



RESEARCH REPORT

Validity and reliability of a thoracic kyphotic assessment tool measuring distance of the seventh cervical vertebra from the wall



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KEYWORDS

community health service;
elderly;
kyphosis measure;
rehabilitation;
round back

Abstract *Background:* In primary healthcare (PHC) service, community residents, village health volunteers (VHVs), and healthcare professionals need to work in partnership to facilitate universal and equitable healthcare services. However, these partnerships may need an appropriate tool helping them to execute an effective health-related activity.

Objectives: To investigate the reliability and validity of a simple kyphosis measure using a perpendicular distance from the seventh cervical vertebra (C7) to the wall (C7WD).

Methods: Elderly people with different degrees of kyphosis ($n = 179$) were cross-sectionally investigated for the intra- and interrater reliability of the measurement by a physical therapist (PT), VHV, and caregiver. The validity was assessed in terms of concurrent validity as compared with the Flexicurve, and discriminative validity for functional deterioration in participants with mild, moderate, and severe kyphosis.

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Results: The method showed excellent reliability among PT, VHV, and caregivers ($ICC > 0.90$, $p < 0.001$), and excellent correlation to the data from the Flexicurve. Results of the assessment were greater than a level of minimal detectable change and could clearly discriminate functional deterioration in participants with different severity of kyphosis ($p < 0.001$).

Conclusion: C₇WD is valid and reliable, thus it can be used to promote the standardisation of kyphosis measures among PHC members.

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Introduction

Structural kyphosis, a condition with rigidity and functional stiffness of the spinal curvature, is commonly found at a thoracic region and in older people (20–40%) [1,2]. It is characterised by a sagittal or backward deviation of the thoracic spine exceeding 50° [3]. The abnormality can affect adjacent structures such as restricted pulmonary functions; induced back pain, digestive problems, and risk of spinal fracture; and reduced ability of balance control due to the forward shift of the body centre of mass [3–5]. Thus it superimposes negative impacts on levels of functioning of older individuals, their quality of life and mortality rate [6,7]. Therefore, apart from treatments, an effective and practical measure is important to early detect the abnormality and minimize the harmful consequences, indicate effectiveness of the treatments, and improve standardisation of a monitoring and referring method of the kyphosis [8,9].

Presently, kyphosis can be measured using invasive and noninvasive methods, in which most of them are executed by a health-professional. Among the noninvasive methods, the Flexicurve has been suggested as a practical and valuable tool to monitor the changes of spinal curvature over time, due to the consequences of age and deterioration process [3,4,10–13]. Outcomes of the measurement are accurate and reliable compared with the findings derived from the DeBrunner's kyphometer and Cobb's method ($r = 0.98$) [13,14]. However, a landmark for the measurement, in particular the 12th thoracic vertebra (T12), may be difficult to identify, and the malleable band of the Flexicurve can change its shape once removed from the spine. Thus the method is susceptible to error, and should be used by a well-trained health professional [3,4].

In a community, primary healthcare (PHC) is an important strategy for universal access to healthcare services, in which community residents, community health workers [or village health volunteers (VHVs) in Thailand], and healthcare professionals need to work in partnership to achieve universal and equitable access to the healthcare system in their communities [15]. However, this partnership may need an appropriate technology or equipment helping them to execute an effective health-related activity.

In epidemiologic studies, severity of kyphosis can be easily quantified using a perpendicular distance from the bony prominence of the seventh cervical vertebra (C7) or occiput to a wall while standing against the wall as the so-called occiput–wall distance (OWD) [7,16]. However, there

was no clear evidence to support its validity and reliability. Thus this study investigated: (1) the intra- and interrater reliability of the kyphosis measure using a perpendicular distance from C7 to the wall (C₇WD) when assessed by a healthcare professional, VHV, and caregiver; (2) the concurrent validity of the method using the Flexicurve as a standard method; and (3) discriminative validity of the results to determine functional deterioration in older people with various degrees of kyphosis. Findings of the study may promote the standardisation of kyphosis assessment and monitoring among PHC members.

Methods

Study design and participants

Older people, age ≥ 60 years, with a body mass index (BMI) between 18.5 kg/m² and 29.9 kg/m² were cross-sectionally recruited from several communities in the northeast areas of Thailand, during January–December 2014. The individuals were recruited if they had various degrees of structural kyphosis in the thoracic area without any signs and symptoms that might affect participation in the study such as using a walking device, and having pain or inflammation in the muscles or joints, other spinal or limb deformities (i.e., scoliosis and leg length discrepancy), and abnormal fat distribution, mass, or tumour in the upper back area. The research protocol was approved by the Office of the Khon Kaen University ethics committee in human research (HE 542111). The participants provided a written informed consent prior to participation in the study. Figure 1 illustrates patients' participation flowchart.

Reliability assessments

Walter et al [18] have provided estimates for sample size requirements for reliability studies using intraclass correlation coefficients (ICC). For a true p_0 of 0.4 (minimally acceptable level for 3 raters) against an alternative p_1 of 0.7, based on a 5% significance level and a power of 80% ($\beta = 0.20$), the study required 21 participants [17,18]. Details of the reliability assessments are as follows.

Kyphosis measured using the distance from the wall

The intra- and interrater reliability of the C₇WD was investigated using three raters, including a PT (a master degree student), VHV (51 years old who had 3 years working

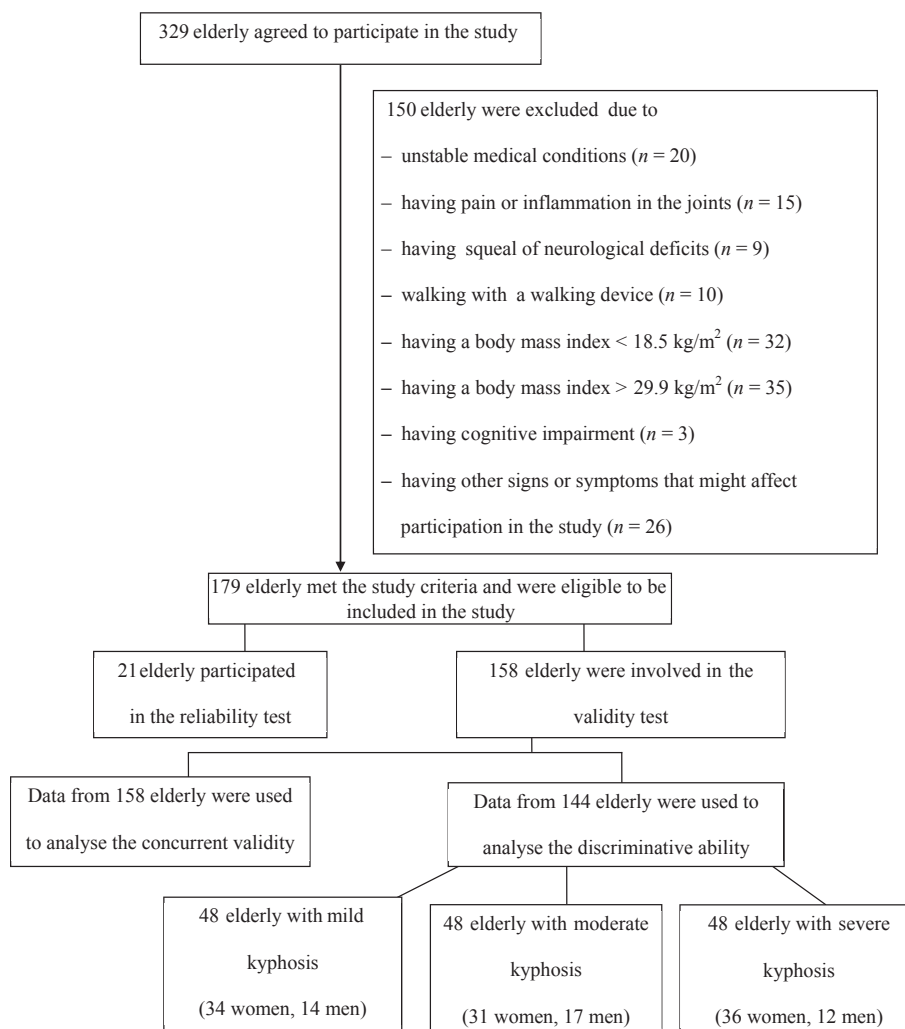


Figure 1. Patient participation flowchart.

experience), and a caregiver (49 years old who was a daughter of an older adult and graduated from secondary school). All raters measured C_7 WD using a kyphosis wall-distance tool (KypDist, petty patent number 9867) and the method proposed for OWD. The KypDist (Figure 2) was developed from a 15-cm digital vernier caliper to minimize chance of errors due to misalignment of the two rulers, i.e., the first ruler is not perpendicular with the wall and the second ruler is not parallel with the landmark (C_7). The tool contains a perpendicular plate, handle, and slide bar (Figure 2A) in order to easily fix it to the wall with a weight ~ 0.6 kg.

Prior to the assessments, all raters were trained to use the tool (the total training time was ~ 30 minutes) and using the prominence of C_7 as a landmark of measurement because it is more stationary and adjacent to the thoracic spine than the occiput [19,20]. Therefore, using C_7 as a landmark for measurement would provide a more accurate compensatory distance due to thoracic kyphosis and reduce errors in the outcomes once the participant moved her head. During the measurement, participants stood upright as tall as possible and looked forward; with the heels, sacrum, and back against the wall (Figure 2B) [8,16]. Then the perpendicular distance

from the bony prominence of C_7 to the wall (C_7 WD) was measured using the KypDisT over three trials with a period of rest as needed between the trials [16]. The average distance over the three trials was used for data analysis.

Kyphosis measured using the Flexicurve

The reliability of Flexicurve measurement was assessed using two PT raters who had a Master degree in Physical Therapy because the method of measurement is susceptible to error, and requires anatomical knowledge and palpation skill more than that necessary for C_7 WD. Prior to the assessments, the raters identified and marked the bony landmarks (C_7 and T12). The C_7 is the lowest and most prominent cervical vertebra that remains stationary during flexion and extension of the cervical spine [19,20]. The T12 was identified by palpating the fourth spinous process superiorly to the fifth lumbar vertebra (L5 or the spinous process above the sacrum) [19]. Then the designated area was confirmed by the area that connected to the last rib (12th) [21].

To clearly reflect structural kyphosis and minimize effects of muscle weakness on the outcomes, the participants were instructed to stand up as tall as possible. The cephalic end of the Flexicurve was placed on the bony prominence

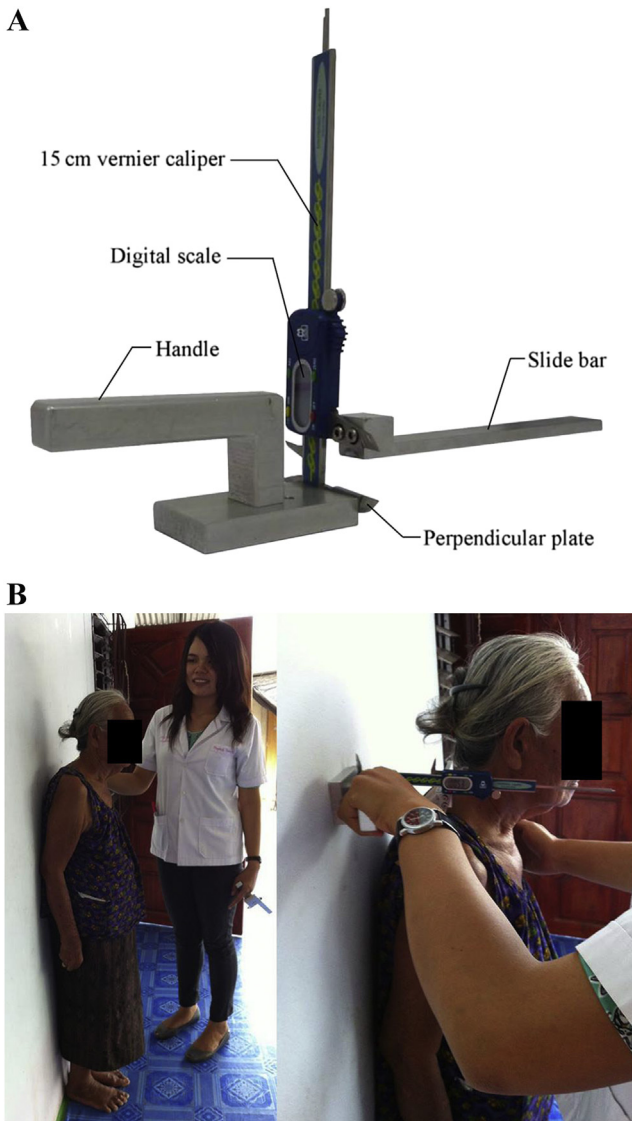


Figure 2. Kyphosis measurement. (A) Components of the kyphosis wall distance tool (KypDist); (B) setting and the method of kyphosis measurement using the KypDist.

of C7 and it was moulded caudally along the spinal curve to T12. Thereafter, the Flexicurve was removed from the spine and traced the shape onto paper [10,11]. A straight line was drawn from the position of C7 to T12 that corresponded to the length of thoracic kyphosis (L). A perpendicular line from the apex of the curve was then drawn to the point at which it intersected the kyphosis length (L) and designated as the kyphosis height (h). Then the kyphosis angle was calculated using the formula [10]:

$$[\theta = 4 \arctan (2 h/L)]. \quad (1)$$

The total training time for the raters took ~ 30 minutes. Each rater measured kyphosis angle for three trials/participant with a period of sufficient rest between the trials, and the average data of the three trials were recorded.

Validity assessments

Concurrent validity

The concurrent validity of the C₇WD was assessed using the Flexicurve as a gold standard in 158 community-dwelling older people with various degrees of thoracic kyphosis [the sample size was derived from that required for a major study on factors associated with severity of kyphosis; in which the proportion of kyphosis (p_2) was 30%, the significant level (α) was 0.05 and power of study ($1-\beta$) was 0.8]. The participants were measured for the C₇WD using the KypDisT and spinal angle using a Flexicurve by a PT in a random order.

Discriminative validity

The sample size was calculated for the pairwise comparison using the formula

$$n = \frac{(Z_{\alpha/2c} + Z_{\beta})^2 \sigma^2}{\Delta^2} \quad (2)$$

and data from a pilot study (i.e., different findings of the functional tests) when set the significant level (α) = 0.05 and power of study ($1-\beta$) = 0.8. The study required at least 48 participants/group, including mild (C₇WD ≤ 5 cm), moderate (C₇WD = 5.1–8 cm), and severe (C₇WD > 8 cm) kyphosis [8,17].

Participants were assessed for the functional ability using the 6-Minute Walk Test (6MinWT). Results of the test reflect the global and integrated responses of the pulmonary, cardiovascular, and muscular systems, and the functional exercise level for daily physical activities [22]. Thus it was used as a gold standard for functional deterioration due to increased severity of kyphosis. The test required participants to walk as far as possible in 6 minutes along a rectangular walkway with the walking path containing as few turns as possible. Every minute, participants were informed regarding the time left and offered encouragement. Then the distance covered after 6 minutes was recorded [23–25].

Data analyses

Descriptive statistics were utilized to explain characteristics of the participants and findings of the study. The reliability of the measurements was analysed using intraclass correlation coefficients [ICC(3,1)], 95% confidence intervals (CI), standard error of measurement ($SEM = SD\sqrt{1-ICC}$), and minimal detectable change ($MDC = 1.96*\sqrt{2*SEM}$) [26,27]. The correlation between the C₇WD and Flexicurve was calculated using the Pearson correlation coefficient. The one-way analysis of variance (ANOVA) was used to analyse the discriminative ability of the C₇WD for functional deterioration in participants with different severity of kyphosis. Then, the *post hoc* (Scheffe) analysis was utilized to identify the differences for each pairwise condition. The level of statistical significance was set at $p < 0.05$, and for the three pairwise comparisons (discriminative ability, Bonferroni correction) at $p < 0.0167$ (0.05/3 groups).

Table 1 Intra- and interrater reliability, SEM, and MDC for the kyphosis wall distance (KypDisT) and Flexicurve.

Variable		Physical therapist 1	Village health volunteer	Caregiver
KypDisT	Intrarater reliability	0.998 (0.997–0.999)	0.968 (0.934–0.986)	0.933 (0.862–0.971)
	SEM/MDC (cm)	0.12/0.34	0.49/1.35	0.69/1.90
	Interrater reliability	0.934 (0.863–0.971)		
	SEM/MDC (cm)	0.69/1.91		
Flexicurve		Physical therapist 1	Physical therapist 2	
	Intrarater reliability	0.968 (0.934–0.986)	0.971 (0.940–0.987)	
	SEM/MDC (degrees)	2.45/6.76	2.69/7.43	
	Interrater reliability	0.944 (0.863–0.977)		
	SEM/MDC (degrees)	3.65/10.08		

Data are presented as the intraclass correlation coefficients (95% confidence intervals) with $p < 0.001$. MDC = minimal detectable change; SEM = standard error of measurement.

Results

Three raters (PT, VHV, and caregiver) could complete the C₇WD measurement within 2 minutes (range, 0.50–1.17 minutes) whereas the PT raters used an average of 3.65 minutes (range, 2.8–4.59 minutes) to complete the Flexicurve measurement. Both tools, C₇WD and Flexicurve, demonstrated excellent intrarater and interrater reliability for all raters (ICC > 0.90, $p < 0.001$). Table 1 shows reliability, SEM, and MDC data of the measurements when assessed by the raters. Furthermore, the C₇WD also demonstrated excellent correlation with spinal angles as measured using the Flexicurve ($r = 0.902$, $p < 0.001$).

When classifying the participants into the groups with different severity of kyphosis using data from C₇WD, they showed no significant differences of the baseline data ($p > 0.05$, Table 2). However, participants with mild kyphosis (C₇WD ≤ 5 cm) could cover the longest distance walk in 6 minutes, followed by those with moderate (C₇WD = 5.1–8 cm) and severe (C₇WD ≥ 8 cm) kyphosis, respectively ($p < 0.001$, Table 2). The distances covered in 6 minutes by participants with severe kyphosis were significantly shorter than those with moderate and mild kyphosis ($p < 0.001$).

Discussion

Thoracic kyphosis, a backward deviation of the thoracic spine, likely causes a compensatory change in other spinal areas, and vice versa [4,28,29]. Consequently, increased thoracic kyphosis commonly associates with increased cervical lordosis that subsequently increases the distance from C7 to the wall or C₇WD during standing against a wall. Therefore, the C₇WD showed excellent correlation with the kyphosis angle as measured using the Flexicurve ($r = 0.902$, $p < 0.001$). The findings confirm concurrent validity of the C₇WD when measured using the KypDisT.

When categorized participants into the groups with different degrees of severity using the data from a PT, the differences of C₇WD and Flexicurve between the groups were greater than the levels of SEM and MDC (Tables 1 and 2). The SEM indicates absolute reliability or the possible margin of measurement error in original unit, and the MDC is the minimal change that falls outside the measurement error in the result of the test used [26,27]. Thus the findings confirm the different severity of kyphosis among the groups. Many studies report that increased thoracic curvature restricts inspiratory capacity and total lung volume that retards pulmonary functions [4,28–30]. Therefore, increased

Table 2 Characteristics of the participants and findings of the study.

Variable	Reliability assessments ($n = 21$)	Severity of kyphosis ^a ($n = 48/\text{group}$)			p^*
		Mild (≤ 5 cm)	Moderate (5.1–8 cm)	Severe (> 8 cm)	
Age (y)	74.1 ± 7.6	70.3 ± 5.5	71.7 ± 6.7	72.8 ± 6.5	0.31
Body mass index (kg/m ²)	21.6 ± 3.7	23.6 ± 3.1	22.7 ± 3.2	21.6 ± 3.0	0.64
Distance from the wall ^a (cm)	8.1 ± 2.8	4.5 ± 0.4	6.2 ± 0.9 ***	9.8 ± 1.2 **,***	< 0.001
Kyphosis angle (degrees)	45.2 ± 13.7	25.5 ± 7.8	40.9 ± 5.7 ***	50.5 ± 6.5 **,***	< 0.001
6-Min Walk Test (m)		389.8 ± 66.9	340.3 ± 67.2	317.3 ± 58.0 ****	< 0.001

Data are presented as mean ± SD.

* p values from the one-way analysis of variance (ANOVA).

*** indicate the group with significant differences from the indicated groups where *** = mild kyphosis group, ** = moderate kyphosis group.

SD = standard deviation.

^a Determined using distance from C7 to the wall (C₇WD).

severity of kyphosis reduces ventilatory capacity, that subsequently decreases functional endurance, and increases oxygen consumption, energy expenditure, and work of breathing [4,29–31]. As a result, participants with severe kyphosis or those who had the longest C₇WD, could cover the shortest distance in 6 minutes. In addition, the distance walked by these participants was clinically less than those with mild kyphosis (> 50 m, Table 2) [32]. The findings confirmed discriminative validity of the C₇WD for functional deterioration in participants with various degrees of kyphosis. However, the low explanatory power (43%) of the comparison between those with moderate and severe kyphosis may suggest effects of other confounding factors, such as daily lifestyle and the number of comorbidities which were not considered in this study. To improve explanatory power, this comparison needs at least 158 participants.

Findings of the study further indicate that the C₇WD as measured using the KypDisT had excellent reliability, not only when used by a health professional (PT), but also a VHV and caregiver (ICCs > 0.9, $p < 0.001$, Table 1). With the limitation of medical skills, an appropriate technology or equipment is needed to help caregivers and VHVs execute an effective health-related activity. A caregiver is a person who provides direct care to a patient, and a VHV is a community member who is trained as a lay health worker and accounted as a backbone of healthcare providers [15]. Therefore, they are important to support the concept of community involvement as a heart and soul of PHC activities [33]. The findings confirm the ease and applicability of the C₇WD measure using the KypDist among PHC members. As the KypDisT is a valid, reliable, and practical tool, it would promote the two cornerstones of PHC, including community participation in healthcare and empowerment leading to self-determination [34].

However, there are some limitations of the study: (1) the C₇WD was measured using KypDist in order to minimise human errors on the outcome. However, the findings may not confirm the psychometric properties for the measurement using rulers; (2) this study recruited older people with structural kyphosis at the thoracic area and a BMI between 18.5 kg/m² and 29.9 kg/m² to minimize effects of other confounding factors on the outcomes, i.e., functional decline of many body systems due to advancing age, substantial fat mass that could increase the C₇WD, and different muscle strength on spinal curvature. These may limit the generalizability of the findings within the criteria of participant recruitments; (3) spinal curvature has kinematic linkage in which the change of thoracic kyphosis associates with the change of lumbar and/or cervical lordosis. Hence, the C₇WD showed excellent correlation with the kyphosis angle as measured using the Flexicurve. Nevertheless, the findings cannot indicate a causal-relationship between the occurrence of increased cervical or lumbar lordosis and thoracic kyphosis; and (4) the researchers applied the Flexicurve as a gold standard because the study was conducted in several communities. Although the Flexicurve has been suggested as an accurate and reliable method, the outcomes may have errors due to the change in its shape when removed from the spine and difficulty in identifying the bony landmarks, particularly in overweight or obese individuals. Therefore, this study used the raters who were health professionals and well-trained for the

anatomical landmark and palpation skill. A further study using the Cobb's method as a gold standard and the C₇WD measured using rulers would strengthen the applicability of the C₇WD and increase generalisability of the findings. In addition, the assessment for other psychometric properties of the tool such as cutoff distance from the wall indicating a risk of vertebral fracture by our colleagues would enhance the benefit of the measurement.

Conclusion

Findings of this study confirm reliability and validity of C₇WD to assess and monitor severity of kyphosis both in clinics and communities by a health professional, VHV, and caregiver. Thus the method can be used to promote the standardization of kyphosis monitoring and referring system among PHC members. In addition, the findings would promote the two cornerstones of PHC, including community participation in healthcare and empowerment leading to self-determination.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Funding/support

No financial or material support of any kind was received for the work described in this article.

Acknowledgements

The researchers sincerely thank Ms. Kittiyawadee Srisim for her contribution in data collection and analysis, and Associate Professor Jiamjit Seangsuwan for her expertise in statistical analysis. This study was supported by the Improvement of Physical Performance and Quality of Life (IPQ) Research Group, and Khon Kaen University, Khon Kaen, Thailand.

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