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Validity and Reliability of a New Device (WIMU®) for Measuring Hamstring Muscle Extensibility

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ABSTRACT

The aims of the current study were 1) to evaluate the validity of the WIMU® system for measuring hamstring muscle extensibility in the passive straight leg raise (PSLR) test using an inclinometer for the criterion and 2) to determine the test-retest reliability of the WIMU® system to measure hamstring muscle extensibility during the PSLR test. 55 subjects were evaluated on 2 separate occasions. Data from a Unilever inclinometer and WIMU® system were collected simultaneously. Intraclass correlation coefficients (ICCs) for the validity were very high (0.983–1); a very low systematic bias (−0.21°– −0.42°), random error (0.05°–0.04°) and standard error of the estimate (0.43°–0.34°) were observed (left–right leg, respectively) between the 2 devices (inclinometer and the WIMU® system). The R^2 between the devices was 0.999 ($p<0.001$) in both the left and right legs. The test-retest reliability of the WIMU® system was excellent, with ICCs ranging from 0.972–0.995, low coefficients of variation (0.01%), and a low standard error of the estimate (0.19–0.31°). The WIMU® system showed strong concurrent validity and excellent test-retest reliability for the evaluation of hamstring muscle extensibility in the PSLR test.

Introduction

Hamstring extensibility is an important component of physical fitness and spinal health. In this context, extensibility is understood as the ability of muscle tissue to lengthen or stretch beyond the resting length [21]. The lack of extensibility in hamstring muscle could affect the quality and quantity of the hip range of motion (ROM) available to perform functional tasks, altering events within the kinetic chain in coordinated actions, such as running [9]. In this sense, several studies have found that reduced hamstring extensibility is associated with a higher risk of spinal alteration, especially in postures with the trunk in flexion [26], as well as with low back pain [32], and changes in lumbopelvic rhythm [10], and it might lead to patellar tendinitis [35] and patellofemoral pain syndrome [31].

Passive stretching is a commonly observed clinical intervention for reduced hamstring extensibility [21], and the passive straight leg raise (PSLR) test is one of the most commonly used tests for evaluating hamstring muscle extensibility [14, 18, 23, 28, 29, 34]. Furthermore, because of its reliability and validity, the PSLR test has been extensively used as the gold standard in studies evaluating several hamstring extensibility tests [2, 15, 16, 18, 19, 27, 39], for which the instrument of evaluation was the Unilever inclinometer (ISOMED, Inc., Portland, OR, USA) [2, 18, 19, 27, 38].

Although inclinometers are very popular as reliable validity instruments for evaluating hamstring muscle extensibility, they are limited in their utility because the data are registered manually on a piece of paper and then must be entered into statistical software. On the other hand, the inclinometers normally have a pointer that is gravity-dependent and reads the angle tangent to the surface being measured [38] with an accuracy of ±2 degrees.

The need for better instruments that are valid, reliable, accurate and easier for use on the field, in sport centres and in laboratories has driven sport scientists and the industry to develop more complete and portable instruments. For example, the new system called the Wimu® system is equipped with a 3D accelerometer 2 G recording at 1 000 Hz to track inclination as well as a 3D gyroscope recording at 1 000 Hz and 2 000 degrees per second to measure the angular speed, roll, pitch and yaw. For these reasons, the Wimu®

system could be used as a digital inclinometer, making it easier and more accurate to use than other inclinometers. However, to the best of our knowledge, no studies have evaluated the validity and test-retest reliability of this new device for measuring hamstring muscle extensibility during the SLR test.

Therefore, the aims of the current study were as follows: 1) to evaluate the validity of the WIMU® system for measuring the hamstring muscle extensibility test using an inclinometer and 2) to determine the test-retest reliability of the Wimu® system to measure hamstring muscle extensibility during the PSLR test.

Materials & Methods

Participants

55 recreationally active, healthy male (age = 19.52 ± 4.94 years, height = 1.76 ± 0.08 m, and body mass = 71.49 ± 9.30 kg) voluntarily participated in the study. Participants were excluded if they suffered pain induced or exacerbated by the test procedures, incurred any injury that prevented participation in training before testing or had any known hamstring injury. None of the participants performed stretching exercises before or after training. All participants were instructed to avoid strenuous training and physical activity 72 h before the study.

Procedures

Prior to the measurements, all participants provided written consent before entering the study. An institutional ethics committee approved the study, which was conducted in accordance with the Declaration of Helsinki; the study was designed and conducted according to the Ethical Standards in Sports and Exercise Science Research [12].

Passive Straight Leg Raise Test

For the PSLR test (left and right legs), the participant was placed in the supine position with the lower extremities in 0 ° hip flexion. While the participant was in the supine position, a WIMU® system was placed over the distal tibia to measure the inclination. A Unilever inclinometer (ISOMED, Inc., Portland, OR, USA) was fixed and secured to the WIMU® system (▶ **Fig. 1**). The use of both devices improves the accuracy of the measurements because both devices are subject to the same biases (such as soft tissue artefacts) [6].

▶ **Fig. 1** ISOMED Unilever inclinometer and WIMU® system fixed for the measurements.

The inclinometer was used as the gold standard in the current study because this device has been used in previous studies as a valid and reliable tool for evaluating hamstring muscle extensibility [17, 18, 20, 24, 27, 29].

The WIMU® system (RealTrack Systems, Almería, Spain) simultaneously recorded the hip flexion angle. The system is a small, wireless device with more than 20 integrated sensors. The sensors include a 1 000 Hz 3D accelerometer, a 1 000 HZ 3D gyroscope with 2 000 degrees per second resolution, a 3D magnetometer, and a barometer that works with an integration of sensors to improve the information. All data regarding the angle reached in each repetition for both legs were sent via Bluetooth to a personal computer, in real time, and were then recorded using Qüiko® software (RealTrack Systems, Almería, Spain).

A lumbar protection support (Lumbosant, Murcia, Spain) was used to maintain neutral lumbar lordosis during the test [27]. Thereafter, the participant's leg was passively lifted by the tester into hip flexion. The knee remained straight during the leg raise, while the pelvis and other leg were fixed by an assistant tester to avoid a posterior pelvic tilt because modifications in the pelvic positions have been reported as factors that could affect the PSLR score [3]. The endpoint for the straight leg raise was determined by one or both of the following criteria: a) the participant reported pain in the hamstring muscle and/or b) there was a palpable onset of pelvic rotation (▶ **Fig. 2**). Moreover, the ankle of the tested leg was restrained in maximum plantar flexion to avoid adverse neu-

▶ **Fig. 2** The endpoint for the straight leg raise test for evaluating the hamstring muscle extensibility with both devices: the ISOMED Unilever inclinometer and WIMU® system.

tral tension [22] that could induce earlier distal muscle activation and reduce hip flexion motion [5]. Each measurement was repeated 3 times within a 3-min rest period. The average of the 3 trials was used for data analysis. To assess the reliability of these devices, all tests and protocols were performed 7 days later, at the same time and under identical conditions.

Statistical analyses

The hypothesis of normality was analysed via the Kolmogorov-Smirnov test. Parametric analysis was performed because the data were normally distributed. Paired Student's t-tests were used to detect any systematic differences (also as reference for bias) between tools (validity) and test sessions (reliability) [1]. The between-group effect sizes (Cohen's d) were calculated using a pooled standard deviation. The effect sizes were evaluated as trivial (0–0.19), small (0.20–0.49), medium (0.50–0.79) and large (0.80 and higher) [7]. The concurrent validity of the WIMU system was examined using linear regression to estimate a calibration equation, standard error of the estimate (SEE) and intraclass correlation coefficients (ICCs) (2,1) [36] with the 95 % confidence interval (CI) [13]. To measure the reliability of the WIMU system, the ICC (2,1) with the 95 % CI [36] and percentage coefficients of variation (CVs) between test and retests [1] were calculated. Statistical power and effect sizes were calculated using G * Power 3.1 [11]. The statistical analyses were performed using Statistical Package "OS X", Version 22.0, Armonk, NY, USA). Statistical significance was set at $p \leq 0.05$. The statistical power was greater than 0.85 for the sample size of 52 participants.

Results

▶ **Table 1** shows the mean values of hamstring muscle extensibility evaluated by inclinometer (used as the gold standard) and the WIMU system. The ICCs for validity were very close to 1 (0.999 in both legs), although a significant systematic bias was observed between both systems and legs. However, the differences between the 2 measurement tools were lower than 0.5 degrees in both legs, and the effect sizes were trivial. Random error and standard error of the estimate were ≤ 0.05 and ≤ 0.5 degrees in both the left and right legs, respectively.

▶ **Fig. 3** represents the results of the regression analysis, linear regression equation and R^2 representing the amount of shared variance of the 2 variables that were accounted for in the regression analysis for the (A) left leg and (B) right leg.

The test-retest reliability of the WIMU® system assessments was excellent in both legs, and there were higher CVs for the inclinometer than the WIMU® system (mean: 0.36 % vs 0.01 %) with similar and excellent ICCs (mean: 0.985) for both legs. Systematic biases were nonsignificant and very close to 0, and the standard error of the estimate averaged 0.25 degrees (▶ **Table 2**).

Discussion

The purpose of the current study was to analyse the concurrent validity and test-retest reliability of a new device for evaluating hamstring muscle extensibility in the PSLR test. The major findings of this study were that the WIMU® system had strong concurrent validity compared with the ISOMED inclinometer as well as excellent test-retest reliability for evaluating hamstring muscle extensibility in the PSLR.

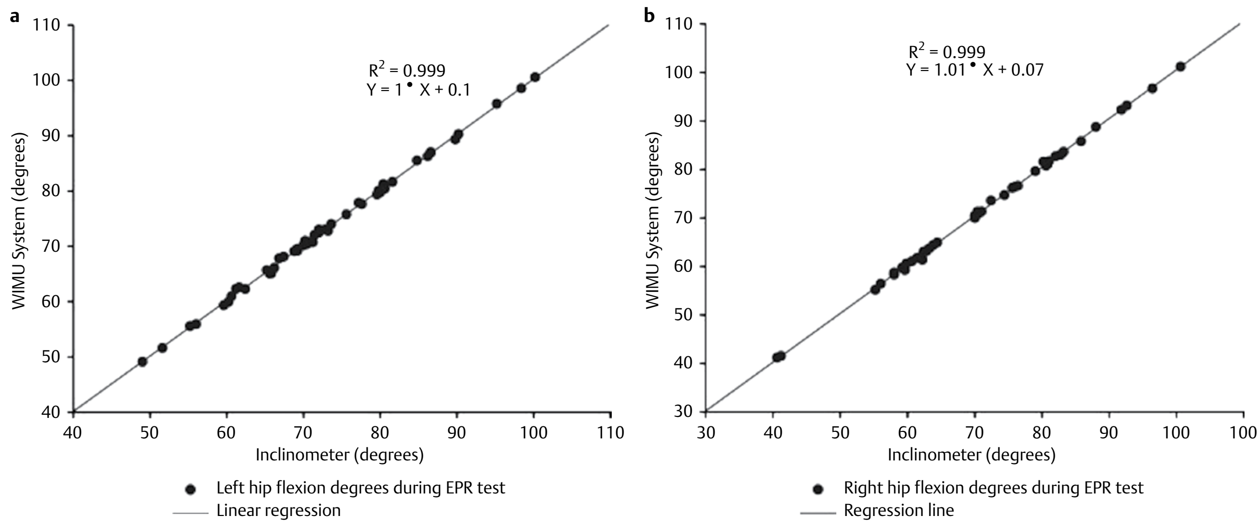
With respect to the WIMU® validity assessments, there was only a systematic difference (bias) lower than 0.5 degrees, and there was a random error equal to or lower than 0.05 degrees as well as a standard error of the estimate lower than 0.5 degrees. Moreover, the ICC and R^2 between both systems was 0.999. Based on the results, the WIMU® had higher validity values than in previous studies. Charlton, Mentiplay, Pua, et al. [6] reported that a smartphone application displayed excellent validity compared to 3-dimensional motion analysis systems. However, these authors reported ICCs < 0.93 for hip flexion movement. Boyd [4] evaluated the measurement properties of a hand-held inclinometer during the straight leg raise. This author reported mean difference scores between hand-held and digital inclinometers (~1.5 °); however, we found the mean difference was lower than 0.5 ° between the inclinometer and the WIMU® system.

The test-retest reliability (i. e., consistency or stability of measurements) of the hamstring muscle extensibility test is critically important to ensure that observed differences in the hip flexion angles between testing sessions are not due to systematic bias, such as a learning effect or fatigue, or due to random error in response to possible biological or mechanical variation [1]. The test-retest systematic bias was lower than 0.6 °, and the CV of the measurements obtained using the WIMU® was 0.01. It has been reported that an analytical goal for the CV of ≤ 10 % might be an indicator of acceptable agreement. The ICC agreement results of the WIMU® system between days one and 2, in the current study, indicated the high reliability for this system in evaluating hamstring muscle extensibility during the PSLR test.

▶ **Table 1** Concurrent validity of the inclinometer and the WIMU® system for measuring hamstring muscle extensibility in the SLR test.

	Left leg	Right leg
Inclinometer ISOMED (95 % CI), (°) *	72.68 ± 11.22† (69.56–75.81)	70.42 ± 12.32† (66.99–76.85)
WIMU System (95 % CI), (°) *	72.89 ± 11.25 (69.76–76.03)	70.85 ± 12.39 (67.40–74.30)
Systematic bias, (°)	− 0.21 ± 0.42	− 0.42 ± 0.34
Random error, (°)	0.05	0.04
SEE, (°)	0.43	0.34
ICC (95 % CI)	0.999 (0.998–1)	0.999 (0.983–1)

* Mean values ± standard deviations; CI = confidence interval; SEE = standard error of the estimate; ICC = intraclass correlation coefficients; † the WIMU system gave higher values than the inclinometer (p ≤ 0.001)



▶ **Fig. 3** Correlation between the hip flexion degrees evaluated with the inclinometer and the WIMU® system in the PSLR test. The solid line shows the linear regression fit of the 2 systems with the associated regression equation. Data points represent individual hip flexion degrees in the PSLR test; **a** left leg and **b** right leg.

▶ **Table 2** Test-retest reliability of the inclinometer and the WIMU® system for measuring hamstring muscle extensibility in the SLR test.

	Inclinometer		**WIMU system**	
	Left leg	**Right leg**	**Left leg**	**Right leg**
Test, (°) *	72.21 ± 1.56 (69.07–75.35)	70.51 ± 1.66 (67.17–73.86)	72.88 ± 1.58 (69.70–76.06)	70.93 ± 1.67 (67.57–74.29)
Retest, (°) *	71.99 ± 1.57 (68.83–75.14)	70.28 ± 1.79 (66.69–73.88)	72.27 ± 1.57 (69.11–75.43)	70.73 ± 1.80 (67.11–74.35)
Systematic bias, (°)	0.22	0.23	0.59	0.20
SEE, (°)	0.12	0.31	0.19	0.31
ICC (95 % CI)	0.997 (0.994–0.998)	0.984 (0.972–0.991)	0.991 (0.982–0.995)	0.984 (0.972–0.991)
CV, (%)	0.71	0.01	0.01	0.01

* Mean values ± standard error; CI = confidence interval; SEE = standard error of the estimate; ICC = intraclass correlation coefficients; CV = coefficient of variation

This study has several limitations. The first is that the validity and reliability of the WIMU® system has been evaluated only in the passive straight leg raise test. In the scientific literature, other angular tests such as the active straight leg raise [25, 37], passive knee extension [25, 26, 33, 34] and active knee extension tests [8, 25, 30] have been used to evaluate hamstring muscle extensibility. Future studies are necessary to evaluate the validity and reliability of WIMU® system in these tests.

A second limitation was that in the current study the validity and reliability was examined only in a population of young, active and healthy males. Therefore, other studies are necessary to evaluate the validity and reliability in other populations with limited hamstring extensibility or pathology.

In conclusion, the results of the current study showed that the WIMU® system is a valid, accurate and reliable device for evaluating hamstring muscle extensibility in the PSLR test. Moreover, with respect to the practical implications, our findings showed that this system could be used interchangeably with the ISOMED Unilever inclinometer. However, because the ISOMED Unilever inclinometer has an accuracy of ± 2 ° (lower than the WIMU® system) and the WIMU® is portable and transfers the data directly to a personal computer, this device could be easier and more accurate for physicians, physiotherapists, coaches or researchers to use in evaluating hamstring muscle extensibility during the PSLR test.

Conflict of interest

The author has no conflicts of interest to declare.

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