Reliability of Measurement of Maximal Isometric Lateral Trunk-Flexion Strength in Athletes Using Handheld Dynamometry

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Context: Lateral trunk-flexion strength is an important determinant of overall trunk stability and function, but the reliability in measuring this outcome clinically in athletic individuals is not known. Objective: To determine the interrater and intrarater reliability of lateral trunk-flexion strength measurement in athletic individuals using handheld dynamometry. Design: Reliability study. Setting: Research laboratory. Participants: 12 healthy, athletic individuals. Intervention: Lateral trunk-flexion strength was measured using handheld dynamometry across 2 different trunk placements (lateral aspect of the axilla and laterally at the level of the midtrunk) and 2 testing occasions by 2 therapists. Three maximum-effort trials during a “make test” at each placement were completed for each therapist on both occasions. Main Outcome Measures: Maximum force output was identified and converted to a torque. Intraclass correlation coefficients (ICC2,1) were calculated for each dynamometer placement, therapist, and test occasion to determine intrarater and interrater reliability. Results: Intrarater reliability was moderate to good (ICC2,1 = .53–.77), while interrater reliability was good to very good (ICC2,1 = .79–.81) at the axilla position. For the midtrunk position, intrarater reliability was good to very good (ICC2,1 = .80–.86), while interrater reliability was very good on both days (ICC2,1 = .87–.88). Finally, the standard errors of measurement were low for the axilla position (0.20 Nm/kg; 95% CI .15, .28) and midtrunk position (0.09 Nm/kg; 95% CI .07, .12). Conclusions: Maximum lateral trunk-flexion strength can be reliably measured in athletic individuals with greater overall strength. Based on the 2 positions used in this study, measurement with a dynamometer placement at the midtrunk may be more reliable than that obtained at the axilla.

Keywords: intraclass correlation, muscle, torque

Control of the trunk in all planes of motion is an important requirement for many sporting activities. Multidirectional control of the spine is an important determinant of overall spinal stability and high-level function. Accordingly, dysfunction of the lateral trunk musculature can result in a decreased ability to resist forces applied to the body in the frontal plane (eg, during a collision), resulting in increased forces transmitted to the spine. Muscle dysfunction can also result in decreased symmetrical stabilization of the spine during movements of trunk in the sagittal plane. As a result, clinical examination of lateral trunk-flexion strength constitutes a key part of an overall examination of patients and may be used to assess the effectiveness of muscle-strengthening interventions.

Despite the importance of lateral trunk-flexion strength, there is very little published research reporting a reliable method of assessing it clinically. A scale for trunk impairment was developed as an outcome measure for patients poststroke, but its strength measures focused mainly on abdominal muscles with trunk flexion and rotation. Other investigations evaluated the reliability of trunk-strength measures, but lateral trunk-flexion strength was not included. Lateral trunk movement was investigated by Paalanne et al, but only as it related to postural assessment. Others have used functional tests such as the side-plank test as a means of implying lateral trunk-flexion strength. However, this test requires force production from muscles other than the lateral trunk flexors (eg, the shoulder abductors) and is predominantly used to assess muscle endurance. Thus, the side-plank test does not permit a quantifiable amount of lateral trunk-flexion strength to be obtained. There are no published reports of lateral trunk-flexion strength in highly functioning individuals such as athletes. Measurement of any strength outcome in athletes places extra burden on the therapist to withstand the additional force output exerted by the athlete. Given the lack of published literature reporting on reliable and quantifiable measurement of isolated lateral trunk-flexion strength, new methods of reliably quantifying lateral trunk-flexion strength in athletic populations are needed to inform clinical management of these individuals, as well as to provide a means of assessing change in strength after treatment.
Handheld dynamometry (HHD) is a quantifiable, objective, and valid measure of muscle strength and has been shown to have high test–retest reliability for testing strength of the extremities. It has been reliably used to assess isometric lateral trunk-flexion strength in sitting in people with central nervous system (CNS) impairment. Although those studies reported excellent test–retest reliability, reliability of measurement of lateral trunk-flexion strength using HHD has not been assessed in individuals without CNS impairment, especially athletes. In addition, a single HHD placement (typically on the lateral shoulder) is commonly used, and the reliability of different positions of the HHD on the trunk during testing has not been evaluated. Different HHD placements enable therapists to modify their mechanical advantage, thus changing the effort required to accurately test muscle strength. Therefore, the aims of this study were to establish the intrarater and interrater reliability of measuring maximal isometric lateral trunk-flexion strength in sitting using HHD in athletic individuals to assess differences based on HHD placement on the lateral aspect of the trunk.

Methods

Participants

Based on a maximum expected ICC of .9 and a minimally accepted ICC of .6 across 2 testing replicates, published sample-size requirements indicated a minimum of 11 participants. Therefore, a convenience sample of 12 athletic individuals (6 men, mean [SD] age 27.9 [9.9] y, body-mass index 22.8 [2.7] kg/m²) was recruited from the community. Of these, 4 were recreational athletes (participation in at least 1 organized sporting activity per week), and the other 8 were current or recent varsity-level athletes (soccer, rugby, ice hockey). Individuals were excluded if they had a history of injury or condition that would impair the measurement of trunk strength. All participants provided written consent, and approval was gained from the institution’s clinical research ethics board.

Procedures

Each participant reported to the laboratory on 2 separate occasions more than 24 hours apart but within the same week. At each test session, participants underwent assessment of maximal isometric lateral trunk-flexion strength of their dominant side (all were right-side dominant) using an HHD (microFET2, Hoggan Health Industries) placed at 2 different positions and by 2 examiners. Order of examiners and HHD placement was randomized but was kept consistent for both testing sessions of the same participant. Participants were secured with straps in a seated position to a plinth, with knees and hips flexed to 90° and their hands placed across their chest. The HHD was positioned in 1 of 2 places on the lateral aspect of the trunk: at the level of the axilla or midtrunk, measured as the midpoint between the axilla and iliac crest (see Figure 1). The therapist was positioned perpendicular to the participant and provided resistance to lateral trunk flexion through the dynamometer to minimize actual lateral

![Figure 1](image-url)  
**Figure 1** — Handheld-dynamometer placement and participant position for (a) the axilla (at the level of the axilla) and (b) the midtrunk (midway between the axilla and iliac crest).
Measuring Trunk-Flexion Strength Using Handheld Dynamometry

trunk-flexion movement. Participants were instructed to attempt as hard as possible to bring their shoulder to their ipsilateral iliac crest and to maintain that movement for 5 seconds. Trials in which excessive movement occurred were discarded. Excessive movement was quantified by the therapist as a detectable amount of movement or rotation in the transverse plane. Adequate rest breaks (minimum 30 seconds) were provided between trials. For each HHD position and therapist, 3 trials were obtained.

Maximal isometric lateral trunk-flexion strength for each trial was determined from the dynamometer output (in kilograms) and converted to Newtons (N). Torque (Nm) was calculated by multiplying force values by the distance (m) from the iliac crest to the HHD and normalized to body mass (Nm/kg). The average torque exerted across the 3 trials was calculated for each participant.

Statistical Methods

Intrarater and interrater reliability of maximal isometric lateral trunk-flexion strength measures in sitting were assessed using average-measure intraclass correlation coefficients (ICC2,1) and 95% confidence intervals (2-way random-effects model, absolute agreement). Reliability values were interpreted based on thresholds suggested by Sasyniuk et al13 for orthopedic-related reliability studies as follows: .41–.60 as moderate, .61–.80 as good, and .81–.99 as very good. Relative reliability was evaluated by assessing the point estimates for ICC2,1, while absolute reliability was assessed using the standard error of measurement (SEM). All statistical analyses were conducted using the Statistical Package for the Social Sciences version 18 (SPSS Inc).

Results

All maximal isometric lateral trunk-flexion strength data are summarized in Table 1. Between-sessions differences in calculated peak torques were less than 0.18 Nm/kg (approximately 7%). Calculated torques were consistently higher when the HHD was placed at the level of the axilla. However, reliability was higher when the HHD was placed at the midtrunk position. Intrarater reliability was moderate (ICC2,1 = .53) to good (ICC2,1 = .77), while interrater reliability was good to very good (ICC2,1 = .79–.81) on both days when assessing strength at the level of the axilla. For the midtrunk position, intrarater reliability was good to very good (ICC2,1 = .80–.86), while interrater reliability was very good (ICC2,1 = .88–.87). When combining data from both examiners, the point estimate for the ICC was .64 (95% CI .19, .84) at the axilla position, and .81 (95% CI .57, .92) for the midtrunk position. SEM was 0.22 Nm/kg (95% CI 0.15, 0.28) for the axilla HHD position, and 0.09 Nm/kg (95% CI 0.07, 0.12) for the midtrunk HHD position.

Discussion

This study found that there was higher calculated lateral trunk-flexion torque produced in sitting as measured using an HHD placed at the axilla than at the midtrunk in athletic individuals. However, it was found that HHD measurement of maximal isometric lateral trunk-flexion strength at the midtrunk position resulted in higher intrarater and interrater reliability values than at the axilla position, although interrater reliability for both positions was deemed very good.

It was also found that the SEM when assessing strength at the midtrunk position was lower than at the axilla position. Identification of this value facilitates interpretation of an individual’s data through calculation of measurement error (by multiplying by the z value for a given confidence level), as well as minimal detectable change (by multiplying the SEM by the z value for a given confidence level and the square root of 2). For example, using the SEM of 0.09 Nm/kg and the 95% confidence level (z = 1.96), the actual strength value from a given assessment can vary by as much as 0.18 Nm/kg in either

<table>
<thead>
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<th>Table 1 Maximal Isometric Lateral Trunk-Flexion Strength Measures (Nm/kg) and Within-Examiner (Test–Retest Reliability) and Between-Examiners Intraclass Correlation Coefficients (ICC) During Each Strength-Testing Session</th>
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<tr>
<td><strong>Examiner 1, mean ± SD</strong></td>
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<tr>
<td><strong>Axilla position</strong></td>
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<td>day 1</td>
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<td>mean difference (95% CI)</td>
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<td>within-examiner ICC2,1 (95%CI)</td>
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<tr>
<td><strong>Midtrunk position</strong></td>
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<td>day 2</td>
</tr>
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<td>mean difference (95% CI)</td>
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direction from the measured strength value simply due to measurement error. Furthermore, a true change in lateral trunk-flexion strength can be concluded with 95% confidence if changes in measured strength values are greater than 0.25 Nm/kg (0.09 Nm/kg × 1.96 × the square root of 2) at follow-up compared with baseline. Smaller errors or change can be obtained using smaller \( z \) values, but with the associated reduction in confidence. These values are important to note when assessing the effectiveness of interventions aiming to improve lateral trunk-flexion strength.

The reliability of HHD measurement of maximal isometric lateral trunk-flexion strength found in this investigation was lower than previously found. However, absolute values obtained cannot be effectively compared due to differences in participant populations.\(^\text{11,14}\) For example, Bohannon\(^\text{11}\) and Larson et al\(^\text{14}\) investigated the reliability of HHD measurements of lateral trunk-flexion strength in populations with CNS impairment and found ICC values greater than .9. The lower reliability coefficients in the current study can likely be attributed to a significantly more functional sample and presumably known to what extent maximal isometric lateral trunk-flexion strength can improve with training or rehabilitation or whether or not this method of measurement will be sensitive to these changes. However, the current study provides initial data required to assess changes in lateral trunk-flexion strength using the methods described herein. Finally, comparison can be made between HHD and an isokinetic dynamometer (gold standard) in assessing lateral trunk-flexion strength to determine the concurrent validity of this measure.

HHD measurement of maximal isometric lateral trunk-flexion strength in athletic individuals is a reliable and clinically useful method to assess lateral trunk-flexion strength. The use of HHD as part of an overall clinical assessment is a cost-effective and reliable measurement tool for measurement of trunk strength.\(^\text{9,10}\) It is still not known whether maximal isometric lateral trunk-flexion strength can improve with training or rehabilitation or whether or not this method of measurement will be sensitive to these changes. However, the current study provides initial data required to assess changes in lateral trunk-flexion strength using the methods described herein. Finally, comparison can be made between HHD and an isokinetic dynamometer (gold standard) in assessing lateral trunk-flexion strength to determine the concurrent validity of this measure.

**References**


