

# Bilateral and Unilateral Measurement of Chest Excursion

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## ABSTRACT

Twenty healthy male college students participated in measurement of the antero-posterior excursion of their right and left hemithoraces using a tape measure and a measuring caliper during volitional deep breathing. The results from these two measuring devices were compared to find out whether or not unilateral measurement of the thorax could be justified. There was a moderate correlation between the two measurements with a high correlation between the amount of hemithoraces excursion obtained by the caliper. There was no significant difference between the results of the right and left hemithoraces excursion, but the result obtained by the tape measure was significantly greater than that for each hemithorax obtained by the caliper, and the total excursion of the bilateral hemithoraces obtained by the caliper was larger than that from the tape measure. We can, therefore, conclude from these results that the caliper cannot be substituted for the use of a tape measure for measurement of hemithoraces excursion. However, the usefulness of the caliper method remains, but the measurement point should be placed on the mid-axillary line instead of at the junction of the 5th/6th costal cartilages in order to account for the crosswise movement of the lower half of the hemithoraces.

## KEY WORDS

chest excursion, bilateral and unilateral measurement, hemithorax

## INTRODUCTION

The role of the thorax has three functions. First and foremost, its structure is such that it allows for ventilatory movement to take place. Second, it provides a firm basis for insertion and origin of the neck, shoulder, and trunk muscles, so they can carry out their various functions. Third, it protects thoracic and upper abdominal viscera. The movement of the thorax is three-dimensional; antero-posterior direction is produced by upper costal expansion, crosswise direction by lower lateral costal expansion, and the superior-inferior direction by expansion produced by the rise of the two uppermost ribs and descent of the diaphragm<sup>1,2)</sup>. Therefore, the overall movement of the thorax is the result of a combination of movements in

all three directions.

A comparison of the crosswise expansion of the hemithoraces has been made by Nakamura<sup>3)</sup> and Mizuno<sup>4)</sup> for clients with hemiplegia. However, their method was limited in the assessment of entire thoracic mobility because no consideration was given to the structural changes which occur in the thorax such as those following unilateral thoracotomy.

Chest excursion measurements are commonly used to assess the effect of a lesion, disease, or surgery on thoracic movement. For instance, following thoracotomy the operated-on hemithorax loses some mobility due to incisional pain and costotomy, and the unoperated hemithorax may gain some compensatory motion. A chest expansometer, which measures chest

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excursion, has been devised<sup>5)</sup>, and Rodholm<sup>6)</sup> applied it successfully for measuring hemithorax excursion and reported that one out of four clients following unilateral thoracotomy demonstrated a decrease in hemithorax excursion on the operated side and an increase in excursion on the unoperated hemithorax. It is a known fact that there is a correlation between chest mobility and respiratory function<sup>7, 8)</sup>.

The purpose of this study was to find out whether there would be any correlation between the results obtained for chest excursion measurement by the tape measure and caliper methods. The significance of this study would be that, if any correlation occurred between the two without a significant difference between the results, unilateral measurement of the thorax would be justified. That is to say, it would be possible to assess any post-thoracotomy change in chest excursion on either the operated or unoperated hemithoraces. Similarly, a unilateral measurement may, then, also be possible on hemithoraces of clients such as hemiplegics and on any unilateral thoracic pathology.

#### PARTICIPANTS AND METHOD

**Selection of the participants** We selected 20 healthy male college students with a mean (and standard deviation or SD) age of 22.1 (2.7) years old, mean (SD) height 170.9 (4.8) cm, and mean (SD) weight 66.6 (8.2) kg, respectively. The participants demonstrated no past history of respiratory conditions or injuries to the trunk and chest.

**Measurement procedure** The measurement tools were a measuring caliper and a tape measure, the former a Martin-type human body measuring device comprised of a compass and two curved arms with a scale at the joint and used for measuring firm objects and thickness of fatty tissue. The latter was a five-metre plastic "Eslon" tape measure (Sekisui Inc., Japan). The measurement points on the thorax and position of the participants were decided as follows. The anterior measurement point was determined to be at the junction where the fifth and sixth costal cartilages merged on the anterior aspect of the thorax (× marks in Fig. 1). The horizontal distance from this point to the anterior midline of the body, which roughly corresponded with the xiphoid process, varied

from person to person because of their physique, so the distance for the anterior measurement points was calculated as  $a$  centimetres (cm) to the right and  $b$  cm to the left of the anterior midline. Next, a point on the posterior midline of the body corresponding with the thoracic spinal process and on a level with the anterior measurement point was selected as the posterior measurement point. The posterior measurement point on each participant's thorax was determined by being  $a$  cm away to the right and  $b$  cm away to the left of the posterior midline.

The participants, with their upper body exposed and seated on a chair, had both upper limbs relaxed by their sides. For the measurement with the caliper the tip of each arm was placed on each respective × mark anteriorly and posteriorly. The tips of the caliper arms were firmly held by the examiner's hands so that the caliper did not deviate during rib movement. The measurement with the tape measure was also carried out at the level of the × marks. The participant was instructed to concentrate his attention to the area where the caliper or tape measure was placed. The examiner read the scale on the caliper and tape measure and recorded the readings following the verbal commands below :

"Breathe out as slowly and deeply as possible"  
(deep expiration)

"Next, breathe in as slowly and deeply as possible"  
(deep inspiration)

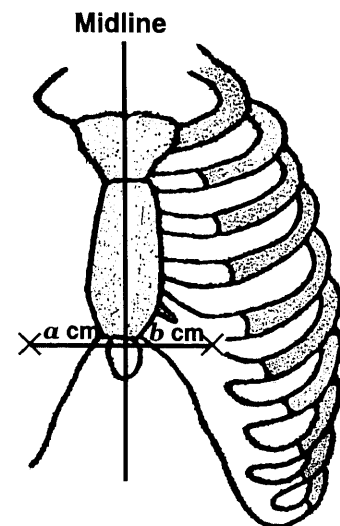


Fig. 1 Determination of the measurement points  
× : Anterior measurement points only

"Now, breathe out as slowly and deeply as possible" (deep expiration)

The amount of chest excursion was measured in centimetres with an increment of 0.5 cm. The excursion of the whole thorax and each hemithorax was calculated using the following formulae :

$$\begin{aligned} \text{Chest excursion} &= TM\beta - TM\alpha \text{ or } TM\gamma \\ \text{Right hemithorax excursion} &= \\ &CR\beta - CR\alpha \text{ or } CR\gamma \\ \text{Left hemithorax excursion} &= \\ &CL\beta - CL\alpha \text{ or } CL\gamma \end{aligned}$$

Where

- TM* = amount measured by the tape measure
- CR* = amount measured on the right hemithorax by the caliper
- CL* = amount measured on the left hemithorax by the caliper
- $\alpha$  = antero-posterior movement of the hemithorax in deep expiration
- $\beta$  = antero-posterior movement of the hemithorax in deep inspiration
- $\gamma$  = antero-posterior movement of the hemithorax in deep expiration

The lesser of  $\alpha$  or  $\gamma$  was chosen for calculating chest excursion. Alternately, the right and left hemithorax and the whole circumference of the thorax were measured three times each for all the participants. The highest of the three measurements was taken as the antero-posterior (AP) excursion of the hemithorax and excursion of the whole thorax. Data collection took place at three separate testing sessions. The actual procedure was carried out by one investigator (HY) to prevent inter-tester variability in the measurement. The ambient room temperature was maintained at 18 to 24 degrees Celsius during the procedure. The procedures and risks of the study were explained to the participants before the measurement took place, and they were asked to sign an informed consent sheet.

**Data Analysis** Calculations were made so as to obtain the correlation coefficient of the values for *TM*, *CR*, and *CL*<sup>9</sup>. A one-way analysis of variance (ANOVA) was employed to calculate *TM*, *CR*, *CL* and the total of *CR* and *CL*. Using the following

formulae and employing the one-way ANOVA we calculated the rates of change derived from the amount of chest excursion measured by the tape measure and caliper :

$$\begin{aligned} TMr &= \frac{TM}{TM\alpha \text{ or } TM\gamma} \times 100 \\ CRr &= \frac{CR}{CR\alpha \text{ or } CR\gamma} \times 100 \\ CLr &= \frac{CL}{CL\alpha \text{ or } CL\gamma} \times 100 \end{aligned}$$

Where

- TMr* = the rate of change in the amount measured by the tape measure
- CRr* = the rate of change in the amount measured by the caliper on the right hemithorax
- CLr* = the rate of change in the amount measured by the caliper on the left hemithorax

The Student's t test was employed with the level of significance at 0.05.

## RESULTS

There was a moderate correlation between *TM* and *CR* and between *TM* and *CL*, and a high correlation between *CR* and *CL* (Table 1).

The mean (SD) *TM* was 5.3 (1.9), *CR* 3.5 (0.8), *CL* 3.4 (0.9), and *CR* and *CL* 6.9 (1.7), respectively. The one-way ANOVA revealed that : there was no statistical difference between *CR* and *CL* ; *TM* was significantly larger than *CR* and *CL* ; and the total of *CR* and *CL* was significantly larger than *TM* (Fig. 2, Tables 2 and 3).

The mean (SD) *TMr* was 6.5 (2.5) %, *CRr* 19.4 (5.5) %, and *CLr* 19.3 (6.2) %, respectively. The one-way ANOVA revealed that there was no statistical significance between *CRr* and *CLr*, and *TMr* was significantly larger than either that of *CRr* or *CLr* (Fig. 3, Tables 4 and 5).

## DISCUSSION

Because of the significant difference in chest excursion between the results of measurements using the

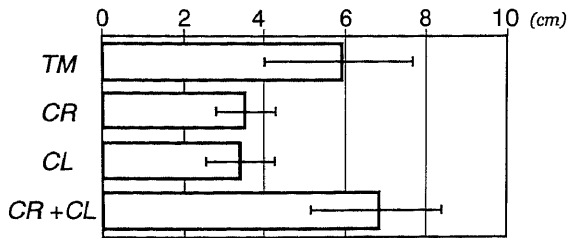


Fig. 2 Mean chest excursion of the whole thorax and hemithoraces. Error bars denote one standard deviation. For abbreviation, see the text.

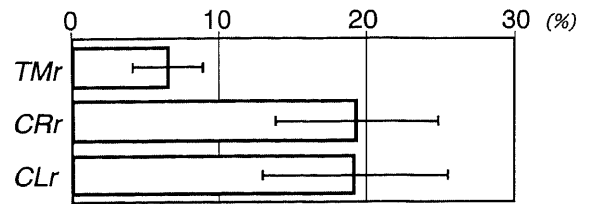


Fig. 3 The rate of change in TMr, CRr, and CLr. Error bars denote one standard deviation. For abbreviation, see the text.

Table 1 Correlation coefficients for TM, CR, and CL. For abbreviation, see the text.

Correlation coefficient	TM	CR	CL
TM	---		
CR	0.47	---	
CL	0.61	0.90	---

Table 2 One-way analysis of variance for measure of mean absolute error by chest excursion measurements. SS, sum of squares ; df, degree of freedom ; MS, mean squares ; p, probability of no difference between relevant effects at significant level  $p \leq 0.05$

Source of Variance	SS	df	MS	F	p
Between measurements	171.08	3	57.03	27.29	0.0001
Within measurements	159.08	76	2.09		
Total	330.28	79			

Table 3 The Student's t test for chest excursion measured by the tape measure and caliper methods. For abbreviation, see the text. \*\*  $p < 0.0001$

TM	---			
CR	4.34**	---		
CL	4.48**	0.14	---	
CR+CL	3.16**	7.50**	7.64**	---
	TM	CR	CL	CR+CL

Table 4 One-way analysis of variance for measure of mean absolute error by the rate of change. SS, sum of squares ; df, degree of freedom ; MS, mean squares ; p, probability of no difference between relevant effects at significant level  $p \leq 0.05$

Source of Variance	SS	df	MS	F	p
Between changes	0.22	2	0.11	36.67	0.0001
Within changes	0.15	57	0.003		
Total	0.37	59			

Table 5 The Student's t test for the rate of change in TMr, CRr, and CLr. For abbreviation, see the text. \*\*  $p < 0.0001$

TMr	---		
CRr	7.42**	---	
CLr	7.39**	0.002	---
	TMr	CRr	CLr

tape measure and caliper it was found that the caliper cannot be substituted for the use of a tape measure for hemithoraces excursion measurement, although there was a correlation between *TM* and *CR* and between *TM* and *CL*. Chest excursion measurement with a caliper reflects antero-posterior movement of the

hemithorax, whereas, with a tape measure, the measurement reflects not only antero-posterior movement of the bilateral hemithoraces but also incorporates crosswise movement.

When comparing these two methods, a further question arose of whether or not thoracic motion

should be considered as a circular expansion or rectangular expansion. For instance, if thoracic motion is assumed to be a circular expansion with the radius as  $r$  and the amount of expansion as  $dr$ , then measurement by the tape measure produces an equation  $2\pi(r + dr) - 2\pi r = 2\pi dr$ , and the rate of change  $2\pi dr/2\pi r = r/dr$ , respectively.

On the contrary, if we assume that the thorax moves in a rectangular expansion with the length as  $l$  and the width as  $w(l < w)$ , the lengthwise expansion would be expressed as  $dl$  and widthwise expansion as  $dw$ . Therefore, chest excursion measurement with the tape measure method would yield  $2\{(l + dl) + (w + dw)\} - 2(l + w) = 2(dl + dw)$  and the caliper method  $dl$ , respectively. In addition, the rate of change would be  $2(dl + dw)/2(l + w) = (dl + dw)/(l + w)$  with the tape measure method and that with the caliper method  $dl/l$ , respectively. Therefore, if  $dw$  is not zero on the assumption that it is a rectangular movement, then there would be no significant difference in circumference using the tape measure method, even though combined excursion could be accounted for by the caliper method. Further, there might be no significant difference even in the rate of change, if  $w$  or the lateral diameter, were measured.

The findings of this study indicate the following : first, the motion of the thorax should be considered as that of a rectangular motion rather than of a circular motion. Second, we cannot totally disregard the question of a crosswise expansion.

Chest excursion for the present study was measured at the level of the xiphoid process. The consensus is that this level is the most important for chest excursion measurements because chest mobility is highest at this level<sup>9)</sup>. However, the xiphoid process is in the domain of the lower thorax, and the crosswise motion is largest at this level, which estimates  $dw$  to be larger. This may explain one of the reasons for why there was a significant difference in the chest excursion between the tape measure and caliper measurements.

The following questions arose from this study. First, the level at the axillary folds is in the domain

of the upper thorax, and antero-posterior expansion is comparatively larger at this level than that of crosswise expansion. Therefore, this may explain the question of why the differences in chest excursion measurements by a tape measure and caliper did not yield a significant difference. Second, considering the above fact, the measurement points used for the caliper measurement at the level of the xiphoid process should be placed more laterally on the mid-axillary line instead of on the fifth-sixth costal junction, so that the bucket-handle and caliper-type movement of the lower ribs would be fully accounted for during chest excursion measurement.

A potential limitation of this study may be the uncertainty of the intra-tester reliability of hemithorax excursion measurements. Although the intra-tester reliability of the whole chest girth has already been established<sup>10, 11)</sup>, it did bring into focus this important point.

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## 胸郭可動域の対称性・非対称性測定

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### 要 旨

一般に胸郭可動域は巻尺を用いて胸囲を測るという左右対称的な測定であるが, 一側胸郭の個別測定, すなわち非対称的な測定と同一視できるのかについて検討した。対象は平均年齢 $22.3 \pm 2.8$ 歳の健常男子大学生20名であった。測定点は第5・第6肋軟骨の接合部およびその真裏の2点とした。巻尺の場合には測定点の高さで深呼吸時と深吸息時の胸囲, 人体計測用キャリパーの場合には一側胸郭の測定点にその各腕を当て, 深呼吸時と深吸息時の目盛を各半側胸郭の可動域とした。巻尺による胸郭可動域とキャリパーによる右胸郭可動域, および巻尺による胸郭可動域とキャリパーによる左胸郭可動域にはかなりの相関が認められたが, 巻尺によるものと左右の半側胸郭可動域の比較では, 前者が有意に大きかった。しかし左右の半側胸郭可動域を合算したものは巻尺によるものに比べて有意に大きかった。巻尺が胸郭の前後方向と左右方向の拡張の両者を反映するのに対し, キャリパーによる半側胸郭可動域の測定では前後方向の動きしか反映しない。剣状突起の高さでの周径においてキャリパーを用いる場合には測定点を中腋窩線上に求めるほうがよいかもしれない。