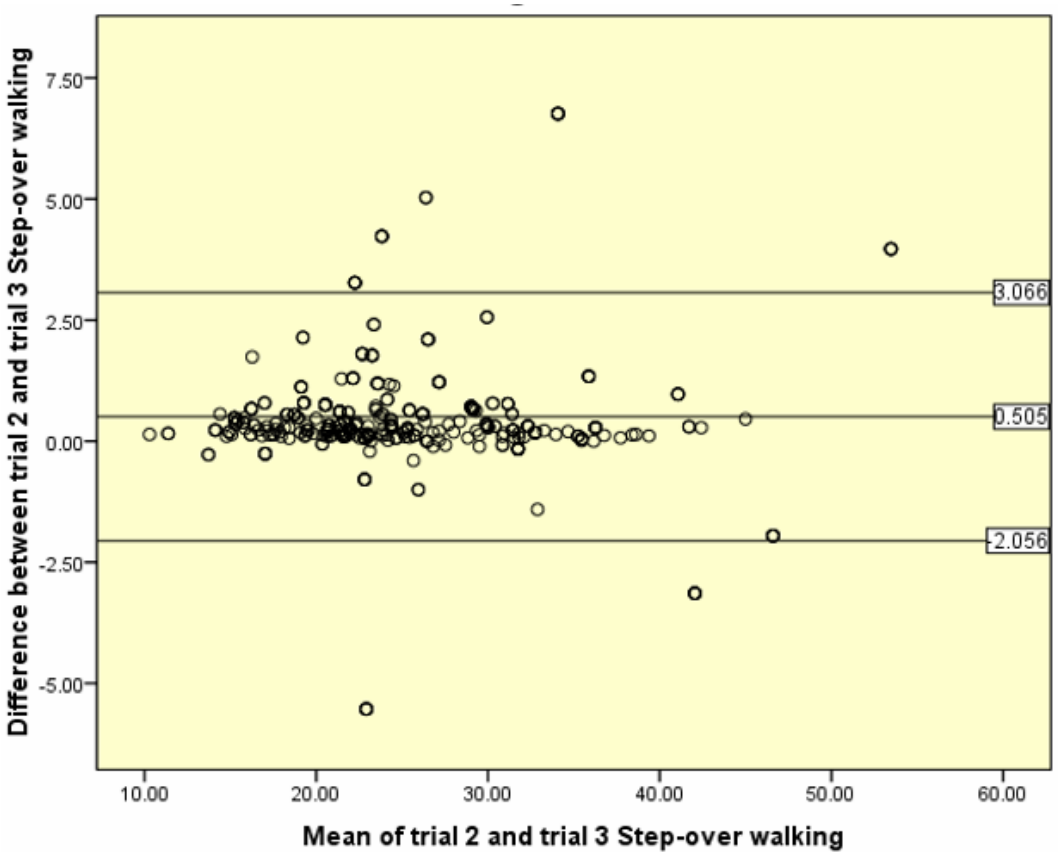

Fig. 1(h). Level of agreement between trial 2 and trial 3 of Step-over walking

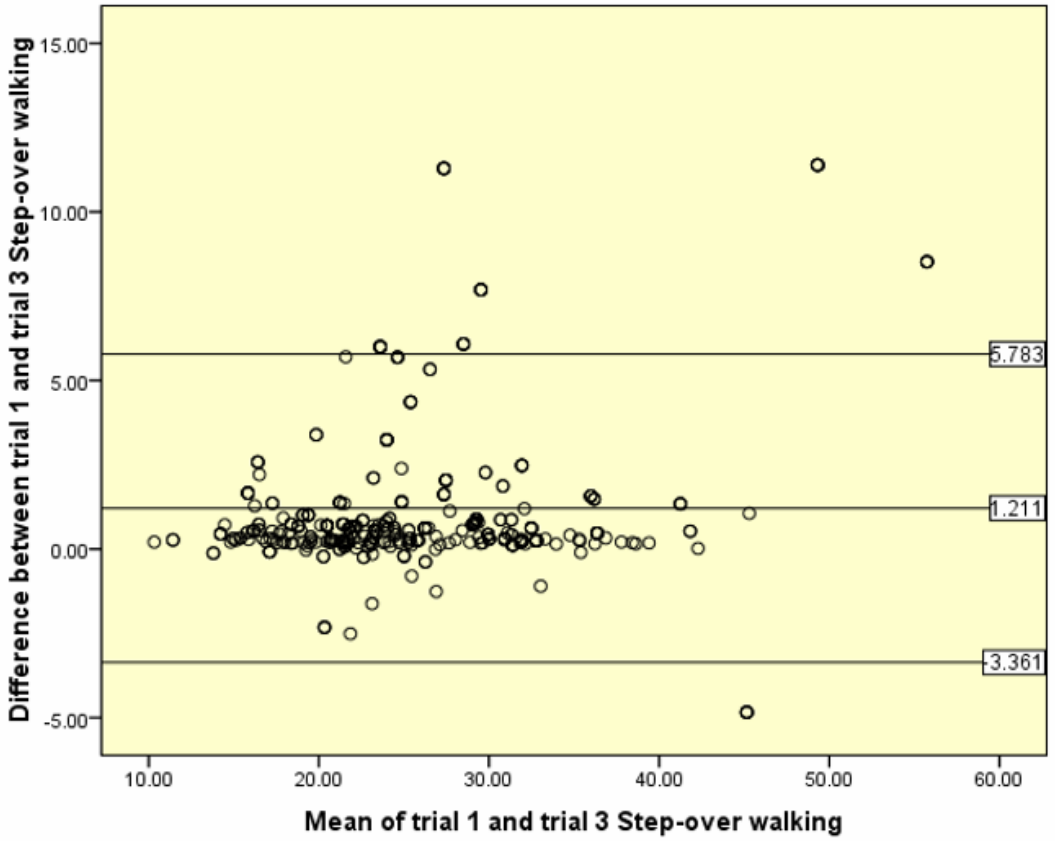

Fig. 1(i). Level of agreement between trial 1 and trial 3 of Step-over walking

on the agreement between the recorded ratings [26]. The purpose of the study was to demonstrate the inter-rater reliability and intra-rater reliability of heel-to-toe walking, lateral walking, and step-over walking used as a screening measure for coordination. A total of 400 young adults, aged between 18 and 25 years, were recruited for the study. Each age group consists of 50 participants, based on the sample size required for reliability [27].

Previous literature reports showed the established test-retest reliability of heel-to-toe walking among different populations. One study showed high test-retest reliability of dual and single-task tandem walking among healthy children and adolescent adults with the interclass correlation coefficient for a single task was 0.86 and for the dual task, tandem walking was 0.84 [14]. Another study showed good internal consistency ($\alpha = 0.88$; $\rho = 0.28–0.81$) and satisfactory inter-rater ($ICC_{2, k} = 0.97$) and intra-rater reliability ($ICC_{3, k} = 1.00$) for a balance and coordination test like community balance and mobility scale among older adults, which consisted of heel-toe walking and lateral walking as its domains as tandem walking and lateral dodging. This study also evaluated the individual inter-rater and intra-rater reliability of its domains, which show moderate inter-rater reliability for both heel-to-toe walking (ICC = 0.74) and lateral walking (ICC = 0.67) and high intra-rater reliability for both heel-to-toe walking (ICC = 0.84) and lateral walking (0.90) [3]. Similarly, one more study was conducted to determine the test-retest reliability of the Turkish version of community balance and mobility among older adults of age over 65. Its results showed excellent reliability of the whole scale with an excellent intra-rater correlation coefficient for each test item. The intra-rater correlation for tandem walking was 0.958 and for lateral dodging it was 0.952 [28]. No prior research had been conducted to explore the reliability of step-over walking.

The present study established the inter-rater and intra-rater reliability of heel-to-toe walking, lateral walking, and step-over walking among healthy young adults, which until that point had not been explored. The study findings show the consistency and stability of the coordination test with excellent inter-rater reliability for heel-to-toe walking (ICC = 0.85), lateral walking (ICC = 0.86) and step-over walking (ICC = 0.73). The study also shows the accuracy of the chosen test with the excellent intra-rater reliability for heel-to-toe walking (ICC = 0.98), lateral walking (ICC = 0.96), and step-over (ICC = 0.96).

Normative standard values of tandem gait, sideways gait, toe walk, cross-step gait, and heel walk among young adults were found to be 37.1 sec, 22.5 sec, 12.6 sec, 32.1 sec, and 17.1 sec, respectively, in terms of geometric mean. One study had already established the normal standard values for tests for coordination tests among a paediatric population [6]. The consistency of the results of these coordination tests reveals that such tests are easy to administer and score. However, they were found to be challenging among this population during the procedure, which also suggests that these tests will be more advantageous for therapists during clinical practice when dealing with both asymptomatic and young adults with no coordination deficit. It is our understanding that this study is the first study to estimate the reliability and reference norms of heel-to-toe walking, lateral walking, and step-over walking among healthy young adults, and was also found to be cost-effective.

The recommendation can be made to conduct more rigorous validation studies among the young population and other clinimetric properties of the outcome measure can also be evaluated in both this population and the patient population.

Conclusions

This study provides evidence of the accuracy of challenging coordination tests like heel-to-toe walking, lateral walking and step-over walking when used as a suitable tool for assessing mobility and coordination among young adults, as these tests were found to extremely reliable. The findings of this study support the use of normative values among healthy populations when assessing the patient population. Hence, this study reveals that equilibrium coordination tests like heel-to-toe walking, lateral walking and step-over walking can be used for therapeutic and diagnostic purposes during neurological examinations among young populations.

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Conflicts of Interest
The authors declare no conflict of interest.

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