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Reliability of Two Protocols for Measuring Chest Wall Dimensions in the Transverse Plane in Individuals with Severe Motor and Intellectual Disabilities

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Abstract. [Purpose] The present study aimed to estimate the reliability of two protocols for measuring chest wall dimensions in the transverse plane in individuals (18 males, 12 females) aged 2 years 6 months to 58 years (mean age 34.7 ± 17.6) with Severe Motor and Intellectual Disabilities (SMID). [Subjects and Methods] For diagnosing pneumonia in individuals with SMID, 30 X-ray computed tomograms were taken at the level of the xiphisternal junction, scanned, and saved on a personal computer. Five therapists examined these images. Anteroposterior (AP) and laterolateral (LL) diameters were measured using two protocols. The largest AP and LL diameters were measured along the gravity line (protocol 1) and along the line where the middle point of the sternum connects with the spinous process of the vertebra (protocol 2). Intraclass correlation coefficients (ICCs) were calculated to estimate the intrarater and interrater reliability of each protocol. [Results] ICCs were >0.85 in protocols 1 and 2 for all measurements, showing these protocols are highly reliable for measuring chest wall dimensions in the transverse plane. [Conclusions] Measurements using these protocols are easy and cheap, and can be performed retrospectively, providing an effective way for evaluating chest wall deformity in individuals with SMID.
Key words: Severe Motor and Intellectual Disabilities, Chest wall deformity, Reliability

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INTRODUCTION

Chest wall deformity secondary to severe kyphoscoliosis occurs frequently in individuals with severe motor and intellectual disabilities (SMID). This deformity restricts lung function by reducing both chest wall compliance and the mechanical advantage of respiratory muscles, and can eventually result in pneumonia[1)].

To quantify the severity of chest wall deformity in children with cerebral palsy, Park et al. conducted measurements using anteroposterior view chest X-rays[2)]. However, this method is limited to the assessment of chest wall deformity in the coronal plane. Measurement in the transverse plane provides a better understanding of chest wall deformity as a three-dimensional condition.

For children with pectus excavatum (PE), Haller et al.[3)] reported a reliable method for measuring chest wall deformity in the transverse plane, using X-ray computed tomography (CT). In addition to this method, Lawson et al.[4)] recently began measuring the asymmetry of the chest wall in children with pectus excavatum. A study by Kilda et al. affirmed that CT allows more accurate assessment of relevant deformation indices, evaluation of chest shape, and asymmetry[5)].

Previous studies have not focused on measuring chest wall dimensions in the transverse plane to assess chest wall deformity in children with SMID.

In this study, we determined the intrarater and interrater reliability of our protocols to measure the chest wall dimensions in the transverse plane in individuals with SMID using personal computer (PC) images scanned from CT films.

SUBJECTS AND METHODS

Thirty individuals with SMID (18 males and 12 females, Gross Motor Function Classification System Levels V) recruited from Nishiotaru Hospital participated in this study. They were included if they had previously undergone chest CT scans (Asteion TSX-021B, TOSHIBA, Japan) for diagnosing pneumonia. The mean age was 34.7 years (SD=17.6 years, range=2–58). Ethics approval was granted from Nishiotaru Hospital, and informed consent was obtained from the parents or guardians of all participants.

Five therapists (one physical therapist and four occupational therapists) participated in this reliability study. They all had more than two years of experience in pediatric rehabilitation (range = 2 months–3.2 years).

Printed CT scan films of the chest wall in the transverse plane at the level of the xiphisternal junction were scanned (CanoScan LiDE 90, Canon, Japan) and saved on a PC. Each participating therapist was supplied with a manual according to the two protocols and 30 digital images of each individual with SMID. No formal training in measurement according to the protocol was provided. Anteroposterior (AP) and laterolateral (LL) diameters were measured by the two protocols on two occasions, one week apart.

In protocol 1, using Microsoft PowerPoint 2003® (PP), a digital image of the chest wall in the transverse plane was inserted in a slide, and a rectangle was drawn on the digital image. The rectangular length was matched to the largest AP diameter, and the width was matched to the largest LL diameter (Fig. 1). The digital image and rectangle were grouped and saved as a picture in JPEG format. The rectangular length and width were measured as AP and LL diameter using the public domain imaging processing program ImageJ®.

In protocol 2, a digital image of the chest wall in the transverse plane was inserted in a slide using PP. After a grid line was imposed on the slide, vertical and horizontal lines were drawn along the grid line. These lines were grouped as the perpendicular bisector. The perpendicular bisector was matched to the inclination and size of the sternum to provide the midpoint of the sternum (Fig. 2-A). A line was drawn connecting the midpoint of the sternum with the tip of the spinous process of a vertebra (Fig. 2-B). After drawing two rectangles, the right side of one rectangle length, and the left side on the other were matched to the connecting line. The rectangular length of each side was determined by the largest AP diameter of the side, and the rectangular side of each side was determined by the largest LL diameter of the side (Fig. 3). The digital image, perpendicular bisector, and rectangles were grouped and saved in JPEG format. ImageJ was used to measure AP and LL diameters. The length between A and B in Fig. 3 was measured as the AP diameter. The length obtained by adding the right rectangular side to the left was measured as the LL diameter.

Analyses were performed using the Statistical Package for Social Sciences (SPSS version 13.0). Intrarater reliability was assessed by calculating the Intraclass Correlation Coefficient (ICC; type 1: 1) and 95% confidence intervals (CI). Interrater reliability was assessed by calculating ICC (type 2: 1) and the associated 95% CI. An ICC greater than 0.75 was defined as good reliability[6].

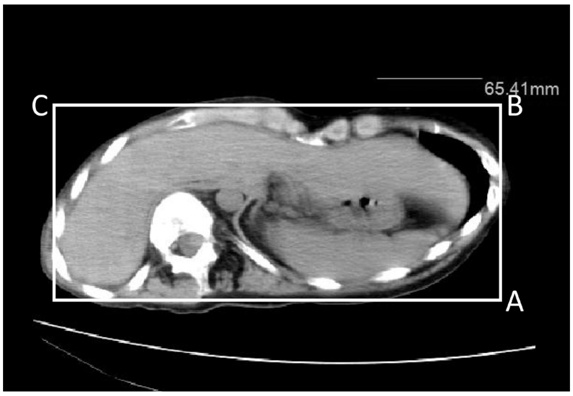

Fig. 1. Protocol 1 for measuring anteroposterior (A-B) and laterolateral (B-C) diameter.

Fig. 2. Protocol 2; The perpendicular bisector was matched to inclination and the size of sternum to provide the midpoint of the sternum (A). A line connecting the midpoint of the sternum with the spinous process of the vertebra was drawn (B).

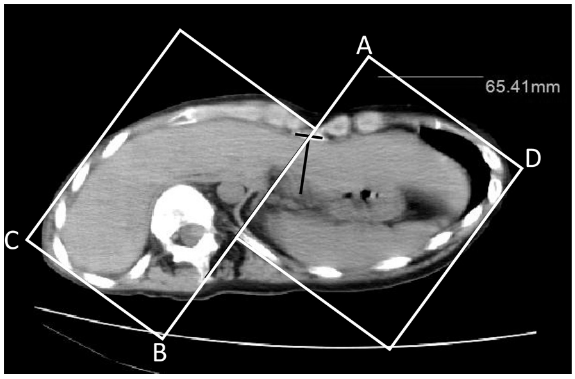

Fig. 3. Protocol 2 for measuring anteroposterior (A-B) and laterolateral (A-D plus B-C) diameter.

In connection with ICC, the standard error of measurement (SEM) was computed as SEM = SD_b*(√1-ICC), where SD_b is the SD of baseline scores[6]. The minimal detectable difference 95% (MDD_{95}) confidence interval (CI) was calculated at 95% CI to provide clinicians with information for determining whether scores on repeat evaluation reflect true change, where MDD_{95}(95% CI) = 1.96*SEM*√2[6].

Table 1. Data of the two protocols for measuring the chest wall in the transverse plane (mm)

		Protocol 1				Protocol 2			
		AP diameter		LL diameter		AP diameter		LL diameter	
		Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Baseline	Rater 1	173.7 (30.7)	128.0–230.3	264.2 (39.3)	197.6–330.5	196.2 (43.6)	133.5–297.7	252.3 (34.8)	196.0–312.9
	Rater 2	178.4 (33.0)	121.7–245.0	270.3 (47.0)	196.1–376.7	201.0 (50.2)	131.8–337.5	257.8 (38.5)	193.4–325.9
	Rater 3	178.0 (31.6)	130.3–249.4	269.5 (39.7)	199.0–347.1	199.3 (43.0)	134.4–310.7	257.3 (34.7)	197.3–327.5
	Rater 4	175.1 (32.2)	129.7–241.1	265.6 (41.8)	196.2–363.0	198.9 (47.8)	136.3–329.9	252.2 (36.3)	193.2–319.5
	Rater 5	17435 (29.0)	125.6–237.2	264.8 (40.0)	197.8–342.9	196.2 (44.3)	133.4–308.3	251.4 (33.3)	196.0–316.6
		Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Retest	Rater 1	172.9 (28.8)	125.1–230.0	263.3 (39.7)	197.1–363.0	193.7 (44.1)	129.9–324.6	251.7 (33.6)	194.3–312.3
	Rater 2	177.5 (31.5)	123.4–238.1	267.8 (41.6)	195.6–370.8	201.3 (47.8)	137.7–337.3	254.8 (36.8)	194.6–316.1
	Rater 3	175.0 (28.3)	130.3–236.3	267.0 (42.3)	199.0–373.1	197.7 (47.4)	134.4–337.2	254.0 (33.9)	197.4–313.7
	Rater 4	175.3 (30.0)	127.1–232.4	266.3 (43.8)	196.3–382.6	198.7 (46.9)	136.3–346.0	254.4 (37.0)	193.6–324.1
	Rater 5	174.5 (29.9)	123.7–227.7	264.6 (40.4)	199.7–344.8	196.2 (44.0)	133.3–313.7	254.8 (35.1)	197.7–314.5

AP, anteroposterior; LL, laterolateral; SD, standard deviation.

Table 2. Intrarater and Interrater reliability of the two protocols for measuring the chest wall in the transverse plane

				ICC (95%CI)	SEM	MDD95
intrarater reliability	Protocol 1	AP diameter	Rater 1	0.98 (0.91-0.99)	4.3	12.0
			Rater 2	0.94 (0.95–0.99)	8.1	22.4
			Rater 3	0.94 (0.88–0.97)	7.7	21.4
			Rater 4	0.97 (0.93–0.98)	5.6	15.5
			Rater 5	0.97 (0.94–0.99)	5.0	13.9
		LL diameter	Rater 1	0.96 (0.93–0.98)	7.8	21.8
			Rater 2	0.91 (0.83–0.96)	14.1	39.1
			Rater 3	0.93 (0.85–0.96)	10.5	29.1
			Rater 4	0.96 (0.92–0.98)	8.4	23.1
			Rater 5	0.97 (0.93–0.98)	6.9	19.2
	Protocol 2	AP diameter	Rater 1	0.97 (0.94–0.99)	7.6	21.0
			Rater 2	0.97 (0.93–0.98)	8.7	24.1
			Rater 3	0.96 (0.92–0.98)	8.6	23.8
			Rater 4	0.95 (0.91–0.98)	10.7	29.6
			Rater 5	0.97 (0.94–0.99)	7.7	21.3
		LL diameter	Rater 1	0.96 (0.91–0.98)	7.0	19.3
			Rater 2	0.87 (0.75–0.94)	13.9	38.4
			Rater 3	0.91 (0.82–0.96)	10.4	28.9
			Rater 4	0.92 (0.84–0.96)	10.3	28.4
			Rater 5	0.88 (0.76–0.94)	11.5	32.0
interrater reliability	Protocol 1	AP diameter		0.94 (0.91–0.97)	7.6	21.0
		LL diameter		0.92 (0.87–0.96)	11.6	32.3
	Protocol 2	AP diameter		0.95 (0.91–0.97)	10.1	28.1
		LL diameter		0.87 (0.80–0.93)	12.7	35.2

AP, anteroposterior; LL, laterolateral; ICC, intra class correlation coefficient;CI, confidence interval; SEM, standard error of measurement; MDD 95,minimal detectable difference at 95% confidence level.

RESULTS

The ICC (type 1: 1) was calculated to confirm intrarater reproducibility. In protocol 1, ICCs of the AP diameter ranged from 0.94 to 0.98, SEM from 4.3 to 8.1 mm, and MDD95 from 12.0 to 22.4 mm. ICCs of the LL diameter ranged from 0.91 to 0.97, SEM from 6.9 to14.1 mm, and MDD95 from 19.2 to 39.1 mm. In the calculation of ICC, a $p<0.001$ for all participating therapists, as well as for each diameter was obtained. In protocol 2, ICCs of the AP diameter ranged from 0.95 to 0.97, SEM from 7.6 to 10.7 mm, and MDD95 from 21.0 to 29.6 mm. ICCs of the LL diameter ranged from 0.87 to 0.96, SEM from 7.0 to 13.9 mm, and MDD95 from 19.3to 38.4 mm. In the calculation of the ICC, a $p<0.001$ for all participating therapists, as well as for each diameter was obtained.

The ICC (type 2: 1) was calculated to confirm interrater reliability. In protocol 1, the ICC of the AP diameter was 0.94, with SEM 7.6 mm and MDD95 21.0 mm. The ICC of the LL diameter was 0.92, with the SEM 11.6 mm and MDD95 32.3 mm. In the calculation of ICC, a $p<0.001$ for each diameter was obtained. In protocol 2, the ICC of the

AP diameter was 0.95, with SEM 10.1 mm and MDD95 28.1 mm. The ICC of the LL diameter was 0.87, with SEM 12.7 mm and MDD95 35.2 mm. In the calculation of ICC, a $p<0.001$ for each diameter was obtained.

DISCUSSION

In this study, we demonstrated that our two protocols are reliable for measuring chest wall dimensions in the transverse plane in individuals with SMID using digitized CT images. Our results demonstrate the reliability of the methods for evaluating chest wall deformity in individuals with SMID.

In this study, films of the chest wall in the transverse plane at the level of the xiphisternal junction were used because chest wall deformity in the transverse plane in individuals with SMID was most notable/ apparent in our pilot study. Protocol 1 was designed with reference to the Japanese Body Dimension Data for Ergonomic Design edited by the National Institute of Bioscience and Human-Technology 7, and protocol 2 was a modified version of protocol 1 because chest wall deformity in the transverse plane in individuals with SMID shows a lateral deviation of spine or sternum or both. The ICC values of intrarater and interrater reliability for all the measurements made by the participating therapists were above 0.85, and the lower limit of the 95% CI was above 0.75. These figures support the use of these two protocols. We previously demonstrated the high reliability of measurements of distance and length between the sternum and vertebra in individuals with SMID using digital images, PP, and ImageJ (in press, in Japanese with English abstract). Our protocols using digital images, PP, and ImageJ enable the assessment of main deformation indices for individuals with SMID.

The high levels of reliability were obtained in the absence of a formal training program. Expensive software is not necessary for these protocols, and we can perform measurements retrospectively even when we only have printed films. The ease of measurement, low cost, and ability to perform retrospective measurements increases the feasibility of the clinical implementation of this method. The protocols will provide rehabilitation practitioners with reliable measurement values for evaluating chest wall deformity in individuals with SMID that can be used to support clinical decisions about individual prognosis and management.

In children with PE, to avoid excessive exposure to X-rays, a single CT slice was taken on the most concave chest area during inhalation and exhalation. Many CT slices are needed for individuals with SMID because of the chest structure changes in the entire chest wall. This involves excessive exposure to X-rays when we evaluate chest wall deformity using these protocols. Alternative methods of measuring chest wall deformity in children with PE 8, 9 have been reported. Further study of chest wall deformity evaluation in children with SMID may be needed to avoid excessive exposure to X-rays.

In conclusion, our protocols using PC images of CT films have high reliability for measuring chest wall dimensions in the transverse plane in individuals with SMID. Measurements using these protocols are easy and cheap, and can be performed retrospectively, providing an effective way of evaluating chest wall deformity in individuals with SMID.

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