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ORIGINAL RESEARCH

Is the inclinometer a valid measure of thoracic kyphosis? A cross-sectional study

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Abstract
Background: Radiographs are used to monitor thoracic kyphosis in individuals with certain pathologies (e.g. osteoporosis), exposing patients to potentially harmful radiation. Thus, other measures for monitoring the progression of thoracic kyphosis are desirable. The gravity-dependent inclinometer has been shown to be reliable but its validity as a measure of thoracic kyphosis has not been investigated.
Objectives: To determine the validity of the gravity-dependent (analogue) inclinometer for measuring thoracic kyphosis.
Design: Cross-sectional study.
Method: Participants ($n = 78$) were recruited as part of a larger study of shoulder impingement syndrome (SIS). Healthy participants ($n = 39$) were age and gender matched to the SIS group Q2 ($n = 39$). Measurements of thoracic kyphosis using a gravity-dependent inclinometer were compared with modified Cobb angle results obtained from a sagittal view of lateral radiographs. A Bland–Altman plot assessed agreement. The Pearson correlation coefficient and linear regression was used to determine the association between modified Cobb angles and inclinometer measurements.
Results: The Bland–Altman plot demonstrated good agreement. The Pearson correlation coefficient, $r = 0.62$ ($p < 0.001$), and linear regression model established a strong association between the thoracic kyphosis angle from the inclinometer readings and the modified Cobb angle measured from the radiographs ($\beta = 0.47$, 95% CI 0.29, 0.65, $p < 0.001$, $R^2 = 0.52$, $n = 78$). Age as a confounder was included in the model ($\beta = 0.35$, 95% CI 0.19, 0.51, $p < 0.001$).
Conclusions: The gravity-dependent (analogue) inclinometer produces angles that are comparable to the modified Cobb angle obtained from radiographs, establishing its criterion validity as a safe clinical tool for measuring thoracic kyphosis.
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Introduction

Accurate measurement of the degree of kyphosis of the thoracic spine in the sagittal plane is important in conditions such as osteoporosis, ankylosing spondylitis and Scheuermann's disease,[1–5] which require regular monitoring, usually with radiographic imaging.[6] In 2011, $4.6 billion was spent in Canada on osteoporosis alone.[7] Early detection of increased angles of thoracic kyphosis could result in early intervention and rehabilitation, potentially preventing health complications and saving costs.[8]

A common measure of the curvature of the thoracic spine in the sagittal plane is the modified Cobb angle (termed 'modified' as the original Cobb angle was designed for coronal plane radiographs). The gold standard for measuring the modified Cobb angle is using lateral thoracic spine radiographs.[9] From the lateral radiographs, projected lines are drawn along two different thoracic vertebra endplates of the section of the thoracic spine being measured. For example, to measure the entire thoracic spine, projections of the top endplate of T1 and the bottom endplate of T12 would be drawn. Their intersection is called the modified Cobb angle. Before the introduction of digital radiographs, the intersection of these lines was hand drawn directly on radiographic films. Currently, the modified Cobb angle is calculated on digital images using computer software.[10]

Using lateral radiographs to monitor the angle of thoracic kyphosis in osteoporosis, ankylosing spondylitis or Scheuermann's disease is undesirable, as it exposes patients to excessive radiation given frequent repeated measures are required. Hence, other clinical measurement tools are needed which are valid, reliable, safe, cost effective, and easily and quickly applied. A systematic review (2014) of non-radiographic measures of thoracic kyphosis[11] identified the gravity-dependent (analogue) inclinometer as a simple economical tool that had previously been shown to be a reliable measure of thoracic kyphosis,[11,12] but at that time, no studies had established its validity.

There are three recent studies comparing inclinometer measurements of the thoracic spine with the modified Cobb angle from lateral radiographs. Two used digital inclinometers to obtain their clinical measure of thoracic kyphosis.[13,14] Azadinia et al.[13] measured 105 hyperkyphotic participants, aged 10–80 years, though only those participants aged between 10 and 30 years were used to establish agreement between the digital inclinometer measure of thoracic kyphosis and the modified Cobb angle.[13] Sangtarash et al.[14] measured 20 women with back pain, aged between 45 and 70 years.[14] Both of these studies obtained their thoracic kyphosis measurements from digital inclinometers and compared them to radiographs taken on previous occasions, with no description of instructions to the participant during the radiograph or the time-frame between the X-ray and the inclinometer measurement.[13,14] The most recent study by Barrett and colleagues[15] used gravity-dependent inclinometers, with each of the 11 participants (mean age 40.9 years, SD 20.1) having both their shoulders and elbows flexed at 90 degrees for the radiograph, but with arms by their sides for the inclinometer measurement.[15] These different arm positions for each measurement may have introduced differences in thoracic posture for the radiographs compared to the posture for the inclinometer measurements. Hence there are no studies that measure the angle of thoracic kyphosis using the gravity-dependent inclinometer and lateral radiograph where both measurements were performed at the same time with the participant standing in the same position.

If the inclinometer was established as a valid clinical tool for measuring an individual's thoracic kyphosis, as comparable to the modified Cobb angle from lateral radiographs, clinicians could confidently use it to regularly monitor changes in thoracic kyphosis in individuals with conditions such as osteoporosis, ankylosing spondylitis and Scheuermann's disease. This would decrease the exposure of patients to harmful ionising radiation as well as save costs.

This study aimed to assess the criterion validity of the inclinometer as a clinical instrument to measure thoracic posture by comparing the angle of thoracic kyphosis, calculated using inclinometer measurements, to the modified Cobb angle obtained from lateral radiographs, the gold standard.

Method and materials

Participants

This study was part of a case–control study investigating the possible relationship between thoracic posture and shoulder impingement syndrome (SIS). Eighty individuals participated. Forty healthy individuals with no shoulder symptoms were age and gender matched to 40 participants with SIS. Individuals with SIS were included if they had experienced shoulder pain for at least three months and were positive for at least three out of five orthopaedic clinical tests for SIS,[16] and also confirmed as having SIS by a radiologist using ultrasound.

Healthy individuals without shoulder pain were included if they were confirmed as not having SIS by a radiologist using ultrasound, had not sought treatment for symptoms in their shoulder, back or neck within the last three months and had never had shoulder symptoms lasting longer than three weeks.

Potential participants were excluded if they had any condition where undertaking a radiograph was contraindicated (e.g. pregnancy); any history of previous traumatic injury or surgery to the shoulder, neck or back; any known, diagnosed malignancy, infectious disease, or inflammatory disease of the shoulder or spine; or any known, diagnosed neurological conditions (e.g., multiple sclerosis or stroke).[17,18]

The sample size was determined based on the number of participants required for the case–control study, which investigated differences in posture between individuals with and without SIS. A 5 degree difference in modified Cobb angle between groups (participants with SIS and healthy controls), with a standard deviation of 10 degrees (estimated from Katzman et al.[19] and Fon et al.[20]) required 34 participants per groups to achieve a 5% level of significance with 80% power. The recruitment target was set at 40 participants per group.

Potential participants were sought from two sources: community advertising and a volunteer research register maintained by a local research institute. Advertising within

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