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Ability of Side Hop Test to Predict Deficits in Dynamic Balance Control and Isometric Strength of Hip and Ankle Muscles in Recreational Male Athletes with Chronic Ankle Instability

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ABSTRACT

Background: The side hop test (SHT) is widely used by physiotherapists to assess functional limitations in athletes with chronic ankle instability (CAI). Determining if diminished SHT performance correlates with specific component deficits could enhance the test's clinical value. Therefore, this study investigates the association between SHT performance, dynamic balance control, and isometric strength of hip and ankle muscles in recreational male athletes with CAI. The aim is to examine the SHT's ability to predict deficits in dynamic balance control and isometric strength of hip and ankle muscles in these individuals.
Methods: Sixty male athletes with CAI (mean age 29.6±6.2 years) participated in this cross-sectional study. The SHT score, dynamic balance control (using the Modified Star Excursion Balance Test [MSEBT]), and maximal isometric strength for invertor, evertor, hip abductor, and external rotator muscles (using hand-held dynamometry) were assessed.
Results: Pearson correlation coefficient analysis revealed fair negative correlations between the SHT and MSEBT in the posteromedial (PM) (r=-0.43, P<0.001) and posterolateral (PL) (r=-0.26, P=0.04) reach directions. A linear regression model showed that SHT scores accounted for only 19% of the variance in the PM reach direction and 7% in the PL reach direction.
Conclusion: The SHT may not be a reliable predictor of deficits in dynamic balance control and isometric strength of hip and ankle muscles in recreational male athletes with CAI.

Introduction

The lateral ankle sprain is among the most frequent injuries in sports [1], accounting for up to 40% of all athletic injuries, particularly affecting athletes in basketball, soccer, and running disciplines [2]. Up to 70% of individuals who experience an acute lateral ankle sprain may go on to develop repetitive sprains and persistent symptoms—such as pain, swelling, and a sensation of "giving way"—collectively termed chronic ankle instability (CAI) [3, 4]. Contributing factors to CAI include muscle strength deficits, decreased balance control, impaired proprioception, and mechanical insufficiencies [5].

In athletes with CAI, only a few functional performance tests (FPTs) have been established to assess functional limitations quantitatively [6]. FPTs integrate multiple components, including muscle strength, power, and balance [7]. Deficits in any of these components can impact an athlete's performance on an FPT. Therefore, understanding the correlation between FPT scores and

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specific functional impairments would benefit sports physical therapists by enabling them to quickly identify impaired components and develop targeted rehabilitation plans for athletes.

Additionally, although FPTs are inexpensive, accessible, and straightforward to implement, assessment of individual FPT components often relies on specialized instruments [8]. Consequently, it is crucial to use a valid FPT that can evaluate multiple movement components and detect specific deficits. Such an approach can streamline rehabilitation for athletes with CAI, supporting their safe and effective return to sports activities.

The Side Hop Test (SHT) is one of the most widely used functional performance tests (FPTs) by physiotherapists to assess functional limitations in athletes with CAI [9]. Notably, it is also the most effective FPT for distinguishing individuals with CAI from healthy individuals [8]. The SHT involves hopping side to side on a single limb [6]. Each landing on the lateral side creates an inversion moment, mimicking the ankle sprain mechanism [9].

Previous studies have demonstrated that athletes with chronic ankle instability (CAI) perform significantly worse on the Side Hop Test (SHT) when using an injured ankle compared to an uninjured one [9]. Proper performance on the SHT relies on dynamic balance control and adequate lower limb muscle strength [10]. Deficits in hip muscle strength (specifically evertors, invertors, hip abductors, and external rotators) are frequently reported in individuals with CAI [11-13]). Additionally, research has documented impairments in both static and dynamic balance in these individuals, especially during dynamic activities [14-18].

Given these findings, there may be an association between reduced SHT performance and deficits in key components, such as dynamic balance control and muscle strength, in individuals with CAI. If diminished SHT performance could pinpoint specific deficits in these components, it would enhance the test's clinical relevance and streamline the assessment process for rehabilitation planning. Therefore, this study examines the relationships between SHT performance, dynamic balance control, and isometric strength of the hip and ankle muscles in athletes with CAI. Specifically, the study seeks to determine how SHT performance can predict deficits in dynamic balance control and isometric strength in these muscle groups.

Methods

Participants

This cross-sectional study included 60 male athletes recruited through convenience sampling from the university community and surrounding areas. Sample size estimation was grounded in prior research on SEBT scores and isometric muscle strength, aiming for a power of 95% (β=0.05) and α=0.05 with an expected correlation (r) of 0.5 [18]. Participants with chronic ankle instability (CAI) met the criteria set by the International Ankle Consortium Position Statement [19]. The inclusion criteria were: (1) Age: 18 to 40 years old, (2) Injury Timeline: Most recent injury occurred more than three months before study enrollment, (3) Ankle Sprain History: At least one unilateral ankle sprain and self-reported "giving way" sensations at least twice yearly during physical activity before study enrollment, (4) Rehabilitation Status: Not currently participating in a rehabilitation program, (5) Functional Deficit: Scored below 90% on the Daily Living subscale and below 80% on the Sports Activity subscale of the Persian Foot and Ankle Ability Measure (FAAM), and (6) Physical Activity: Minimum of 30 minutes of moderate-to-high intensity exercise at least three times per week (recreational athlete) [19].

FAAM is widely regarded as an effective tool for assessing functional limitations in patients with various limb, foot, and ankle conditions. Mazaheri et al. have validated the Persian version of FAAM, establishing it as a reliable and valid instrument for evaluating physical function in these patient populations [20]. Participants were excluded if they had (1) Bilateral Ankle Instability, (2) Acute Injury Signs: Evidence of ankle sprain symptoms, such as pain, swelling, or ecchymosis, at the time of testing, (3) Surgical History: Any history of surgery on either lower limb., (4) Balance-Affecting Conditions: History of conditions like concussions or vestibular disorders that could impair balance. The study was conducted under ethical guidelines approved by the University's Institutional Review Board (IR.AJUMS.REC.1400.283). All participants provided written informed consent before participating in the study.

Procedures

In this study, the Side Hop Test (SHT), Modified Star Excursion Balance Test (MSEBT) for dynamic balance control, and maximal isometric strength of the muscles (invertor, evertor, hip abductor, and external rotator muscles) were randomly assessed using hand-held dynamometry. The procedures for performing each test and the related variables are described in detail as follows:

Side Hop Test

In this study, participants performed the SHT for three sets of 10 repetitions. Participants stood on the injured limb and jumped side-to-side as quickly as possible between two parallel lines placed 30 cm apart [6]. The test was recorded as successful if participants completed the ten repetitions without the tested limb stepping on the line or the untested limb touching the floor [21]. If there was any unsuccessful repetition, the test was restarted. The time taken to perform each set was measured with a hand-held stopwatch. The average time of three successful sets was recorded in seconds for analysis. To minimize fatigue, at least a 1-minute rest was allowed between sets [22]. Before data collection, participants were instructed to perform the SHT, and two practice attempts were allowed.

Modified Star Excursion Balance Test

Dynamic balance control was evaluated using the Modified Star Excursion Balance Test (MSEBT) [23]. This test involved three lower extremity reaching tasks, requiring each participant to stand barefoot on the affected foot at the center of a circle with three radii set at 135 degrees. The examiner instructed the participant to reach as far as possible in the anterior (MSEBT-ANT), posterolateral (MSEBT-PL), and posteromedial (MSEBT-PM) directions. These three directions are considered the most effective for assessing and detecting reach deficits associated with chronic ankle instability (CAI) [7].

The reach distance was normalized to account for the association between reach distance and limb length. Specifically, the reach distance (in cm) was divided by the length of the lower limb and multiplied by 100 [24]. The length of the lower limb was measured from the anterior superior iliac spine to the inner end of the medial malleolus. Trials were discarded and repeated if participants: 1) placed weight on the reaching foot; 2) failed to return the reaching foot to the starting position without losing control; 3) did not keep both hands on their hips; 4) did not maintain the stance foot in the same position; or 5) lifted the forefoot or heel of the stance foot off the floor [25].

Each direction was tested thrice, with a minimum rest period of 30 seconds between attempts. To avoid order effects, the sequence of reaching directions was randomized. Data analysis was performed using the average of the three successful trials for each reach direction.

Maximal Isometric Strength

The maximal isometric strength of the hip and ankle muscles was measured for the injured limb using a hand-held dynamometer (JTECH Medical, Salt Lake City, UT) (Figure 1). The device has a measurement range of 0–500 newtons and is calibrated to a sensitivity of 0.1% according to the manufacturer's specifications. Testing was conducted by an experienced clinician following a standardized protocol. Isometric muscle strength was assessed randomly for the invertor, evertor, hip abductor, and external rotator muscles.

For ankle muscle testing, participants were positioned side-lying with approximately 20° of hip flexion and instructed to grasp the sides of the table for stabilization. The dynamometer was positioned as follows: for testing invertor muscle strength, it was placed on the medial border of the foot at the midpoint of the shaft of the first metatarsal; for evertor muscle testing, it was placed on the lateral border of the foot over the midpoint of the fifth metatarsal [26].

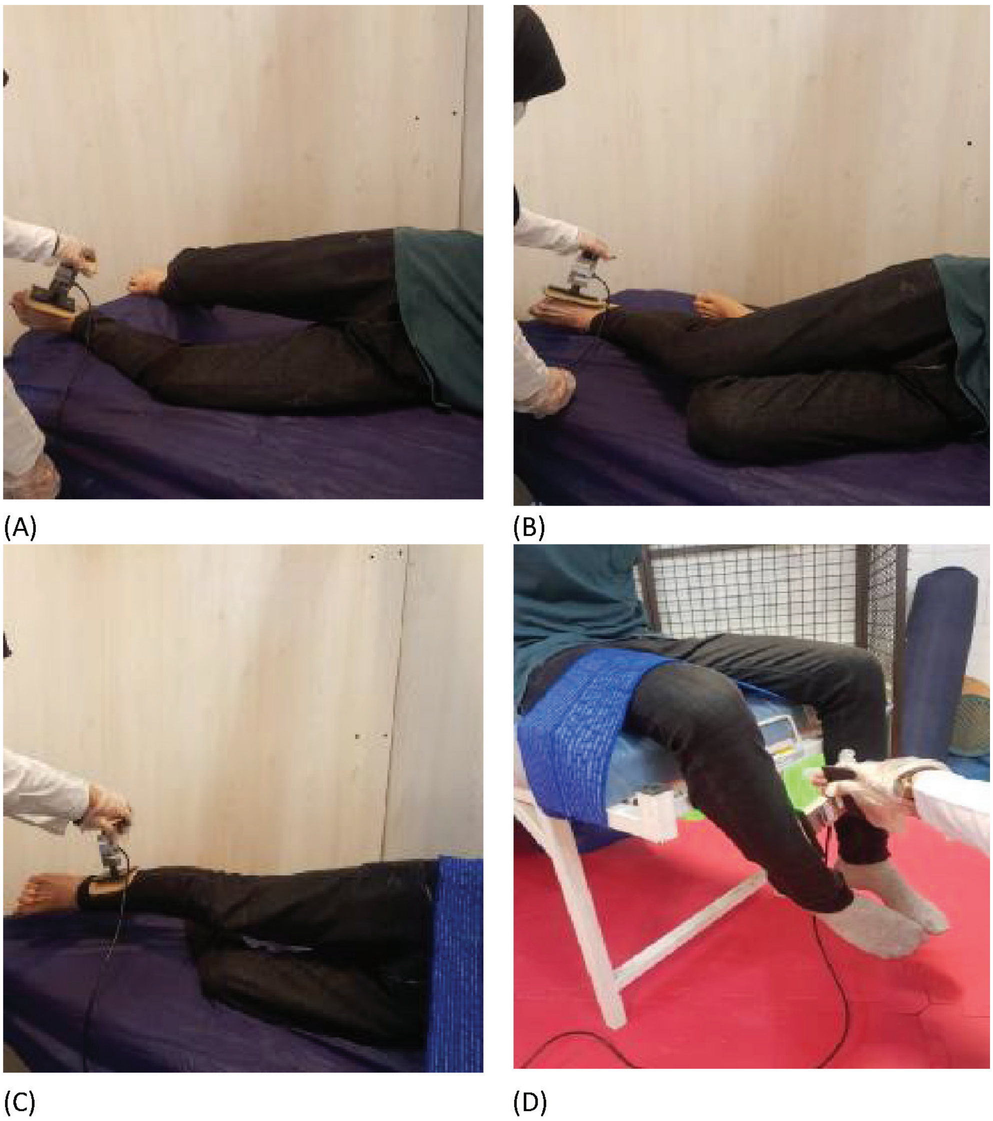

Figure 1: Assessing the maximal isometric strength for invertor (A), evertor (B), hip abductor (C), and external rotator (D) muscles using hand-held dynamometry

For hip abductor muscle strength testing, participants remained in a side-lying position with stabilization straps secured across the iliac crest, and the dynamometer was placed above the lateral malleolus [23]. For testing hip external rotator muscle strength, participants were seated with a single stabilization strap secured across their thighs, and the dynamometer was positioned five centimeters proximal to the medial malleolus [27].

Each muscle test included one practice trial followed by three test trials. Participants were instructed to gradually increase the intensity of the contraction for the first three seconds, followed by maximal effort during the fourth and fifth seconds. A 30-second rest period was allowed between each trial. The maximum force for each trial was recorded in newtons and averaged across the three trials. Excellent test-retest reliability has been reported for hand-held dynamometry measurements of hip abductor (ICC=0.76), external rotator (ICC=0.95), invertor (ICC=0.92), and evertor (ICC=0.84) strength [26].

Statistical Analyses

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) software version 22. The Kolmogorov-Smirnov test confirmed that all variables exhibited normal distribution (P>0.05). Descriptive statistics, including means, standard deviations (SDs), and range values, were calculated for each variable.

Bivariate correlations were employed to investigate the relationships between the Side Hop Test (SHT), dynamic balance control, and isometric muscle strength. The strength of the relationships was interpreted as follows: little or no relationship (r=0.0-0.25), fair relationship (r=0.25-0.50), moderate to good relationship (r=0.50-0.75), and good to excellent relationship (r>0.75) [28].

Additionally, simple linear regression analysis was conducted to determine how much the SHT predicted each dependent variable: dynamic balance (MSEBT score) and isometric muscle strength. An alpha level of P<0.05 was set for all analyses.

Results

Sixty male athletes (mean age: 29.6±6.2 years; height: 178.35±5.35 cm; weight: 82.15±10.31 kg) participated in the study. Participants reported an average of 82% (±10%) and 70% (±11%) functional limitations in the Daily Living and Sports Activity subscales of the Foot and Ankle Ability Measure (FAAM) questionnaire, respectively.

Table 1 presents the descriptive statistics for the Side Hop Test (SHT), Modified Star Excursion Balance Test (MSEBT), and maximal isometric strength of the injured limb muscles.

Table 1: Descriptive statistics for maximal isometric strength of injured limb muscles, MSEBT, and SHT in 60 recreational male athletes with chronic ankle instability.

Variable	Range	Mean±SD
Isometric strength of hip Abductor muscles in the injured limb (newton)	2.61-13.50	7.87±2.61
Isometric strength of ankle Invertor muscles in the injured limb (newton)	2.53-11.50	6.85±2.26
Isometric strength of ankle Evertor muscles in the injured limb (newton)	3.02-12.90	6.37±2.09
Isometric strength of hip External Rotator muscles in the injured limb (newton)	4.27-14.23	9.03±2.51
*MSEBT-ANT (%)	66.32-85.71	78.41±4.33
MSEBT-PM (%)	90.36-113.19	102.30±5.86
MSEBT-PL (%)	77.89-107.69	92.23±6.08
SHT (second)	8.28-18.58	11.18±2.14

SD: Standard deviation; ANT: Anterior; PM: Posteromedial; PL: Posterolateral; SHT: Side hop test; MSEBT: Modified Star Excursion Balance Test; *MSEBT are expressed as a percentage of limb length (direct reach distance divided by limb length and multiplied by 100).

Table 2: Bivariate correlations between maximal isometric strength of injured limb muscles, MSEBT, and SHT in 60 recreational male athletes with chronic ankle instability

		SHT	Isometric strength of Abductors	Isometric strength of Invertors	Isometric strength of Evertors	Isometric strength of External Rotators	MSEBT –ANT	MSEBT -PM	MSEBT -PL
SHT	Pearson Correlation	1	-0.11	0.12	0.06	0.07	-0.12	-0.43	-0.26
	P value		0.38	0.33	0.61	0.56	0.34	<0.001 *	0.04*
Isometric strength of Abductors	Pearson Correlation		1	0.67	0.53	0.56	-0.05	0.23	0.40
	P value			<0.001 *	<0.001 *	<0.001 *	0.65	0.07	<0.001 *
Isometric strength of Invertors	Pearson Correlation			1	0.74	0.061	-0.24	-0.11	0.14
	P value				<0.001 *	<0.001 *	0.05	0.38	0.25
Isometric strength of Evertors	Pearson Correlation				1	0.72	0.17	-0.03	0.15
	P value					<0.001 *	0.09	0.80	0.23
Isometric strength of External Rotators	Pearson Correlation					1	-0.22	-0.08	0.02
	P value						0.08	0.50	0.86
MSEBT –ANT	Pearson Correlation						1	0.28	0.24
	P value							0.02 *	0.05
MSEBT -PM	Pearson Correlation							1	0.75
	P value								<0.001 *
MSEBT -PL	Pearson Correlation								1
	P value								

SHT: Side hop test; ANT: Anterior; PM: Posteromedial; PL: Posterolateral; MSEBT: Modified Star Excursion Balance Test; Significant *P*-values are in mark with*.

Table 3: Linear Regression Results for SHT predicting maximal isometric strength of invertor, evertor, hip abductor, and external rotator muscles and MSEBT in anterior (ANT), posteromedial (PM), and posterolateral (PL) directions in 60recreational male athletes with chronic ankle instability

Variable	R^2	P value
MSEBT –PM	0.19	<0.001*
MSEBT -PL	0.07	0.04*
MSEBT -ANT	0.01	0.34
Isometric strength of hip Abductor muscles in the injured limb	0.01	0.38
Isometric strength of hip External Rotator muscles in the injured limb	0.00	0.56
Isometric strength of ankle Invertor muscles in the injured limb	0.01	0.33
Isometric strength of ankle Evertor muscles in the injured limb	0.00	0.61

ANT: Anterior; PM: Posteromedial; PL: Posterolateral; SHT: Side hop test; MSEBT: Modified Star Excursion Balance Test; Significant *P*-values are in mark with*.

The results of the Pearson correlation coefficient analysis indicated fair negative correlations between the Side Hop Test (SHT) score and the Modified Star Excursion Balance Test (MSEBT) in the posteromedial (PM) (r=-0.43, P<0.001) and posterolateral (PL) reach directions (r=-0.26, P=0.04) (Table 2). The linear regression model revealed that only 19% of the variance in the PM reach direction and 7% of the variance in the PL reach direction of the MSEBT were explained by SHT performance. Therefore, the SHT was identified as a fair predictor of MSEBT performance in the PM and PL directions.

Additionally, the SHT did not explain a significant variance in the isometric strength of hip and ankle muscles or the MSEBT in the anterior (ANT) reach direction among male athletes with CAI (Table 3).

Furthermore, a fair, positive relationship was observed between the maximal isometric strength of hip abductor muscles and the PL reaching the direction of the MSEBT (r=0.40, P<0.001). The PM reach direction demonstrated a good to excellent relationship with the PL reach direction (r=0.75, P<0.001) and a fair relationship with the ANT reach direction of the MSEBT (r=0.28, P=0.02).

Discussion

This study examined the relationships between performance on the Side Hop Test (SHT), dynamic balance control, and maximal isometric strength of hip and ankle muscles in recreational male athletes with CAI. Additionally, it sought to determine the predictive ability of the SHT for deficits in specific movement components. The study's main finding was a fair negative correlation between the SHT and PM (r=-0.43) and PL (r=-0.26) reach directions of the MSEBT. This fair negative correlation suggests that reduced performance on the SHT (longer test completion time) has a limited association with impaired dynamic balance control, particularly in the PM reach direction.

Furthermore, the findings demonstrated that only a small percentage of the variance in MSEBT scores was explained by the SHT. Specifically, approximately 80% of the variance in the PM reach direction, more than 90% of the variance in the PL reach direction, and nearly all of the variance in the ANT reach direction remained unexplained by SHT performance. This suggests that the SHT's ability to predict deficits in dynamic balance control among recreational male athletes with CAI is minimal.

In line with these results, Docherty et al. also reported a weak positive relationship between the sensation of ankle instability and poor performance on the SHT in individuals with CAI [7]; these findings should be interpreted cautiously. Shelley et al. noted that individuals who take more than 12.88 seconds to complete the SHT can be categorized as having postural instability [29], while the time to complete the SHT among the athletes in this study was 11.18 seconds. This shorter completion time may have influenced the results, and future research should explore the relationship between MSEBT and longer SHT times in individuals with CAI to gain further insights.

Another finding of this study was the lack of correlation between the SHT and isometric strength of the hip and ankle muscles in the injured limb. Furthermore, the SHT could not predict the isometric strength of hip and ankle muscles in recreational male athletes with CAI. Several studies have previously examined the relationship between functional performance tests (FPTs) and maximum lower limb strength [30, 31]. In line with the study findings, a study by Kamonseki et al. reported no significant correlations between the SHT and isometric strength of lower limb muscles in healthy male adolescents [30]. This suggests that it may be associated with other aspects of muscle strength, such as rate of force development and strength endurance, rather than maximum isometric strength. Future studies are warranted to investigate this hypothesis.

The study results revealed a small positive relationship between the isometric strength of hip abductor muscles and the PL reach direction (r=0.40). Consistent with this finding, previous studies have demonstrated that stronger hip abductors enable individuals to reach a greater distance in posterior directions [5, 32]. While our study does not determine the cause of the differences observed between associations of isometric muscle strength with the SHT and MSEBT, it is essential to note the differing demands of these two tests. The hip abductor muscles are crucial for controlling pelvic position in the frontal plane and preventing pelvic drop during single-limb tasks [33]. However, trunk position, movement direction, and base of support can affect hip abductor muscle activity [34].

Additionally, a review indicated that hip abductor activation varies widely across tasks, ranging from 9% to 74% of maximal isometric contraction [34]. It's worth considering that the SHT requires participants to complete a task as quickly as possible on a single limb, requiring a more complex neuromuscular strategy and greater explosive strength to ensure lateral stability [35]. In contrast, the MSEBT involves moving the body over a stationary support base [8]. We speculate that these two tests may be associated with specific deficits in muscle strength; however, this hypothesis warrants investigation in future research.

We acknowledge several limitations that should be addressed in future studies. First, this study focused on recreational male athletes with CAI, so the findings may not be generalizable to female athletes. Importantly, the prevalence of CAI is higher in female athletes than in males [36]. The decision to enroll only male athletes was based on the low availability of female athletes with CAI in our population. Second, we did not include healthy male athletes as controls. Third, this study assessed only one aspect of strength—maximum strength. Future studies would benefit from evaluating additional strength attributes, such as rate of force development and strength endurance, to gain further insights into the movement components underlying FPTs.

Conclusion

The results of this study suggest that the SHT alone may not be sufficient to predict deficits in dynamic balance control and isometric strength of the hip and ankle muscles in recreational male athletes with CAI. Clinically, it may be beneficial for physiotherapists to incorporate a combination of functional and specialized tests rather than relying solely on the SHT to better identify specific deficits in this population.

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Conflict of Interest: None declared.

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