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Reliability of transverse plane pelvic alignment measurement during the bridge test with unilateral knee extension

Confiabilidade da mensuração do alinhamento pélvico no plano transverso durante o teste da ponte com extensão unilateral do joelho

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Abstract

Background: The bridge test with unilateral knee extension evaluates the stability of the trunk and pelvis. The evaluation of this stability can contribute to the understanding of the occurrence of musculoskeletal injuries. **Objectives:** To investigate the intra- and inter-rater reliability of a qualitative analysis and intra-test reliability of a quantitative analysis of transverse plane pelvic alignment during the bridge test with unilateral knee extension. **Method:** Thirty participants (24.73±4.24 years old) were tested. The qualitative analysis was conducted by asking two raters to judge the transverse plane pelvic alignment and its reliability was assessed with the weighted kappa coefficient (k_w). The quantitative analysis was conducted by measuring the greatest pelvic tilt angle in transverse plane and its reliability was assessed by use of the intraclass correlation coefficient (ICC); the mean change, which was evaluated using 95% confidence interval of the mean difference (95%CI $\bar{d}$) and Bland-Altman plot; and the quantification of measurement variability, which was assessed using standard error of measurement (SEM) and the coefficient of variation of the typical error (CV_{TE}). In addition, the minimal detectable change (MDC_{95}) was determined. **Results:** The intra-rater reliability ranged from fair to moderate (k_w=0.32 to 0.58) and the inter-rater reliability was substantial (k_w=0.80). The intra-test reliability was excellent (ICC=0.82), the 95%CI $\bar{d}$ ranged from -0.51° to 1.99°, the SEM was 2.38° and the CV_{TE} was 28.75%. The MDC_{95} was 6.59°. **Conclusions:** The inter-rater reliability was greater than the intra-rater reliability; the intra-test reliability was excellent and showed no systematic or random error.

Keywords: pelvis; bridge test; core stability; reliability; physical therapy.

Resumo

Contextualização: O teste da ponte com extensão unilateral do joelho avalia a estabilidade de tronco e pelve. A avaliação dessa estabilidade pode contribuir para o entendimento da ocorrência de lesões musculoesqueléticas. **Objetivos:** Investigar a confiabilidade intra e interexaminador de uma análise qualitativa e a confiabilidade intrateste de uma análise quantitativa do alinhamento pélvico no plano transverso durante o teste da ponte com extensão unilateral do joelho. **Método:** Foram avaliados 30 participantes (24,73±4,24 anos). A análise qualitativa foi realizada pelo julgamento do alinhamento pélvico no plano transverso por dois examinadores, e sua confiabilidade determinada pelo Coeficiente Kappa Ponderado (k_w). A análise quantitativa foi realizada pela medida do maior ângulo de desalinhamento pélvico no plano transverso e a confiabilidade determinada pelo Coeficiente de Correlação Intraclasse (CCI); pela análise da mudança na média dos dados, utilizando-se o intervalo de confiança de 95% da média da diferença (IC95% $\bar{d}$) e método de Bland-Altman; pelo dimensionamento da variabilidade entre medidas, considerando-se o erro-padrão da medida combinado (EPM) e coeficiente de variação do erro típico (CV_{ET}). Além disso, verificou-se a mudança mínima detectável (MMD_{95}). **Resultados:** A confiabilidade intraexaminador variou de razoável a moderada (k_w=0,32–0,58) e a confiabilidade interexaminador foi substancial (k_w=0,80). A confiabilidade intrateste foi excelente (CCI=0,82) e apresentou o IC95% $\bar{d}$ de -0,51° a 1,99°, EPM de 2,38° e o CV_{ET} de 28,75%. O MMD_{95} foi de 6,59°. **Conclusões:** O índice de confiabilidade interexaminador foi superior ao intraexaminador, a confiabilidade intrateste foi excelente e não apresentou erro sistemático e aleatório.

Palavras-chave: pelve; ponte; estabilização central; confiabilidade; fisioterapia.

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Introduction

The presence of an adequate core stability maximizes body function by integrating proximal and distal segments in strength generation, balance and movement[1-3]. This stability is related to the control of trunk over pelvic movements in response to internal and external pertubations[1]. Studies have demonstrated the influence of trunk and pelvic characteristics in the occurrence of low back pain[4,5], knee[4, 6-8] and ankle[4,8] injuries. Clinical assessment of trunk and pelvic stability during tests that challenge the musculoskeletal system can be useful to identify patients who require rehabilitation and to monitor treatment progress[9-11]. To be practical and useful, these tests need to be simple, valid and reliable[11]. Therefore, clinical tests with appropriate clinimetric properties are necessary in the assessment of trunk and pelvis because of the importance of these structures in integrating the proximal and distal parts of the body as well as in preventing musculoskeletal injuries.

Several tests can be used in the evaluation of trunk and pelvic stability. Tests that simulate tasks of higher demand can better represent the patient's muscle performance in usual activities[12]. Hip bridge is described as a clinical test used to evaluate lumbo-pelvic stability in patients with low back pain[13]. This test, when progressed to an associated knee unilateral extension, is used to evaluate muscle resistance[11]. Moreover, the bridge with unilateral knee extension is also used as an exercise for treating patients with low back pain[14-16] and for preventing injuries in athletes[15,17]. Thus, the bridge test with unilateral knee extension evaluates trunk and pelvic stability in a task of high demand that can reflect the patient's pelvic control.

In the bridge test with unilateral knee extension, it is possible to identify imbalances, asymmetries and compensations performed by the individual for the maintenance of trunk, pelvic and lower limbs alignment[13]. Transverse plane pelvic evaluations during this test can identify the capacities of the trunk and pelvis to withstand the demands of rotational torques generated by knee extension[11]. During the execution of this test, studies have identified an increased electromyographic activity of the hip and spine extensors, in addition to the contralateral external oblique and ipsilateral internal oblique to the lower limb in elevation[11,18]. The identification of a pelvic tilt on the transverse plane might suggest low passive and active resistance torque of the abdominal obliques. This evaluation might contribute to the understanding of musculoskeletal injuries in the lower limbs that are commonly associated to excessive movements in the transverse plane such as the excessive hip internal rotation observed in patients with patelofemoral pain syndrome[19].

In spite of the clinical relevance, there is no documentation on the clinimetric properties of the bridge test with unilateral knee extension. The reproducibility of a test informs about its consistency and, thus, allows the safe use of the data collected both in clinical practice and research[20]. Several statistical approaches are indicated in the literature for the assessment of the reproducibility of a test. The use of each test depends on, among other factors, the characteristic of the variable being measured[21]. In this view, reliability of ordinal variables is commonly assessed using the weighted kappa coefficient[21,22]. On the other hand, there is less consensus in literature on the use of reproducibility tests for continuous variables[21]. However, there is an indication for the use of tests that address the relative reliability, in other words, the level in which the participants measurements maintain their position within the sample among repeated measures, as well as absolute reliability, which indicates the level to which repeated measures vary for the participants[21,23]. Among the tests that measure relative reliability, intraclass correlation coefficient (ICC) is cited as the most indicated[21,24]. Absolute reliability can be analyzed through indexes that verify the changes in data mean such as 95% confidence interval of the mean difference between measures (95%CI $\bar{d}$) and the Bland-Altman plots[23,24]. Absolute realiability can also be analyzed by indexes that verify the measure variability, such as the standard error of measurement (SEM) and the coefficient of variation of the typical error (CV_{TE})[23,24]. Another attribute of a measure is the clinically significant difference that allows a better interpretation of the results of an instrument in relation to what they may clinically represent[25]. Among these indexes, the minimal detectable change (MDC) indicates the minimal amount of change that is not probably due to the random variation of a measure[25]. Therefore, prior to the use of the bridge test with unilateral knee extension in the assessment of transverse plane pelvic alignment, it is necessary to verify its reliability through statistical approaches relevant to the characteristics of the data collected.

The bridge test with unilateral knee extension is a simple clinical tool to evaluate core stability and contributes to the understanding of the mechanisms of musculoskeletal injuries associated to abnormal movement patterns in the transverse plane. Because of the importance of the clinimetric properties of a test, this study aimed to investigate the bridge test with unilateral knee extension in the assessment of pelvic transverse plane alignment using two analyses: (1) intra- and inter-rater reliability of a qualitative analysis for judging pelvic alignment and (2) intra-test reliability of a quantitative measurement of pelvic alignment.

Method

Participants

Thirty two participants (22 men and 10 women) were recruited by convenience at the university community. The inclusion criteria were: age between 18-35 years, absence of low back pain or musculoskeletal injuries in lower limbs. The exclusion criteria was the presence of cramps or pain that prevented test continuity, as well as the examiner's impossibility to visualize the reflexive markers, placed on the participant's anterior superior iliac spines during testing. Participants' characteristics are shown on Table 1. Two participants were excluded from this study, one due to the presence of hamstrings' cramps and the other due to the difficulty in visualizing the reflexive markers during test performance. An additional participant dropped out of the study and therefore, the intra-rater reliability of the qualitative analysis and the intra-test reliability of the quantitative analysis were performed on 29 participants. The inter-rater reliability of the qualitative analysis was performed with the data collected on the first day and included 30 participants. Among those who participated in the study, 17 (56.7%) performed physical activity regularly, and 13 (43.3%) were sedentary.

This study was approved by the Ethics in Research Committee of the Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, MG, Brazil (Protocol n° ETIC 280/09).

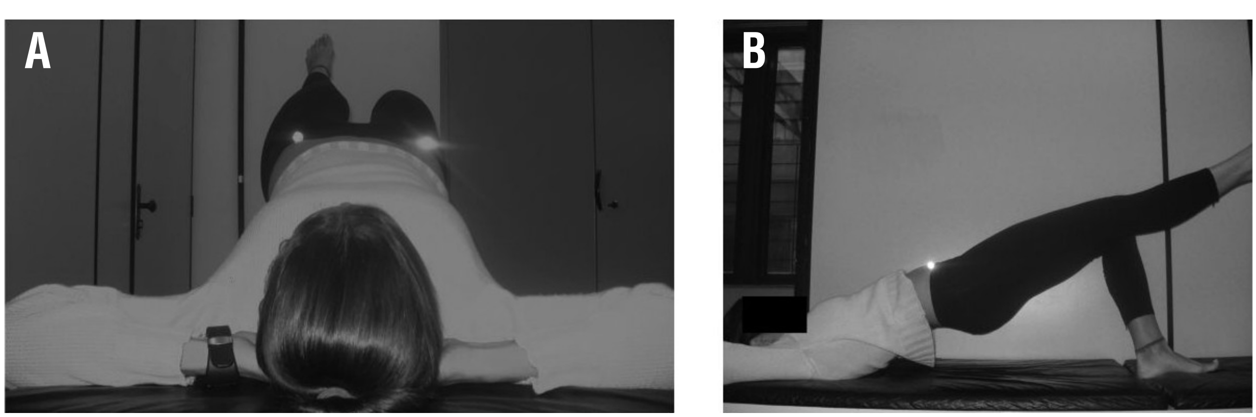
Procedures

After signing the free informed consent, participants answered to a demographic characteristics questionnaire and if they practiced physical activity regularly. Two data collections were performed with each participant within an one week interval. In each data collection, a physical therapist, previously trained in a pilot study, placed a reflexive marker of 10 mm on each participant's anterior superior iliac spine to aid in the identification of these structures during analysis. Each participant was positioned in supine position, with hands placed under the head, with hips and knees flexed in a self-selected range of motion and with the feet soles close together and supported on the assessment bed. The self-selected knee flexion range of motion was used to guarantee that participants were comfortable during testing and that the position selected was the most adequate to each individual's anthropometric characteristics. The degree of knee flexion adopted on the first day was measured for each participant to guarantee that the same joint position was kept in the second collection day. Participants were oriented to raise the pelvis from the assessment bed and perform the extension of one knee, maintaining the trunk, hip and lower limb on a straight line at the same level as the thigh of the opposite side (Figure 1). Before beginning data collection, participants performed the test once with the purpose of familiarization. During data collection, the test position was held for 10 seconds and then the test was repeated with the other lower limb. Each participant determined the order of the lower limbs to be tested. Instructions for the execution of the test was standardized and delivered by a physical therapist with experience in conducting these test in clinical evaluations.

Table 1. Participants' characteristics presented as mean and standard deviation.

Characteristics	(n=30)
Age (years)	24.7 (4.2)
Weight (Kg)	66.9 (10.0)
Height (m)	1.70 (0.09)
BMI (Kg/m^2)	23.0 (1.9)

BMI=Body Mass Index.



(A) Rater view of participant pelvic transverse plane; (B) Lateral view of the participant during the test.

Figure 1. Participants position during the assessment of pelvic alignment.

The qualitative analysis was performed by two physical therapist raters, with distinct clinical practice experience (rater 1: two years; rater 2: six years). Both raters were experienced in conducting this test in clinical practice but not in using the proposed classification. Thus, before beginning data collection, raters performed training sessions on ten volunteers. During the test, the examiners were positioned behind the participants' head, with the eyes leveled with the participant's pelvis. These raters only judged the test; they did not provide the instructions for the test or the positioning of the volunteers. The evaluation consisted in judging the maintenance of an adequate alignment of the pelvis through the observation of the position of the anterior superior iliac spines in a line parallel to the assessment bed on a transverse plane. When a misalignment was observed, the rater classified the amount that the anterior superior iliac spine dropped in relation to the opposite side. In order to assess this displacement, the rater judged the angle formed between the line that ran from each reflective marker and the horizontal line parallel to the assessment bed. This angle was judged qualitatively in relation to the maximal possible excursion of the anterior superior iliac spine of the raised lower limb, from an horizontal line parallel to the assessment bed to the point at which the participant touched the assessment bed (Figure 2). The greater misalignment observed during the 10 seconds in which the participant remained with the knee extended was classified as no pelvic tilt, a slight pelvic tilt (0-25% of the possible excursion of the tilt), a moderate pelvic tilt (25-75% of the possible excursion of the tilt) or an accentuated pelvic tilt (>75% of the possible excursion of the tilt). Blinding between raters was performed by not allowing one rater to have access the other rater's data[22]. Additionally, within rater's blinding was performed as they did not have access to their previous judgment and the participants' order was randomized to reduce memory effect[22].

The test performed during the qualitative assessment was registered with a digital camera (SC-D385, Samsung®, China) placed on a tripod at a distance of 80 cm of the extremity of the assessment bed. The camera on the tripod was aligned with the aid of an inclinometer (Mundo Sat, Brazil), to be parallel with the floor and with height determined by each participant anthropometric characteristics in a way that the plane for image capture would stay orthogonal to pelvic transverse plane during the test. This position allowed the pelvis to be centralized in the image captured during the test. Following imaging capture, a two-dimensional (2D) analysis of movement was performed using the program *SIMI MotionTwin®* (*SIMI Reality Motion Systems*, Germany) to determine the greater degree of pelvic tilt. This represented the greater inclination achieved during the 10 seconds of the test between the line of the anterior superior iliac spines and a horizontal line on pelvic transverse plane. A calibration of the analysis software was conducted prior to data analysis, informing the system 30 cm distance, pre-determined in the test lab environment. The angle of pelvic tilt was determined by the intersection of the straight line that passed in the centre of each reflexive marker with the horizontal determined by the program. The procedure of identification of the greater pelvic misalignment, using this program, was conducted by two raters. On a pilot study in which ten videos were analyzed in two different occasions with one week interval, these two raters were found to have excellent intra- and inter-rater reliabilities ($ICC_{3,2}$=0.95 to 0.99). This procedure aimed to ensure a good reliability for the use of the program in a controlled situation.

Statistical analysis

Categorical data (no pelvic tilt, slight, moderate and accentuated pelvic tilt) were expressed regarding their overall frequency. Quantitative data of the degree of pelvic tilt was expressed in mean and standard deviation. Reliability data analysis was performed with data collected while the participant's dominant lower limb was supported on the assessment bed. The reliability analysis of the intra- and inter-rater qualitative assessments were performed by the calculation of weighted kappa coefficient, assigning incremental weight, in order to differentiate the weight of the disagreements, followed by its respectives 95% confidence intervals[20,22,26] The interpretation of weighted kappa was in accordance to Landis and Koch[27] (≤0, poor; 0.01-0.20, slight; 0.21-0.40, fair; 0.41-0.60, moderate; 0.61-0.80, substantial; 0.81-1.0, almost perfect). The reliability of the quantitative analysis was separated into absolute and relative reliabilities.

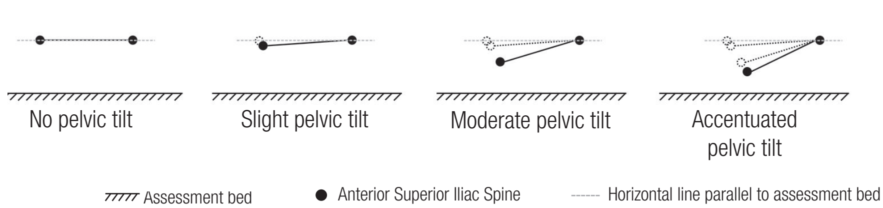


Figure 2. Rater's judgment of pelvic position on the qualitative analysis.

Relative reliability

Intra-rater reliability of the degree of pelvic tilt between the two sessions was determined using $ICC_{3,2}$ followed by their respective 95%CI[24]. The interpretation of the ICC was in accordance to Fleiss[28] (<0.40, poor reliability; 0.40-0.75, good reliability; >0.75, excellent reliability).

Absolute reliability

The verification of the occurrence or not of systematic or random changes in data mean was performed through the calculation of 95% confidence interval of the mean differences (95%CI $\bar{d}$) between the data collected on the two occasions and through the use of Bland-Altman plot[24,29,30]. The variability between the measures was also verified by combined standard error of measurement (SEM) and the coefficient of variation of the typical error (CV_{TE})[24].

Another attribute verified from the quantitative analyses was the minimal detectable change for the 95%CI (MDC_{95})[24,25]. Statistical analysis was performed using the software Stata/SE®, version 10.0 and the *Statistical Package for Social Sciences* (SPSS®), version 15.0. A level of significance (α) of 0,05 was used for all tests.

Results

Categorical data are presented on Table 2. Weighted kappa coefficient of the qualitative analysis were classified as fair for the intra-rater reliability of rater 1 (k_w=0.32; 95%CI=0.05 to 0.59); moderate for the intra-rater reliability of rater 2 (k_w=0.58; 95%CI=0.30 to 0.85) and substantial for the inter-rater reliability (k_w=0.80; 95%CI=0.68 to 0.92).

In the quantitative analysis the peak of pelvic tilt was 8.65±5.74º on the first collection day and 7.91±5.47º on the second collection day. The ICC for the analysis of greater degree of pelvic tilt between the two collection days was 0.82 (95%CI=0.65 to 0.91) showing an excellent intra-test reliability. In relation to the analysis of change in data mean, the 95% confidence interval of the mean difference (95%CI $\bar{d}$) were -0.51º to 1.99º. The Bland-Altman plot is presented on Figure 3. The statistical measures of variability demonstrated that the combined SEM was 2.38º, the CV_{TE} was 28.75%. The MDC_{95} was 6.59º.

Discussion

This study examined the intra- and inter-rater reliabilities of a qualitative analysis of judgment about transverse plane pelvic alignment during the bridge test with unilateral knee extension, as well as the intra-test reliability of a quantitative analysis of this alignment. Intra-rater reliability ranged from fair to moderate, and the rater with the shortest time of professional practice had lower reliability. This result might indicate that the reliability of the test is dependent on the rater's experience, despite prior training. In addition, the coefficients found in the qualitative analysis may have been influenced by the various possibilities of judgment (no pelvic tilt, slight, moderate and accentuated pelvic tilt) for a small range of motion on the transverse plane observed in the participants, which may have increased the chance of dissagrements between the evaluators[22]. Inter-rater reliability was found to be superior than the intra-rater reliability, indicating a higher agreement between raters at one point in time when compared to the agreement of one rater at different points in time. This fact may indicate that the examiner's judgment from different points in time may have suffered interference from a change that can be random or systematic, i.e. the chance of disagreement on two different days may have been influenced, for example, by the excessive amount of categories or by a learning effect from the evaluators[24,32,31]. This interpretation becomes speculative, since the kappa index does not allow differentiation between the random and systematic errors[31]. One factor that might have contributed positively to the results of qualitative analysis was the use of reflective markers due to the better visualization of the bony prominences.

The quantitative analysis through the use of ICC showed excellent intra-test reliability demonstrating the consistency of the test in measuring pelvic alignment in the transverse plane through a 2D analysis program. The presence of systematic error was not confirmed since zero was included in the 95%CI $\bar{d}$ and the points were symmetrically distributed around the zero on the Bland-Altman plot (Figure 3)[29,33]. The

Table 2. Categorical data distribution and frequency (no pelvic tilt, slight pelvic tilt, moderate pelvic tilt, accentuated pelvic tilt).

Category	Rater 1	Rater 2	Rater 1	Rater 2
	Day 1 (n=30)	Day 1 (n=30)	Day 2 (n=29)	Day 2 (n=29)
No pelvic tilt	2 (6.67%)	3 (10.00%)	1 (3.45%)	1 (3.45%)
Slight pelvic tilt	8 (26.67%)	12 (40.00%)	11 (37.93%)	12 (41.38%)
Moderate pelvic tilt	17 (56.67%)	10 (33.33%)	14 (48.28%)	12 (41.38%)
Accentuated pelvic tilt	3 (10.00%)	5 (16.67%)	3 (10.34%)	4 (13.79%)

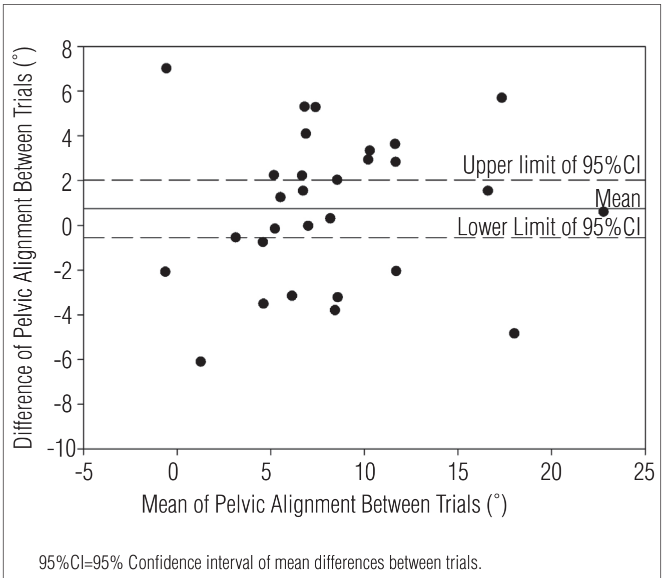


Figure 3. Bland-Altman plot for pelvic alignment.

Bland-Altman plot also demonstrated an absence of random error as there was no tendency of an increase or decrease in the dispersion of points with the increase in mean values[29,33]. The absence of systematic error indicates that the volunteers did not perform the test better or worse on the second day and were not influenced by factors such as change in behavior and learning effect. The absence of random error indicates that a change did not occur because of the method or analysis used[24]. The measure demonstrated a small SEM and therefore, it is expected that a measure conducted on the same person at different points in time would have a variation of 2.38º that is related to the measure error rather than to an improvement or worsening of the patient in the test[23,24]. One of the advantages of SEM is that it is highly independent of the population in which it was determined and can be considered as a fixed characteristic of a measure[34]. In addition, by informing the variability of a measure in percentage, the CV_{TE} found can be used for comparisons with other independent measures or scales, facilitating the comparison with other studies[24,32].

The MDC_{95} found indicates that a change in pelvic alignment between the two occasions above or below 6.59° the original measure has a chance of less than 5% to be due to random variation or a random error of measure[25]. Thus, this index can be used to indicate whether a real change has occurred in pelvic alignment in a particular patient over time[25]. The MDC_{95} is one of the indexes that infer about clinically significant differences. For a better understanding of this attribute, it is recommended that future studies consider the combination of MDC with the minimal clinically important difference (MCID), the index that takes into account the individual self-report, for example, if the observed change is important for the patient or physical therapist[24,25].

A comparison between the reliability coefficients found in this study with other studies is limited as this is the first study to examine the pelvic alignment in the transverse plane during the bridge test with unilateral knee extension. Other studies have investigated similar tests that intended to assess core stability. Tidstrand and Horneij[13] investigated the reproducibility of the *unilateral pelvic tilt* test, in which the participant elevated the pelvis from the assessment bed with one leg supported and the other elevated, with the hip and the knee flexed to 90º. This test was judged to be positive if the patient was unable to maintain the position, or negative, if the patient was able to do it. The *unilateral pelvic tilt* for maintaining hip and knee flexed probably generates a lower rotational torque on the pelvic transverse plane than the bridge test with unilateral knee extension. In addition, although the test had less categories for judgment than in this study, the study demonstrated an inter-rater reliability coefficient classified, according to Landis and Koch[27], as moderate to substantial (k=0.47 to 0.61), while the reliability found in the current study was substantial (k_w=0.80). However, methodological differences between the aforementioned study and the current do not allow comparison between reliability coefficients. Schellenberg et al.[11] investigated the intra-test reliability of a measure of fatigue time on a supine bridge test. To perform this test the volunteer elevated the hip and if he could stay in this position for two minutes then he was requested to extend the knee of the dominant leg. The time to fatigue was shown to have good reliability, determined by a strong correlation coefficient (r=0.84). Although similar to the bridge test with unilateral knee extension, this study did not provide similar analysis, since it evaluated the core stability through time until fatigue.

The results of this study can be generalized to active and sedentary young adults. The software used for quantitative analysis are still uncommon in clinical practice. However, it is cheaper when compared to three-dimensional motion analysis systems and its use could facilitate research and monitoring of patients' evolution. A limitation of this study was the number of possible judgment classifications within the qualitative analysis, which may have restricted the identification of larger intra-rater reliability coefficients. Future studies on clinimetric properties of the bridge test with unilateral knee extension should consider a smaller number of judgment classifications of the qualitative analysis, as well as the investigation of different populations such as patients with low back pain and athletes. In addition, the test has other variables that were not the aim of this study, that may contribute to the evaluation of core stability, such as the analysis of other anatomical planes and the quality of the test execution, such as the presence or absence of muscle fibrillation.

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