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Validity and reliability of tape measure in the assessment of leg length discrepancy

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The objectives were determining the validity and reliability of tape measure compared with computed tomography (CT) scanogram in assessing leg length discrepancy, determining the interrater reliability for investigators with different levels of experience, and detecting the relation and effect of body mass index (BMI) on tape measure error. Twenty four participants with leg length discrepancy were investigated. Their mean±SD age, mass, and height were 30.25±8.9 y, 78.42±11.48 kg, and 1.68±0.08 m, respectively. Discrepancy was assessed both radio graphically using CT scanogram and clinically using tape measurement. Each participant was assessed clinically by two therapists. Pearson correlation coefficient (r) was used to assess tape measure validity. Intraclass correlation coefficient (ICC) and mean difference detected by paired t-test with their 95% confidence intervals were used to assess tape measure reliability. Pearson correlation coefficient and one way ANOVA were used to detect the relation and effect of BMI on tape measure error. Tape measure validity for discrepancy assessment was r= 0.90 between therapist 1 and CT scanogram, r=0.89 between therapist 2 and CT scanogram, and r=0.96 between both therapists. Regarding tape measure reliability compared with CT scanogram, it was ICC=0.89 with mean difference=0.45 mm for therapist 1 and ICC=0.88 with mean difference=0.91 mm for therapist 2. Excellent interater reliability ICC=0.96 with mean difference=0.45 mm was also found. No correlation (r=0.02, p=0.92) and insignificant effect of BMI on tape measure error (p=0.75) were found. Tape measure is valid and reliable compared with CT scanogram for discrepancy measurement. Therapist's level of experience and participants' BMI have no effects on tape measure reliability.

Keywords: leg length discrepancy; tape measure; computed tomography scanogram; reliability.

INTRODUCTION

Leg length discrepancy (LLD) is a physical problem associated with a variety of orthopedic disorders and biomechanical changes (Sanhudo and Gomes, 2014). Successful treatment of LLD requires careful clinical assessment and diagnosis (Gogia and Braatz, 1986). LLD can be measured either radiographically or clinically. Radiography is considered the most accurate and standard method to assess LLD and evaluate the clinical methods validity (Brady et al., 2003; Harris et al., 2005; Middleton-Duff et al., 2000).Various radiographic methods are used to assess LLD; teleroent genography, orthoroentgenography, scanography, and computed tomography (CT) scanogram (Brady et al., 2003). Additionally, three-dimensional ultrasonography and magnetic resonance imaging have also been used (Gurney, 2002). Computed tomography scanogram is the preferable modality to measure LLD as it has a high sensitivity to detect even one mm LLD and produces a radiation dose 80% less than orthoroentgenogram (Aaron et al., 1992; Carey et al., 1987). Moreover, CT scanogram use, especially in patients with knee flexion deformities was recommended (Sabharwal and Kumar, 2008). However, CT scanogram still possesses some disadvantages (Jamaluddin et al., 2011;

Neelly et al., 2013). These include the risk of radiation exposure, unavailability of its equipment to many therapists, and its high cost. Moreover, the time needed for patient's referring and imaging completion could postpone the management (Jamaluddin et al., 2011; Neelly et al., 2013). The clinical methods used to assess LLD include indirect (lift blocks) and direct (tape measure) methods. The indirect method refers to placing blocks of different heights beneath the short leg until leveling of the pelvis occurs (i.e. both posterior superior iliac spines become at the same level) (Gogia and Braatz, 1986; Middleton-Duff et al., 2000 Gurney, 2002; Brady et al., 2003; Harris et al., 2005; Sabharwal & Kumar, 2008; Neelly et al., 2013). The height of these blocks determines LLD magnitude. The direct method refers to using a tape measurement to measure the lower limb length between two landmarks (usually, anterior superior iliac spine and medial malleolus) from supine lying position (Gogia & Braatz, 1986; Middleton-Duff et al., 2000; Gurney, 2002; Brady et al., 2003; Harris et al., 2005; Sabharwal & Kumar, 2008; Jamaluddin et al., 2011; Neelly et al., 2013). The difference in length between both limbs refers to LLD magnitude. Tape measurement is such modality that provides direct, easy, quick, costless, and radiation free measurement of the lower limb length hence assessment of LLD. However, a great debate surrounds the accuracy of tape measure for assessing LLD (Gurney, 2002; Brady et al., 2003; Sabharwal and Kumar, 2008). Previous researchers (Gurney, 2002; Brady et al., 2003; Sabharwal & Kumar, 2008; Neelly et al., 2013) reported that tape measure accuracy may be limited by several factors. These factors include difficulty in palpating bony landmarks especially in case of obesity or thighs circumference difference, iliac crests un-leveling, unilateral deviations in the long axis of the lower limb (e.g. genu valgum), asymmetrical position of the umbilicus, and joint contractures. Others (Gogia and Braatz, 1986; Beattie et al., 1988; Beattie et al., 1990; Middleton-Duff et al., 2000; Harris et al., 2005; Terry et al., 2005; Jamaluddin et al., 2011; Neelly et al., 2013) found it to be valid and reliable modality in measuring lower limb length or assessing LLD in comparison to other radiographic modalities. To the best of our knowledge, no studies were conducted to investigate the validity and reliability of tape measure in assessing LLD compared with CT scanogram. The conducted ones (Gogia and Braatz, 1986; Beattie et al., 1988; Neelly et al., 2013) investigated the accuracy of tape measurement in measuring the lower limb length not for assessing LLD. Others (Gogia & Braatz, 1986; Beattie et al., 1990; Terry et al., 2005) assessed the validity of tape measure compared with radiographic modalities other than CT scanogram. Only one study by Jamaluddin et al., (2011) assessed the validity of tape measuring in assessing LLD compared with CT scanogram. However, they assessed the validity using a technique of recording the tape reading to a nearest five mm. This technique is less accurate than one mm technique and could be a source of error when assessing tape measure validity and reliability (Neelly et al., 2013). Thus, the current study aimed to assess the validity of tape measuring to the nearest one mm in comparison with CT scanogram in assessing LLD. Additionally, the previous studies (Gogia and Braatz, 1986; Harris et al., 2005; Jamaluddin et al., 2011; Neelly et al., 2013) assessed the interrater reliability by investigators with the same level of experience. Consequently, the second aim was to determine the interrater reliability of investigators with different levels of experience. Moreover, no studies were conducted to assess the effect of body mass index (BMI) on tape measure accuracy. Consequently, the correlation and effect of BMI on tape measuring error were assessed in the current study. It was hypothesized that tape measure is valid and reliable compared with CT scanogram in assessing LLD. Additionally, there were no influences for therapist's level of experience and participant's BMI on tape measure reliability.

MATERIALS AND METHODS

Participants

Twenty four adult participants (10 males and 14 females) with LLD were included in the study. The ranges of participants' age, mass, height, and BMI were 18-44 y, 55-92k g, 1.56-1.83 m, and 18.5-35 kg/m^2, respectively. Exclusion criteria included hip dislocation, limited range of motion for hip adduction or abduction greater than 15° and asymmetrical knee deformity (Jamaluddin et al., 2011). Participants were also excluded if they had any serious medical condition that may affect the lower limb function or prevent the participant from exposure to radiation. The sample size was estimated based on the power analysis. Power analysis (using G*power 3.0.10) revealed that 24 participants were sufficient to produce a power level of 80% with a detected alpha level of 0.05

and an effect size of 0.44.The study procedure was explained for participants. Written informed consents were collected from them prior to the study. The study was performed in accordance with the Declaration of Helsinki and approved by the Research Ethical Committee of Faculty of Physical Therapy, Cairo University, Egypt. NO: P.T.REC/012/00809.

Procedure

The magnitude of LLD for each participant was measured clinically by two physical therapists. Therapist 1 had an experience of 15 years in the field of physical therapy and therapist 2 had an experience of three years. The two therapists measured the length of the lower limb using standard tape measures marked in 1mm increments. The participant was positioned in supine and his position was checked to maintain leveling of both anterior superior iliac spines. Participant was instructed not to move during measurement. The limb length was measured to the nearest one mm from the anterior superior iliac spine to the distal tip of the medial malleolus. Each limb length was measured three times and the mean value was recorded as the limb length. The difference in length between both limbs was recorded as the magnitude of LLD for each participant. Both therapists assessed LLD magnitude for each participant in a sequential manner in the same day. Each therapist measured and recorded his measurement while the other therapist was outside the room. The discrepancy was also radiographically assessed using CT scanogram. The CT scans were captured at a local hospital by a radiologist, using GE Bright speed™ Edge 8-slice CT scanner (GE Yokogawa Medical Systems, Ltd. Tokyo, Japan). The participant was positioned in supine with leveling of both anterior superior iliac spines, extending both knees and keeping neutral ankles posture. An anteroposterior scout scanogram of the lower limbs was captured. The limb length was assessed by measuring the distance between the anterior superior iliac spine and the medial malleolus. The difference in length between both limbs was recorded as the magnitude of LLD for each participant. After collecting the participants' data, the magnitude of tape measure error was calculated. Then, the data were classified according to the value of BMI into three equal groups of eight (normal, overweight, and obese). This classification was done to detect the relation and effect of BMI value on tape measure error.

Statistical analysis

All statistical measures were performed through SPSS v.20 (Armonk, NY: IBM Corp). Data were screened for normality using Shapiro-Wilk's normality tests. Once data were found not to violate the assumption, parametric analysis was conducted. Pearson (r) and Intra-class (ICC) correlation coefficients were calculated to detect the agreement between the measurements of both therapists and that of each therapist to the measurements of the CT scanogram. Paired t-test was conducted to detect any difference between the mean value of LLD measured by both therapists and that of each therapist compared with CT scanogram. Moreover, Pearson correlation coefficient was computed to detect the relation between BMI and tape measure error. In the current study, tape measure error refers to the absolute value of difference between CT scanogram and mean value of tape measure by both therapists. This difference was used as a representation to the magnitude of error produced by tape measurement in relation to CT scanogram. Finally, participants' data were classified by BMI into three equal groups of eight; Normal (BMI=18.5 to <25 kg/m^2), Overweight (BMI ≥25 to <30 kg/m^2), and Obese (BMI ≥30 kg/m^2).One way between subject ANOVA was used to detect the effect of BMI on tape measure error.

RESULTS

The measured variables included; LLD measured by CT scanogram; LLD measured using tape measurement by both therapists; tape measure error and BMI. The descriptive statistics for the measured variables were presented in table (1). Pearson correlation coefficient showed strong significant positive correlations between CT scanogram and first therapist measurements ($r=0.90$, $p< 0.01$), CT scanogram and second therapist measurements ($r=0.89$, $p< 0.01$), and both therapists' measurements ($r=0.96$, $p< 0.01$).

The results of ICC with 95% CI showed excellent agreement between both therapists' measurements and between scanogram and each therapist's measurements (Table 2). Paired t-test showed insignificant differences between the mean values of LLD measured by both therapists and that of each therapist compared with CT scanogram ($p> 0.05$). The mean differences calculated for each pair using paired sample t test were shown in table (2).

Table 1: Descriptive statistics for the measured variables

Variable	Mean	Standard deviation
CT scanogram measurement (mm)	14.16	6.01
Tape measure ;Therapist 1 (mm)	13.70	6.98
Tape measure; Therapist 2 (mm)	13.25	6.89
Tape measure error (mm)	2.54	1.56
BMI (kg/m^2)	27.41	4.73

Tape measure error= the absolute value of difference between CT scanogram measurement and the mean value of tape measure by both therapist, BMI= body mass index

Table 2: Reliability of tape measure, using intra class correlation coefficients (ICC) and mean difference detected by paired t-test and their 95% confidence intervals, to assess leg length discrepancy compared with computed tomography scanogram

Comparisons	ICC (95%CI)	Mean difference (95%CI)	p-value
CT vs. Tape measure of Therapist 1	0.89 (0.76- 0.95)	0.45(-0.81- 1.73)	0.46
CT vs. Tape measure of Therapist 2	0.88 (0.76- 0.95)	0.91(-0.37- 2.20)	0.15
Therapist 1 vs. Therapist 2	0.96 (0.92- 0.98)	0.45(-0.31- 1.23)	0.23

*Significant at alpha level <0.05

Pearson correlation coefficient showed a very weak insignificant positive correlation between BMI and tape measure error (r=0.02, p=0.92). One way ANOVA revealed insignificant effect of BMI on the mean value of tape measure error (F=0.29, p= 0.75) (Table 3)

Table 3: Descriptive statistics and one way Analysis of Variance (ANOVA) for the mean tape measure error (mm) of the Normal, Overweight and Obese participants with LLD

Groups	Mean ±SD of tape measure error in mm
Normal	2.68 ±1.55
Overweight	2.18 ±1.73
Obese	2.75 ±1.55
One Way Between Subject ANOVA	
F= 0.29	p= 0.75

*Significant at alpha level <0.05

DISCUSSSION

Successful management of LLD starts with its accurate assessment and measurement (Gogia and Braatz, 1986).A valid, reliable, accurate, and easy to be used tool is required to achieve this target. Consequently, the first purpose of the current study was to assess the validity and reliability of tape measurement compared with CT scanogram in the assessment of LLD. Considering tape measure validity, there were strong significant positive correlations between the three conducted comparisons (between CT scanogram measurement and each therapist's measurement, and between both therapists' measurements. Regarding tape measure reliability, the findings of the current study revealed an excellent agreement between CT scanogram and each of the first (ICC=0.89) and second (ICC=0.88) therapists' measurements. The findings of the current study are supported by previous researchers (Gogia & Braatz, 1986; Beattie et al., 1988; Beattie et al., 1990; Terry et al., 2005; Jamaluddin et al., 2011; Neelly et al., 2013). However, there are two main methodological differences between the current study and these previous studies. That the previous studies by Gogia and Braatz (1986); Beattie et al. (1988), and Neelly et al., (2013) assessed the validity and reliability of tape measure in measuring the lower limb length. However, the current study assessed the reliability of tape measure in assessing LLD. The second difference that our study compared tape measure with CT scanogram, however the previous studies compared tape measure with other radiological techniques. Beattie et al., (1990) assessed the reliability of a single tape measurement compared with mini-scanogram X-rays in assessing LLD. They found that the validity of tape measure (ICC) was 0.693.In addition, Gogia and Braatz (1986) assessed the validity of tape measure for measuring the lower limb length compared with slit scanography X-ray method using three sequential exposures centered over the hip, knee, and ankle. They found that the validity of tape measurement (ICC) was 0.99. The current study was different from that of Jamaluddin et al. (2011) they compared tape measuring method with CT scanogram in assessing LLD through recording the tape reading to the nearest five mm. However, in the current study the reading of tape was recorded to the nearest one mm to increase the accuracy of measurement and avoid introducing errors when assessing validity and reliability of tape measure. This less accurate measurement may be responsible for increasing the mean difference value 0.93 (-4.68 to 6.54) mm compared with that of the current study 0.45 (-0.81 to 1.73) mm. The second purpose of the current study was to assess the interrater reliability for two therapists with different levels of experience. The interrater reliability of tape measure to assess LLD was ICC=0.96. This finding was in accordance with those for Jamaluddin et al., (2011) who reported ICC=0.92, Neelly et al., (2013) found ICC=0.99, Gogia and Braatz (1986) reported ICC=0.99, and Terry et al., (2005) reported ICC=0.83. Moreover, paired t-test revealed that there is no significant difference in the mean value of LLD measured by both therapists. This implicates that the different levels of experience have no effect on the reliability of tape measure. This in turn confirms that tape measure is a simple tool that possesses high clinical relevance (Neelly et al., 2013). Previous researchers reported that obesity is a causative factor for introducing error when using tape measure to assess LLD (Gurney, 2002; Brady et al., 2003; Sabharwal and Kumar, 2008; Neelly et al., 2013). Obesity may prevent accurately localizing the bony landmarks and assessing the limb length and LLD using tape measure (Gurney, 2002; Brady et al., 2003; Sabharwal and Kumar, 2008; Neelly et al., 2013).Thus, the current study aimed to clarify if there was any relation between BMI and the reliability of tape measurement in assessing LLD. The current findings revealed that there was a very weak insignificant correlation between BMI and tape measure error. Additionally, the statistical analysis revealed that there was insignificant effect for BMI on tape measure error. Moreover, there was insignificant difference in the mean value of tape measure error among the three BMI groups (Normal, Overweight, and Obese). This indicates insignificant effect of the BMI on tape measure reliability. In the current study, the relation between tape measure error and BMI values up to 35 kg/m^2 was assessed. Additional studies are required to detect the implication of greater BMI values on the clinical and radiological methods of LLD measurement. Moreover, the validity of tape measure for investigators with different specialties in assessing LLD is required to be assessed.

CONCLUSION

Tape measure revealed its validity and reliability to assess LLD compared with CT scanogram. Participants' BMI and investigators' levels of experience have insignificant effects on tape measure reliability.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

All authors contributed equally in all parts of this study

REFERENCES

Aaron A, Weinstein D, Thickman D, Eilert R. 1992. Comparison of orthoroentgenography and computed tomography in the measurement of limb-length discrepancy. J Bone Joint Surg (Am) 74: 897-902

Beattie P, Isaacson K, Riddle DL, Rothstein JM. 1990. Validity of derived measurements of leg-length differences obtained by use of a tape measure. PhysTher 70: 150-157

Beattie P, Rothstein JM, Kopriva L. 1988. The clinical reliability of measuring leg length. Abstract Phys Ther 68:588.

Brady RJ, Dean JB, Skinner TM, Gross MT. 2003. Limb length inequality: Clinical implications for assessment and intervention. J Orthop Sports Phys Ther 33:221-234.

Carey RP, de Campo JF, Menelaus MB.1987. Measurement of leg length by computerised

tomographic scanography: Brief report. J Bone Joint Surg (Br) 69: 846-7.
Gogia PP, Braatz J H. 1986. Validity and reliability of leg length measurements. J Orthop Sports PhysTher 8: 185-188.
Gurney B. 2002. Leg length discrepancy. Gait Posture 15:195-206.
Harris I, Hatfield A, Walton J. 2005. Assessing leg length discrepancy after femoral fracture: Clinical examination or computed tomography? ANZ J Surg 75: 319-321.
Jamaluddin S, Sulaiman AR, Imran MK, Juhara H, Ezane MA, Nordin S. 2011. Reliability and accuracy of the tape measurement method with a nearest reading of 5 mm in the assessment of leg length discrepancy. Singapore Med J 52(9): 681-4.
Middleton-Duff T, George K, Batterham A. 2000. The reliability and validity of the 'Tape' and 'Block' methods for assessing anatomical leg length discrepancy. Physical Therapy in Sport 1(3): 91-99.
Neelly K, Wallmann HW, Backus CJ. 2013. Validity of measuring leg length with a tape measure compared to a computed tomography scan. Physiother Theory and Pract 29(6): 487-92.
Sabharwal S, Kumar A. 2008. Methods for assessing leg length discrepancy. Clin Orthop Relat Res 466 (12): 2910-22.
Sanhudo JAV, Gomes JLE. 2014. Association between leg length discrepancy and posterior tibial tendon dysfunction. Foot Ankle Spec 7(2): 119-126.
Terry MA, Winell JJ, Green DW, Schneider R, Peterson M, Marx RG, Widmann RF. 2005. Measurement variance in limb length discrepancy: clinical and radiographic assessment of interobserver and intraobserver variability. J Pediatr Orthop 25:197-201.