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Original Research

Hip Stability Isometric Test (HipSIT): Concurrent Validity and Reference Values for CrossFit® Participants

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Background

The Hip Stability Isometric Test (HipSIT) is a practical clinical assessment of posterolateral hip muscle performance. There is no information regarding the validity of the HipSIT in participants exposed to high-intensity training, such as CrossFit®.

Purpose

The purpose of this study was to investigate the Hip Stability Isometric Test (HipSIT) concurrent validity with the isokinetic assessment in CrossFit® participants. A secondary purpose was to characterize posterolateral hip muscular performance with HipSIT according to sex and lower limb dominance in athletes who participate in CrossFit®.

Study Design

Cross-sectional.

Methods

One-hundred and eleven CrossFit® participants were evaluated. The posterolateral hip muscles were evaluated using the HipSIT with a hand-held dynamometer. The hip extensors and abductors' peak torque and maximum work were assessed with the Biodex System® 4 Pro isokinetic dynamometer at 60º/s. Concurrent validity between measurements was assessed with the Spearman correlation coefficient and Bland-Altman analyses. The comparison of results between sexes and between limbs was also performed.

Results

Spearman analyses indicated a significant positive correlation with medium effect size between HipSIT and isokinetic variables (ρ = 0.36 to 0.49). Bland-Altman analyses showed that most measures were within the 95% limits of agreement. The HipSIT was greater in males than females ($p < 0.001$) and greater in the dominant than non-dominant limb ($p = 0.03$).

Conclusion

The findings support using HipSIT in the clinical assessment of CrossFit® participants. Clinicians can use the data as reference values for athletes who participate in CrossFit® and should consider the difference between sexes and lower limbs.

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Level of evidence

3

INTRODUCTION

The Hip Stability Isometric Test (HipSIT) is a clinical examination of hip posterolateral muscle strength (i.e., hip abductors, lateral rotators, and extensors).[1] This test is considered more functional and quicker to perform than the traditional uniplanar assessment of hip muscles.[1] The hip posterolateral muscles are commonly considered during sports assessment since their deficits in torque favor altered hip motion and greater stress on the musculoskeletal system, such as the anterior cruciate ligament, increasing the risk of sports injuries.[2,3] In support of that, a previous study showed that the HipSIT outcome was one of the variables that classified mountain bikers with and without anterior knee pain.[4] Therefore, the HipSIT is a practical clinical test for sports assessments.

The HipSIT has been previously investigated regarding measurement properties in females with and without patellofemoral pain, showing appropriate reliability and validity.[1] Although this test is valid for a population with low force generation capacity, there is no information regarding its measurement properties for assessing participants with greater muscular performance due to high-intensity training. For this reason, CrossFit® participants were chosen for this investigation as this sport involves high-intensity strength and power activities,[5,6] typically requiring the recruitment of hip muscles to contribute to proper body alignment, propulsion, and force transmission among segments.[7,8]

The validity of the HipSIT among CrossFit® participants can be examined by correlating its results to the results from isokinetic assessment, commonly considered the standard reference measure of muscle performance. If valid, the HipSIT may be viewed as a preferable alternative to the gold-standard isokinetic dynamometer within the context of sports applications. The isokinetic dynamometer is a non-portable device that requires more time and training of the evaluator to assess hip muscle performance than the HipSIT assessment. These characteristics prohibit the use of the isokinetic dynamometer for quick evaluations on the field, and perhaps during preseason assessments with a large number of athletes. Also, the cost of an isokinetic dynamometer is higher than that of a hand-held dynamometer, such as that used with the HipSIT. Therefore, despite the isokinetic dynamometer providing objective muscle performance data with remarkable quality, the HipSIT could be a good option for a quick, easy, and valid clinical assessment of hip muscle performance, especially in clinical and sports settings involving large-scale assessments.

In addition to validity, the HipSIT can be used to assess any differences in hip muscle performance between males and females and between dominant and non-dominant lower limbs. Thus, the purpose of this study was to investigate the Hip Stability Isometric Test (HipSIT) concurrent validity with the isokinetic assessment in CrossFit® participants. A secondary purpose was to characterize posterolateral hip muscular performance with HipSIT according to sex and lower limb dominance in athletes who participate in CrossFit®.

METHODS

Participants

CrossFit® practitioners (58 males and 53 females) were recruited by posting announcements in CrossFit® gyms. The inclusion criteria were age between 18 and 40 years, at least one year of CrossFit® practice, absence of musculoskeletal injuries in the last six months, and absence of surgery in the previous year. The musculoskeletal injury was defined as time loss of the practice equal to or greater than seven days or 14 days with reduced training capability.[9] The exclusion criteria were any pain during the procedures or inability to perform the tests. No participants were excluded. The sample size was estimated based on a priori power analysis with the following parameters: significance level of 0.05, statistical power of 80%, and medium effect size ($\rho = 0.30$). This analysis revealed that a minimum sample size of 84 participants would be necessary to ensure that the correlation between variables would differ from 0. All the participants provided written informed consent before participation. The ethics in research committee of the Universidade Federal de Minas Gerais approved this study (Protocol number: CAAE 93670418.9.0000.5149).

PROCEDURES

The participants answered a questionnaire about the characteristics of their CrossFit® training, and then their body mass and height were measured. To warm up, the participants did jump jacks for one minute. Subsequently, they performed one submaximal repetition of the HipSIT and isokinetic assessment for familiarization. The dominant lower limb was assessed first, followed by the non-dominant one. The dominant lower limb was defined as the preferred leg to kick a ball as far as possible.[10]

The HipSIT was performed as described by Almeida *et al.*[1] The participant was positioned side-lying, with 45° of hip flexion, 20° of hip abduction, and 90° of knee flexion (Figure 1A). A manual dynamometer (microFET2; Hoggan Scientific, LLC, Salt Lake City, UT, USA) was positioned with a rigid strap at 5 cm superior to the lateral femoral epicondyle. The participants were instructed to lift the knee of the upper leg, keeping contact between heels, and pushing the dynamometer with maximum force for five seconds. Three measures were performed on each limb, with one minute of rest between the attempts. The mean peak torque was considered for analysis. If any compensation was observed during the test, the attempt was discarded, and the trial was repeated. The intra-rater reliability was examined in a pilot study with 10 participants assessed during two

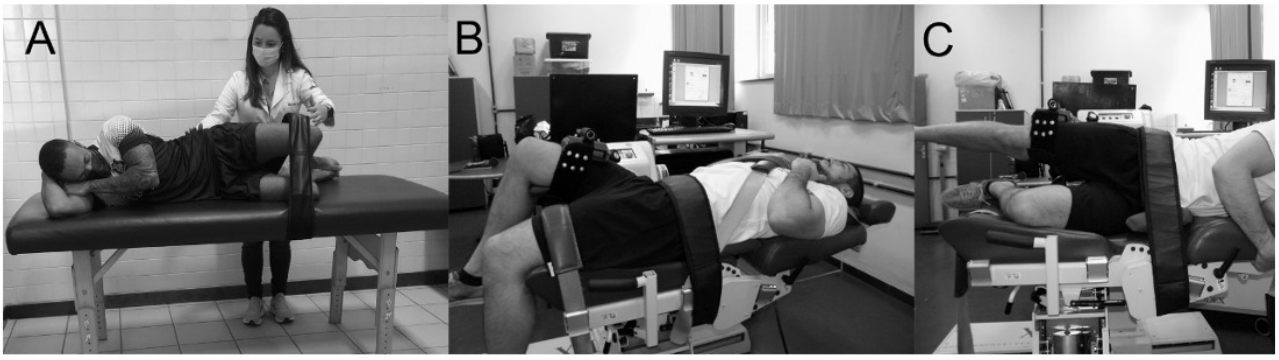

Figure 1. (A) Hip Stability Isometric Test – HipSIT, (B) Isokinetic assessment of hip extensors, and (C) Isokinetic assessment of hip abductor.

sessions seven days apart. The results showed excellent intra-rater reliability (overall ICC = 0.921, 95% Confidence Interval = 0.790-0.978; Standard Error of Measurement - SEM = 6.86 N m).

Isokinetic assessment of hip extensors and abductors was performed with the Biodex System® 4 Pro dynamometer (Biodex Medical System Inc., Shirley, NY, EUA) in concentric mode.[11,12] Previous authors have demonstrated that the isokinetic assessment presented adequate measurement properties.[13,14] The hip extensors were assessed in a supine position; the trunk was stabilized with two straps crossed over it, and another strap was placed proximal to the iliac crest (Figure 1B). The range of motion was set at 110° (10° to 120° of flexion). The hip abductors were assessed in a side-lying position,[15] with the hip parallel to the ground at a neutral position; the trunk was stabilized with a belt proximal to the iliac crest; the contralateral hip and knee were flexed and stabilized with straps (Figure 1C). The range of motion was set at 45° (0° to 45° of hip abduction). For both tests, the rotational axis was aligned with the greater trochanter of the femur, the attachment was positioned on the distal third of the thigh, and the participants performed five repetitions at 60°/s. The assessed limb was weighted to correct the gravity effects on the torque measured.[16] The peak torque and maximum work (i.e., extracted from the repetition with the greatest amount of work) were selected for analysis.

STATISTICAL ANALYSIS

Descriptive statistics were used to characterize HipSIT data (non-normalized and normalized by body weight) according to sex and limb dominance. Muscle strength normalized by body weight is usually recommended to compare the performance of different subjects and, thus, helpful in the clinical setting as reference data. Kolmogorov-Smirnov test revealed that the data showed a significant non-normal distribution. The comparison of the non-normalized HipSIT data between sexes was performed with the Mann-Whitney U test. The comparison between limbs was performed with the Wilcoxon test.

The consistency between the HipSIT and isokinetic variables was investigated with the Spearman correlation coefficient (r_s).[17] The closer r_s is to -1 or +1, the stronger the relationship is compared to values closer to zero. Values of $r_s = \pm 0.1$ indicate a small effect size, $r_s = \pm 0.3$ a medium effect size, and $r_s = \pm 0.5$ a large effect size.[18] Also, the Bland-Altman analysis and its 95% limits of agreement (LoA) were used to graphically show the agreement between HipSIT and isokinetic peak torque measurements.[17,19] This analysis reveals the spread of the difference between methods according to each participant against the mean score.[17,19] The Bland-Altman analysis was performed only with the isokinetic peak torque measurement since this variable is expressed in the same unit of HipSIT output. A significance level of 0.05 was used for all analyses.

RESULTS

The anthropometric and training variables are presented in Table 1. Descriptive data for the HipSIT are shown in Table 2. The HipSIT performance was greater in males than in females for the dominant ($p < 0.001$) and non-dominant limbs ($p < 0.001$). Also, the HipSIT was greater in the dominant than non-dominant limb ($p = 0.03$).

Spearman analyses indicated a significant positive correlation with medium effect size between HipSIT and isokinetic variables ($\rho = 0.36$ to 0.49) (Table 3). The relationship between variables is shown in scatter plots (Supplementary material).

Bland-Altman analyses showed that most measures were within the LoA (Figure 2). The analyses showed the following trend: the difference between measures tended to be greater with greater peak torque values.

DISCUSSION

This study investigated the validity of the HipSIT with the isokinetic assessment in CrossFit® practitioners and showed a positive correlation with medium effect size between these measurements. Furthermore, this study provides data using the HipSIT that can be used as reference values for future research and clinical practice. Hip muscular performance was greater for males than females in both limbs. Also, the performance was greater in the dom-

Table 1. Characteristics of the CrossFit® practitioners (*n* = 111)

Variable	
Age (*years*)	29.3 (5.5)
Body mass (*kg*)	73.1 (12.1)
Height (*m*)	1.70 (0.08)
Sex (Female/Male)	53/58
CrossFit® time practice (*months*)	27.8 (15.7)
Training hours/week	6.8 (3.7)
Levels of workout difficulty	
Scale	40
Intermediate	34
RX	37

Note: All variables except the sex and category are presented as mean (standard deviation). The sex and category are presented as the observed frequency. RX: workout performed as prescribed for each exercise; Intermediate: a modified version of the RX workout for more experienced athletes; Scale: workout adapted for athletes with little experience.

Table 2. Descriptive data of hip posterolateral muscle performance according to the HipSIT

	Non-normalized data (N-m)			Data normalized by body weight (N-m/kg)		
	Lower limb		Both limbs	Lower limb		Both limbs
	DOM	NDOM		DOM	NDOM	
Males (*n* = 58)						
Median (IQR)	51.50 (21.92)	48.00 (25.83)	51.50 (20.04)	0.62 (0.28)	0.59 (0.31)	0.60 (0.26)
Mean (SD)	49.53 (13.22)	48.80 (13.26)	49.16 (12.59)	0.62 (0.19)	0.61 (0.18)	0.61 (0.18)
95% CI	46.05 - 53.00	45.31 - 52.29	45.85 - 52.48	0.57 - 0.67	0.56 - 0.66	0.57 - 0.66
Females (*n* = 53)						
Median (IQR)	39.33 (11.00)	35.67 (12.50)	38.33 (11.33)	0.63 (0.23)	0.57 (0.20)	0.61 (0.23)
Mean (SD)	38.31 (8.21)	36.45 (9.57)	37.38 (8.34)	0.61 (0.15)	0.57 (0.14)	0.59 (0.13)
95% CI	36.05 - 40.57	33.81 - 39.09	35.08 - 39.68	0.57 - 0.65	0.53 - 0.61	0.55 – 0.63
All participants (*n* = 111)						
Median (IQR)	42.33 (17.67)	40.67 (18.33)	41.17 (18.33)	0.63 (0.26)	0.58 (0.24)	0.61 (0.23)
Mean (SD)	44.17 (12.41)	42.90 (13.15)	43.54 (12.25)	0.61 (0.17)	0.59 (0.16)	0.60 (0.16)
95% CI	41.84 - 46.51	40.43 - 45.38	41.23 - 45.84	0.58 - 0.64	0.56 - 0.62	0.57 - 0.63

Note: DOM = Dominant, NDOM = Non-dominant, IQR = Interquartile range, SD = Standard Deviation, CI = Confidence Interval.

inant than the non-dominant limb. Thus, the hip posterolateral muscle strength measured by HipSIT showed adequate properties to be used with CrossFit® practitioners.

The HipSIT and isokinetic assessment were positively correlated, however may assess different properties of muscle performance. The isokinetic test analyzes the hip muscle performance according to the muscle actions of the tested groups (i.e., hip extensors and abductors) during a constant angular speed throughout the range of motion.[20] On the other hand, the HipSIT measures the isometric torque generated by three hip muscle groups simultaneously at a single point in the range of motion.[1] Despite these differences between the tests, the HipSIT demands hip posterolateral muscles to generate a combined isomet-

Table 3. Correlation between HipSIT and isokinetic variables

	HipSIT	
Isokinetic variables	Dominant	Non-Dominant
60°/s		
Peak of torque		
Hip extensors	ρ = 0.45, *p* <0.001	ρ = 0.49, *p* <0.001
Hip abductors	ρ = 0.37, *p* <0.001	ρ = 0.48, *p* <0.001
Maximum work		
Hip extensors	ρ = 0.44, *p* <0.001	ρ = 0.49, *p* <0.001
Hip abductors	ρ = 0.36, *p* <0.001	ρ = 0.42, *p* <0.001

The level of significance was 0.05.

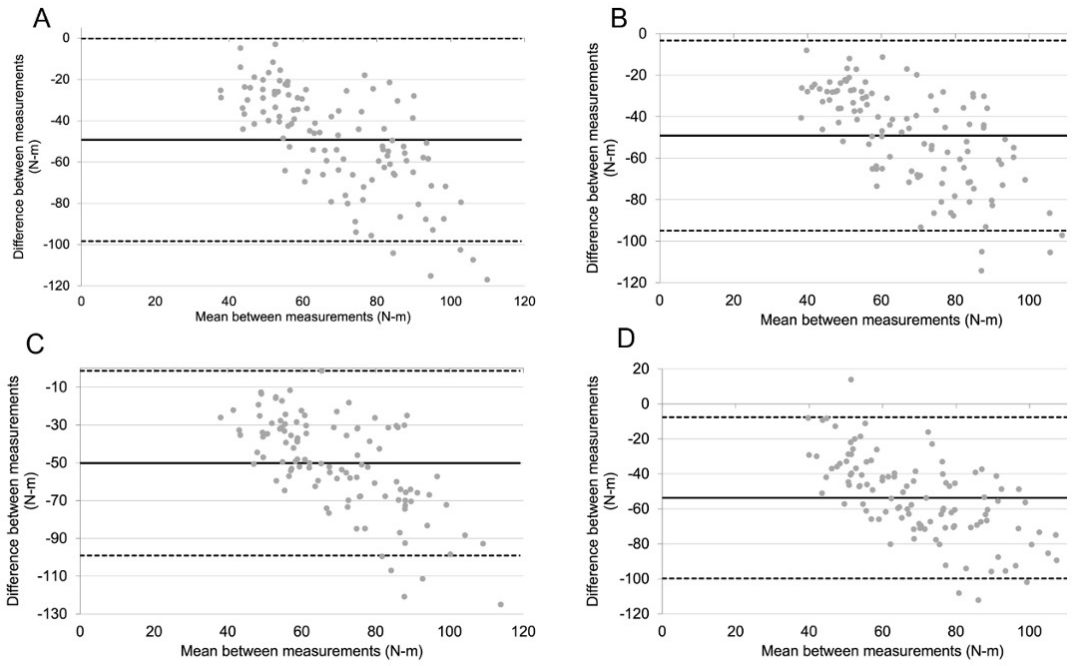

Figure 2. Bland-Altman plots between HipSIT and the following isokinetic variables: peak of torque of the dominant hip extensors (A), non-dominant hip extensors (B), dominant hip abductors (C), non-dominant hip abductors (D).

ric torque related to each hip muscle's capacity to generate torque, explaining the moderate correlations seen. The HipSIT could be used as a valid clinical way to measure the hip extensors' and abductors' combined performance of CrossFit® practitioners.

The HipSIT presented a slightly greater strength of association with hip extensors (ρ = 0.44 to 0.49) than abductors (ρ = 0.36 to 0.48). These results suggest that HipSIT may better represent the performance of hip extensors than abductors. In support of this interpretation, authors have previously described the greater activity of the gluteus maximum than medius during clamshell exercise, a position like the one adopted to perform the HipSIT test.[21,22]

The HipSIT was correlated with both peak torque and maximum work. A previous study indicated that the maximum work best represented the torque generation capacity, and the peak torque should not be used solely to represent this capacity.[23] The isokinetic peak torque represents the maximum torque generated at a single point of the entire range of motion, whereas maximum work represents the capacity to generate muscle torque throughout the full range of the movement.[24] Bland-Altman analysis revealed that most data were within the LoA. Furthermore, the plots showed a tendency for greater differences between measurements in the participants that generated the greatest torque mean values. Therefore, it appears that the HipSIT measure is mainly related to the hip extensors' capacity to generate torque in CrossFit® practitioners, and the measurements tend to show greater differences in those that produced greater torque.

The measurement properties investigated in the current study complemented the previous research that examined

reliability and validity of the HipSIT. The prior study validated HipSIT with isometric hand-held dynamometry in 49 recreational physically active females and found a large correlation with hip abductors (r = 0.535), extensors (r = 0.514), and lateral rotators (r = 0.536).[1] The present study investigated validity with a reference standard device for assessing hip muscle performance in a larger sample, including both males and females practicing CrossFit®. Since the HipSIT maintained a medium correlation to the reference measurement, the test may be considered a practical clinical assessment for participants in high-intensity conditioning programs.

The second aim of this study was to characterize the hip posterolateral muscle muscle performance according to sex and limb dominance. Males presented greater performance than females, which is not surprising. A similar finding has been shown for shoulder and knee muscles assessed with an isokinetic dynamometer in participants enrolled in high-intensity training programs.[25] The HipSIT also differed between lower limbs: the dominant limb presented greater performance than the non-dominant. This result also corroborates the observed difference between limbs for knee flexors' peak torque, as shown previously.[25] Clinicians assessing CrossFit® participants should consider the difference between sexes and limbs, and the current results could be used as reference data.

This study showed some limitations. The findings of this study are generalizable to healthy CrossFit® practitioners. Despite the inclusion criterion of an absence of injury in the prior six months, a limitation would be that any injury history beyond this period could influence hip performance. However, due to the cross-sectional design of the current study, the reporting of this information could be affected by memory bias. Future studies may be designed to investigate HipSIT in other samples and other measurement properties (e.g., responsiveness). In addition, future prospective investigations may look for the capacity of this clinical test outcome to predict sports injuries.

CONCLUSIONS

In CrossFit® practitioners, the hip posterolateral performance assessed using HipSIT showed acceptable concurrent validity with the peak torque and maximum work of the hip extensors and abductors assessed isokinetically. The observed correlations and their medium association suggest that the relationship between these measures occurs mainly with hip extensors' performance. Furthermore, posterolateral hip performance values as measured by the HipSIT were greater in males than females and in the dominant versus the non-dominant limb.

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SUPPLEMENTARY MATERIALS

Supplementary material

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