RESEARCH ARTICLE

Ratio for upper, middle and lower chest expansion in healthy Malaysian adults aged 20 to 40 years

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Abstract:

Background: Assessment of chest expansion by using the cloth tape measurement (CTM) has been reported to have between moderate and strong measurement properties. The test is used as a routine assessment technique in cardiorespiratory physiotherapy and is taught in undergraduate physiotherapy course. However, it appears that the test was done quite differently between studies and interpreted in various ways among the clinicians. Purpose: To determine the ratio for upper, middle and lower chest expansion among adults aged 20 to 40 years and to investigate whether change in test position (sitting vs. standing) affects the upper, middle and lower chest expansion. Method: Students and staff at Faculty of Health Sciences, UiTM were approached to participate in this study. Anthropometric and demographic data were taken. Assessment of chest expansion was done using CTM at three landmarks (i.e. upper [2nd intercostal space], middle [4th intercostal space] and lower [xiphoid] chest). The measurement was taken three times in two positions (i.e. sitting and standing). Result: Mean chest expansion for all participants (n=212) in sitting and standing positions for upper, middle and lower chest were 3.3±1.4cm, 3.7±1.2cm, and 3.2±1.4cm (1.03:1.16:1; p>0.05), and 3.4±1.3cm, 3.5±2.4cm and 3.1±1.5cm (1.1:1.13:1; p>0.05), respectively. There was no significant different in expansion between upper, middle and lower chest in different test positions in all participants (p>0.05). Conclusion: Although middle chest has the biggest expansion, the expansion ratio between the other levels is about the same. There is not much change in chest expansion when measurement was taken in either sitting or standing.

Keywords: Cardiorespiratory physiotherapy, chest-expansion, cloth-tape measurement

1. INTRODUCTION

Assessment of chest expansion by using cloth tape measurement (CTM) was first introduced in 1972 by Moll & Wright [1] as an objective tool to measure mobility of the thoracic cage. In this study, CTM was used in both healthy individuals (n=262) and patient population (ankylosing spondylitis [n=37], chronic chest disease [n=31] and obese [n=22]) and they found that CTM is a sensitive tool to discriminate difference in thoracic cage mobility between patient and healthy individuals. Since then, several studies have been published reporting the validity, reliability and responsiveness of CTM as a measure of thoracic cage mobility. With regard to validity, CTM has been reported to have between moderate to strong association with electromagnetic sensor (r=0.53-0.60; p<.05) and laser displacement sensor (r=0.46-0.50; p<0.01) in measuring chest expansion in healthy adults. Mohan et al. and Bockenhauer et al. [2-3] have reported ICC between 0.93 to 0.97 and 0.85 to 0.97 for CTM over test repetition. The tool has also been reported to be responsive to change following physiotherapy intervention such as chest percussion, postural drainage and breathing exercises in patients with ankylosing spondylitis, chronic obstructive pulmonary diseases (COPD) and asthma [4-6]. However, despite the strong psychometric properties for CTM as a tool to measure thoracic cage mobility, it appears that the method used for interpreting the results from CTM varies greatly between clinicians/ institutions. Some used i) ratio 1:2:2 for upper: middle: lower chest expansion in male and 2:2:1 for female, ii) ratio of 1:2:3 for both genders and iii) 1-2cm for upper chest, 2-3cm for middle chest and 3-5cm for lower chest. Surprisingly, all of these interpretation strategies were not backed by evidence and no literature or previous research were found stating as such.

Other than studies are limited reporting the interpretation strategies of the CTM, the only two studies that produced reference values to estimate the results of CTM also yielded two inconsistent findings. Specifically, Pagare & Pedhambkar [7] conducted a study on reference value for chest expansion in Pune, India found that the lower chest produced the biggest expansion among the three levels of the chest while a study conducted in Ile Ile, Nigeria [4] found that the upper chest has bigger chest expansion when compared to the lower chest. We hypothesised that the differences whether the upper chest or the lower chest has bigger expansion could be due to the difference in position when the measurement was taken. For example, Ackermann et al. [8] stated that standing position increased the activation of abdominal muscles and the dimension of the abdominal cavity. This may affect the chest expansion resulting in bigger lower chest expansion in standing when compared to the measurements taken in supine. Factors such as differences in assessment protocol could also have influenced the discrepancies in findings.

Hence this study was carried out to (i) determine the ratio for upper, middle and lower chest expansion measurement and (ii) investigate whether change in position of the participant (sitting vs. standing) affects the upper, middle and lower chest expansion.

2. MATERIAL AND METHODS

2.1 Research design

This was a cross-sectional observational study where the collection of the data was taken only once. The research study was approved by the Human Research Ethics Committee (HREC) of UiTM (600 TNCPI [5/1/6]). All the participants of this research study were told about the nature and outcome of the study and written informed consent was taken prior to data collection.

2.2 Participants

The participants of the study were the staffs and students of UiTM Puncak Alam Campus. The students were recruited from advertisement which were blasted through social media application (e.g. WhatsApp) while the staffs were recruited through visiting their offices and asking them if they would like to participate in the study. The inclusion criteria were volunteers aged between 20 and 40 years with normal Body Mass Index (BMI) of 18.5 – 24.9 Kg/m^2. Individuals with history of pulmonary disease, surgery in the chest area and a smoking history of more than 10 pack years were excluded from the study.

2.3 Sampling size and sampling method

The Gpower 3.1 software was used to calculate the sample size. A total of 212 participants was required for this research study. The participants were selected through convenience sampling. A convenience sample is a data collection method where the participants approached are those easily accessible and willing to participate in this study as volunteers. The required 212 participants were then stratified to two groups based on gender and age category. The ratio was decided based on the population of the age group in the study setting.

2.4 Procedure

Anthropometric data (e.g. height, body weight and Body Mass Index) and demographic data such as age and gender were taken. Assessment of chest expansion was done using the cloth tape measurement (CTM) at three landmarks (i.e. upper, middle and lower chest). The anatomical landmarks used were as followed; (i) 2nd intercostal space for the upper chest, (ii) 4th intercostal space for the middle chest and (iii) the xiphoid process for the lower chest. The measurement was taken in two positions. For assessment in sitting position, the participant was asked to sit in an upright position on a chair with back supported, knees and ankles at 90◦ and hands rested on hips. For assessment in standing position, the participant was asked to stand with elbows slightly flexed so that the hands rested on hips.

Before taking the measurements, the participants were first told to exhale the air as much as possible then take the deepest breath possible. The difference between full expiration and full inspiration was recorded. Measurement were taken three times at all three levels and the average were recorded.

2.5 Statistical analysis

Data were analysed by using the Social Package of Social Sciences (SPSS) version 23.0. Descriptive statistics were used to compute the mean and standard deviations of the demographic data and to compute the mean value for chest expansion at upper, middle and lower chest. Paired t-test was used to test the difference in measurement of chest expansion at three levels (upper, middle and lower) between sitting and standing position. Statistical significance was taken at p-value less than 0.05.

3. RESULT AND DISCUSSION

3.1. Participants

A total of 212 participants were recruited (**Figure 1)** and the demographic data of the participant are presented in **Table 1**.

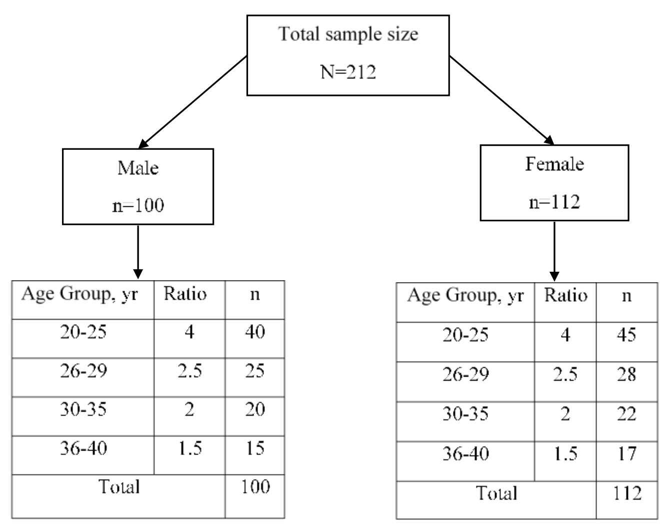

Figure 1. Sample stratification based on gender and age group

Table 1. Demographic characteristic of the study participants

	All (N=212)		Male (n=100)		Female (n=112)	
	Mean ± SD	n (%)	Mean ± SD	n (%)	Mean ± SD	n (%)
Age, yr	28 ± 6		28 ± 6		28 ± 6	
20-25	23 ± 2	85 (40)	23 ± 1	40 (40)	22 ± 2	45 (40)
26-29	27 ± 1	53 (25)	27 ± 1	25 (25)	27 ± 1	28 (25)
30-35	32 ± 2	42 (20)	32 ± 2	20 (20)	32 ± 2	22 (20)
36-40	38 ± 1	32 (15)	38 ± 2	15 (15)	38 ± 1	17 (15)
Height, m	1.6 ± 0.1		1.7 ± 0.1		1.6 ± 0.1	
Weight, Kg	61.8 ± 10.3		68.2 ± 9.0		56.0 ± 7.6	
BMI, Kg/m^2	23.1 ± 2.5		23.9 ± 2.8		22.4 ± 2.0	

Abbreviations: BMI, body mass index; SD, standard deviation.

3.2. Chest Expansion at three levels and their ratio

The chest expansion measurement at upper, middle and lower chest and their ratio in sitting and standing positions are presented in Table 2.

The first objective of this study was to determine the ratio for upper, middle and lower chest expansion in healthy adults aged between 20 and 40 years. This study hypothesized that chest expansion increases from the upper chest to the lower chest. The result showed that it is on the contrary. In Table 2, for all of the participants, it is shown that the middle chest has the biggest expansion compared to the other levels. It is then followed by the upper chest and lastly the lower chest which has the smallest expansion among them all.

In contrast, a study done in India [7] found that among the three levels, the lower chest has the biggest expansion. Specifically, they found that in both males and females, the lower chest has the biggest chest expansion followed by upper chest and lastly the middle chest.

On the other hand, Adedoyin et al. [4] who conducted the study in Nigeria and Abd Ali et al. [9] who conducted the study in Iraq have found similar findings. Both studies found that the upper chest had the greatest expansion compared to the lower chest. The result found by Pagare & Pedhambkar [7], differ from study by Adedoyin et al. and Abd Ali et al. [4,9], even though their participants position when the measurement was taken was the same (standing).

Table 2. Chest Expansion Measurement at three levels and their ratio

	All (N=212)		Male (n=100)		Female (n=112)	
	Sitt. Mean±SD	Std. Mean±SD	Sitt. Mean±SD	Std. Mean±SD	Sitt. Mean ± SD	Std. Mean ± SD
Upper, cm (2nd ICS)	3.3 ± 1.4 (1.0 - 5.3)	3.4 ± 1.3 (0.8 - 7.2)	3.8 ± 1.6 (1.2 - 5.3)	4.0 ± 1.2 (1.5 - 7.2)	2.9 ± 1.0 (1.0 - 5.0)	3.0 ± 1.2 (0.8 - 6.2)
Middle, cm (4th ICS)	3.7 ± 1.2 (0.7 - 7.2)	3.5 ± 2.4 (7.3 - 7.5)	3.9 ± 1.1 (0.7 - 7.2)	3.6 ± 3.3 (7.3 - 7.5)	3.5 ± 1.3 (1.0 - 7.0)	3.5 ± 1.1 (1.5 - 5.8)
Lower, cm (Xiphoid)	3.2 ± 1.4 (0.5 - 6.5)	3.1 ± 1.5 (2.0 - 7.3)	3.7 ± 1.3 (1.0 - 7.0)	3.8 ± 1.5 (2.0 - 7.3)	2.7 ± 1.3***** (0.5 - 6.0)	2.5 ± 1.2***** (0.5 - 6.0)
Ratio	1.03 : 1.16 : 1	1.10 : 1.13 : 1	1.03 : 1.05 : 1	1.11 : 1 : 1.06	1.07 : 1.30 : 1	1.2 : 1.4 :1

Abbreviations: ICS, intercostal space; Std., standing; sitt., sitting. *$p<0.05$ for the different between sitting and standing position, $p<0.05$ for the different between upper, middle and lower chest expansion.

The inconsistent findings may be explained by the fact that different races have different lung functions. Adedoyin et al [4] stated that white race has a greater lung function compared to that of African-American and Nigerian. Whittaker et al. [10] found that white race has a larger Force Vital Capacity (FVC) and Force Expiratory Volume in the first second (FEV_1) compared to Asians of the same height. Whittaker et al. [10] further stated that ethnic plays a significant role in predicting lung function.

As the matter of fact, Reddy et al. [11] and Lanza et al. [12] stated that lung function parameters (FVC, FEV_1 /FVC and VC) positively correlate with chest expansion measurements. Lanza et al. [12] further elaborated that a greater lung function will lead to a larger chest expansion. This was also supported by Kim et al. [13] that stated respiratory function is connected to the chest expansion of an individual. This suggest that different race and ethnicity have different lung function parameters thus affects the chest expansion measurement obtained. As to how different race has different lung function parameters, Whittaker et al. [10] suggest that it may be due to difference in lung and chest wall compliance and inspiratory muscle strength.

The result of this study appears to be consistent with previous studies [4,9] who both found that the upper chest was bigger than the lower chest. It is also important to note that although they found that upper chest has bigger expansion than the lower chest, the landmark they used for upper chest was similar (5^{th} spinous process of thoracic vertebra vs. 4^{th} intercostal space) to the landmark we used for middle chest. The 5^{th} thoracic vertebra is located on the same level as the 5^{th} rib as they articulate posteriorly to the thoracic vertebrae [14] while the 4^{th} intercostal space lies just above the 5^{th} rib. This may suggest that the upper chest expansion measurement taken [4,9] may actually represents the expansion for the middle chest.

Mohan et al. [2] stated that 4^{th} intercostal space represents the right middle and left lingular lobe of the lungs. Heřmanová et al. [15] supported this by stating that the horizontal fissure (that separates the right middle lobe from the right upper lobe) meet the anterior thoracic wall at the level of the 4^{th} rib. This showed that the 4^{th} intercostal space and the 5^{th} rib which is just below it, best represents the middle chest and not the upper chest. Thus, making the findings from previous studies [4,9] may actually be that the middle chest has biggest expansion and not the upper chest.

The reason on why the middle chest has the biggest expansion compared to other levels could be due to the biomechanics of the rib cage during breathing. Gan et al. [6] stated that the upper thoracic region, is mainly anterior-posterior direction expansion or pump-handle motion, whereas lower thoracic region is mainly lateral direction expansion or bucket-handle motion. This might cause the upper chest and middle chest to expand larger than the lower chest.

3.3. Chest expansion in sitting and standing positions

The second objective of this study was to investigate whether change in position from sitting to standing affects the upper, middle and lower chest expansion. As seen in Table 2, this study found that only the lower chest in females have significant difference in chest expansion when test position is changed from sitting to standing ($p<0.05$).

Although the female lower chest expansion was bigger in sitting than standing, given that data on Minimal Clinically Important Differences (MCID) for chest expansion has not been established, it is difficult to conclude whether the 0.2 cm difference make a difference. In fact, a study on intrarater reliability of chest expansion using CTM conducted by Mohan et al. [2] found that the standard error of mean (SEM) at the xiphoid level (lower chest) was 0.1 cm while Reddy et al. [11] found that the SEM for ranged from as high as 0.81 cm to 1.3 cm. This suggest that the 0.2 cm difference found in this study, although statistically significant ($p<0.05$), may occur due to standard error when taking the mean value as the subject changes position from sitting to standing.

Although there was a difference in chest expansion when changing position from sitting to standing in all the participants and in males, the differences were not statistically significant ($p>0.05$). This may suggest that chest expansion measurement can be taken in both position (standing and sitting) as it does not affect the expansion of the upper, middle and lower chest significantly.

Brożek et al. [16] found that FVC and FEV_1 value was higher in standing then in sitting but the difference did not reach statistically significant. Brożek et al. [16] also suggested that there was no difference of FVC and FEV_1 value during standing or sitting. Patel & Thakar [17] agreed to this as it is found that the mean difference of the FVC and FEV_1 between standing and sitting were small and not statistically significant. Thus, small change that occur in FVC and FEV_1 in sitting and standing may not affect the chest expansion.

4. CONCLUSION

In conclusion, the findings of this study show that i) in all participants, the middle chest had the greatest chest expansion followed by the upper and then the lower chest, ii) an expansion of $\geq$ 3cm is regard as normal chest expansion in all three levels (upper, middle and lower chest) and iii) there was no difference in chest expansion when measurement is taken in either sitting or standing position; thus practitioner may choose the position that best suits their patients ability when performing the test (at baseline or re-assessment).

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