ASSESSMENT OF THORACIC KYPHOSIS USING THE FLEXICURVE FOR INDIVIDUALS WITH OSTEOPOROSIS

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Abstract: Thoracic kyphosis is one of the manifestations of spinal osteoporosis. Since kyphosis is associated with patient symptoms and is a risk factor for loss of function, it would be beneficial to have simple, noninvasive measurement techniques that can be applied in clinical practice. The purpose of this study was to assess the test-retest reliability of the measurement of thoracic kyphosis using the flexicurve ruler in individuals with osteoporosis. Twenty-six females (mean age, 67 yr) diagnosed with osteoporosis had measurements of kyphosis taken in standing by aligning a flexible drafting ruler before and after a 12-week exercise program. The time period was chosen to be consistent with the duration of a physiotherapy intervention. Measures of kyphosis height (cm), length (cm), and an index of kyphosis (height/length) were recorded. Data analysis (intraclass correlation coefficients [ICC]) indicated that the reliability between the trials of the measurement of kyphosis height (0.89) and index of kyphosis (0.93) were high; however, the reliability estimate of kyphosis length was less with an ICC value of (0.54). This study supports the use of the flexicurve ruler for the measurement of kyphosis in elderly women with osteoporosis based on reliability outcomes and the fact that it is noninvasive, inexpensive, and easy to use in a clinical setting. The measurement of kyphosis may be used to determine the response to a therapeutic intervention and in monitoring kyphotic progression.

Key words: kyphosis, osteoporosis, measurement, reliability

Introduction

Osteoporosis is a systemic skeletal disease characterized by low bone mass and microarchitectural deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fractures [1]. It is a nonfatal condition that leads more to changes in the quality of life rather than to changes in the mortality rate [2].

Osteoporosis affects some 75 million people in the United States, Europe, and Japan combined. This includes one in three post-menopausal women and an increasing number of elderly men [1]. In Asian urbanized countries, osteoporosis is also rapidly becoming a major public health problem in the aged [3]. According to the Chinese Statistics Bureau [4], China has the largest population of aged people in the world, and the population of aged adults is increasing at an annual rate of more than 3.2%. The incidence of osteoporotic-related fractures in Hong Kong Chinese has doubled in the last 20 years [5], and it is predicted that in Asia, there may be a tenfold increase in osteoporotic fractures by the year 2050 [1].

Marked kyphosis of the thoracic spine because of vertebral fractures is one of the most common clinical manifestations of spinal osteoporosis [6]. The fracture or collapse of a vertebral body results in anteriorly wedge-shaped, codfish-shaped, or flat vertebral body deformities. These deformities develop along planes of stress because of the centre of gravity of the body, causing a kyphotic or increased forward posture [6]. Kyphosis may also result from non-osteoporotic conditions such as weight gain, decreased muscle strength, and degeneration of intervertebral discs [7]. Kleerekoper and Nelson [8] have...
indicated that, progressive wedging of the thoracic vertebral bodies resulting in deformity may occur with the natural ageing process in the absence of accelerated bone loss or osteoporosis. Kyphosis due to osteoporosis and ageing has been documented as a gradually progressive deformity [9]. It has been suggested that subjects who are physically active may retard the progression of kyphosis associated with osteoporosis and ageing [9].

Physical and social outcomes of spinal kyphosis include a decline in height, a protuberant abdomen, a downward gaze, back pain, digestive problems, impairment of respiratory function, decreased mobility, poor self-image, and loss of independence leading to a decreased quality of life [2]. An individual with kyphosis is easily fatigued and has considerable difficulty with activities requiring an upright posture or exercise tolerance such as walking, climbing stairs, household, and reaching overhead [10]. Therefore, basic activities of daily living, leisure, and emotions are negatively affected by spinal deformity [11]. The functional consequences of this postural deformity and the overall decline in quality of life are often overlooked.

To better understand the consequences of spinal kyphosis, investigators have begun to measure kyphosis using specialized equipment such as the flexicurve ruler, DeBrunner’s kyphometer, roentgenographs, and inclinometers [6]. The Osteoporosis Society of Canada recommends that thoracic kyphosis be measured when investigating patients who are at high risk for or have been diagnosed with osteoporosis [12]. Since kyphosis is a risk factor for loss of function, it is beneficial to have a technique for the measurement of kyphosis that can be applied in clinical practice [10].

Instruments used to assess kyphosis must be viewed in terms of their accuracy, reliability, and practicality. The ideal clinical instrument for measurement of kyphosis should be precise, accurate, and inexpensive. It should allow for efficient measurement, and should not subject the individual to high doses of radiation. Reliability studies that examine various non-invasive instruments should have testing sessions that span the duration of the experiment or intervention. The timeframe of the study should be typical of a physical therapy intervention. Although the time allotted between testing sessions will have an impact on the reliability of the measure, often studies do not report the timeframe between test and retest. Many reliability studies are conducted in a time frame that is artificially short. Measurements should be taken on the same population for which the measure is intended, as well. However, studies use subject populations of healthy elderly individuals, and not osteoporotic individuals [13]. Therefore, the purpose of this study was to assess the test–retest reliability of the measurement of thoracic kyphosis using the flexicurve ruler with individuals diagnosed with osteoporosis.

Methodology

Subjects
All subjects were volunteers and had enrolled in the Trym Gym Osteoporosis Exercise Program at the University of Calgary. The exercise programme did not specifically target the treatment of thoracic kyphosis. Furthermore, thoracic kyphosis is a very stable condition, which will not change over a short period of time despite a general physical training programme to the body. The inclusion criteria for the study were: diagnosis of osteoporosis; female gender; ages 50 to 80 years; and the ability to walk without aids. Exclusion criteria were symptomatic heart disease, systemic steroid therapy, and central neurological disorder. Prior to participation, informed written consent was obtained from each subject as approved by the Institutional Ethics Committee at the University of Calgary.

Procedure
The testing protocol outlined below was administered prior to a 12-week modern dance and aerobic activity programme, and repeated upon completion.

Spinal kyphosis was measured in each subject using the flexicurve ruler (Staedtler Mars Inc, Nurnberg, Germany), which is a malleable band of metal covered with plastic and approximately 60 cm in length. The ruler can be bent in only one plane and retains the shape to which it is bent. It is available from most drafting supply stores. The subject was instructed to stand up straight and as tall as possible, and the flexicurve ruler was aligned to the anterior-posterior curves of the spine from C7 to T12 (Fig. 1). The ruler was then placed flat on paper and its outline was traced. A straight line was then drawn from the ruler position of C7 to T12 that corresponded to the length of thoracic kyphosis (l) and was measured in cm. The height of the thoracic kyphosis (h) in cm was determined by drawing a perpendicular line from the highest point in the thoracic curve to the

Figure 1. Measurement of thoracic kyphosis using the flexicurve ruler
point at which it intersected the straight line drawn from C7 to T12. The index of kyphosis was calculated by applying the formula: \((h/l) \times 100\).

The protocol used in this study to measure spinal kyphosis differed slightly from others in the literature. In this study, the distance from C7 to T12 was measured with the flexicurve ruler. Previous studies have used the flexicurve to measure from the C7 spinous process to the L5–S1 junction [6], thus measuring both thoracic kyphosis and lumbar lordosis. The rationale for the extended reference points is that thoracic kyphosis resulting from osteoporosis is often associated with a compensatory increase in lumbar lordosis [14]. This hyperlordosis along with a more upright positioning of the sacrum has also been noted by Lundon et al [6]. Other researchers have also indicated that greater stiffness in the thoracic spine may produce compensatory changes in the more mobile lumbar region [15].

The purpose of measuring the thoracic spine from (C7 to T12) in the current study was to isolate the specific region of interest. If both the thoracic and lumbar curves were measured, it would be difficult to determine which region was responsible for any change that may be observed. Therefore, the intent was to isolate the measurement to the thoracic spine to provide a more definitive interpretation of the results.

### Statistical Design

A two-way analysis of variance intraclass correlation coefficient (ICC), as described by Shrout and Fleiss [16], was used to measure test–retest reliability for all the parameters mentioned previously. ICC (3,1) is defined by:

\[
\text{ICC (3,1) = } \frac{\text{BMS–EMS}}{\text{BMS + (k–1) EMS}}
\]

where BMS = mean square between (between subject variance), EMS = mean square error, and k = number of trials. The 95% confidence intervals for values of ICC were estimated according to Shrout and Fleiss [16].

A paired t-test was performed on the measures of kyphosis height, kyphosis length, and index of kyphosis to examine any statistical difference between measures before and after the 12-week period.

The degree of change between two measurements that would have a low probability to occur by chance (i.e., the change in measurements is not likely due to the measurement error) was also established. To determine the smallest detectable difference that would be observable using the flexicurve measurement of thoracic kyphosis, we used the Generalizability Theory described by Roebroeck et al [17]. From the smallest detectable difference, a therapist knows what differences need to be measured to conclude that real change has occurred rather than measurement error [17].

### Results

A total of 26 women who were enrolled in the Trym Gym Osteoporosis Exercise Program qualified as subjects for this study. Baseline anthropometric characteristics of the participants are displayed in Table 1.

Figures 2 through 4 display the distribution of pre-test measures of the subject sample for kyphosis height, length, and index of kyphosis respectively. The results of the test–retest measures (mean ± SD) for kyphosis height, length, and index of kyphosis using the flexicurve ruler are shown in Table 2.

<table>
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<th>Table 1. Subjects’ baseline anthropometric data</th>
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The calculated correlation coefficient [ICC (3,1) and 95% confidence interval (CI)] for test–retest reliability revealed highly reliable results for kyphosis height (0.89, CI 0.77–0.94) and index of kyphosis (0.93, CI 0.85–0.97). The greatest variability within each subject between testing sessions occurred in the length measurement. The measurement of kyphosis length was less reliable, with an ICC value of 0.54 (CI 0.20–0.76).

The results of the paired t-test showed no significant difference in thoracic kyphosis measurement over time. There was no significant difference found between testing sessions in kyphosis height (\(p = 0.38\)), kyphosis length (\(p = 0.26\)), or index of kyphosis (\(p = 0.46\)).

The smallest detectable difference not likely due to measurement error of thoracic kyphosis height was 0.26 cm. The smallest detectable difference for index of thoracic kyphosis was 0.73%.

<table>
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<th>Table 2. Summary of kyphosis measurement results.</th>
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<td>Kyphosis height (cm)</td>
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Discussion

The results from this particular study showed good reliability in the measurement of thoracic kyphosis height (0.89), and index of kyphosis (0.93), using the flexicurve ruler. The use of this instrument on osteoporotic individuals is substantiated on the basis that the data collected was from a comparable subject sample. As well, these measures were found to be reliable over a 12-week period, which was the duration of the exercise intervention. Thoracic kyphosis length was less reliable (0.54).

The correlation coefficients obtained from our data using our testing protocol are comparable with the reproducibility results of Milne and Lauder [13], which were found to be 0.94 for kyphosis height and 0.78 for kyphosis length. However, their index of kyphosis had a lower reliability coefficient of 0.78. Their study assessed subjects representative of a healthy elderly population, rather than an osteoporotic population, and assessed the length of the spine from C7 to S1 (kyphosis/lordosis) as opposed to only the thoracic region.

The smallest detectable difference indicated the level of change in a measurement that would likely be due to measurement error and not likely due to a change in patient status. The smallest detectable differences for both kyphosis height and index of kyphosis are acceptable from the perspective of clinical relevance because the values are relatively small compared to the expectation for clinically meaningful change.

There was no measurable change in thoracic kyphosis over time, and thus the 12-week time period between testing sessions should not influence any conclusions made regarding the reliability of measures.

The flexicurve has demonstrated value in assessing thoracic kyphosis in a normal, healthy, elderly population. The results from this study show that the flexicurve is also a reliable tool to determine the height of thoracic kyphosis in osteoporotic individuals. Chow and Harrison [9], have used the flexicurve to determine that fitter individuals, especially those with normal bone mass, have a significantly lower index of kyphosis than those who are less fit. They concluded that poor posture and poor habits predispose an individual to accentuation of the kyphotic curve. Therefore, subjects who are physically active may retard the progression of kyphosis associated with ageing and osteoporosis as activity may prevent normal bone loss in the spine that occurs with age, and achieve greater back muscle strength and tone.

The flexicurve has advantages over other methods of measurement of thoracic kyphosis. The flexicurve was easier to use, convenient, lightweight, less expensive, and provided more accurate and reproducible results than inclinometers in a comparative study by Thompson and Eales [18]. Lundon et al [6] compared the flexicurve to DeBrunner’s kyphometer and roentgenographic results. No significant difference was found in the reliability of all three instruments. In such a case, a non-invasive instrument has an advantage over the roentgenograph, a costly, invasive procedure for determining the degree of kyphosis in individuals with osteoporosis. Lundon et al. [6], concluded that the DeBrunner’s kyphometer and flexicurve ruler may be used interchangeably, however, the flexicurve is lighter, easier to position accurately on spinal landmarks, and
less expensive than the kyphometer [19]. The flexicurve is useful in a clinical setting for an osteoporotic population. It is non-invasive and safe to use, the measurements are simple and quick to perform, and it obtains reliable, quantitative and objective measurements of thoracic spinal posture. The limitation to this method of assessing spinal curvature is an increased chance for error in tracing the shape of the spinal curvature, as the flexicurve can be susceptible to changes in shape once removed from the spine.

The use of the flexicurve for repeated measurements is probably more important for detecting overall change rather than for making absolute measurements. This instrument may be useful in monitoring the change in spinal curvature over time as a consequence of age and deteriorating general health. In addition, the measurement of kyphosis is a good indicator of the effects of postural retraining and response to an intervention [7]. Therefore, the flexicurve may be used in conjunction with the design of a specific physical therapy management strategy for the purpose of postural retraining. It is also useful for the longitudinal study of kyphotic curvature change induced by disease progression [7]. Furthermore, it has been suggested that the flexicurve allows less experienced investigators to make reliable measurements. This is particularly pertinent in a clinical setting where, due to the diversity of therapists taking measurements, the attainment of reliable spinal traces should be minimally dependent upon expertise or training [20].

Conclusion

The conclusion of the current study is that the flexicurve is a reliable instrument for the measurement of kyphosis height and index of kyphosis in elderly women with osteoporosis. As well, it is non-invasive, inexpensive, and easy to use in a clinical setting. Our findings suggest that measurement of thoracic kyphosis using the flexicurve may be useful in examining the degree of kyphosis due to osteoporosis, measuring the response to a therapeutic intervention, and monitoring kyphotic progression.

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References