MJIT 2016 Malaysian Journal of Industrial Technology

CONCURRENT VALIDITY OF CHEST WALL EXPANSION BETWEEN CLOTH TAPE MEASURE, ELECTROMAGNETIC AND LASER DISPLACEMENT SENSORS

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Abstract

Chest wall expansion examination previously has been determined by cloth tape measure using circumference approach. There may be a potential to measure chest wall expansion using new technological devices such as electromagnetic and laser displacement sensors. However, research studies that compare these two measurement approaches are scarce. The objective of this study was to determine the concurrent validity of chest wall expansion using cloth tape measure, electromagnetic and laser displacement sensors. This cross-sectional study involved 62 males aged 18-30 years. Upper and lower chest expansions were measured using cloth tape measure, electromagnetic and laser displacement sensors. Spearman's rho analysis showed that there was a significant moderate positive correlation ($p<0.01$) between chest wall expansion measured using cloth tape measure, electromagnetic sensor ($r=0.53$-0.60) and laser displacement sensor ($r=0.46$-0.5). The study results suggest that there is concurrent validity (analysed using correlation test) between chest wall expansion using tape cloth measure, electromagnetic sensor and laser displacement sensor. However, further studies are required to compare chest wall expansion measurements to a gold standard measurement tool.

Keywords: Chest wall expansion; Circumference; Anteroposterior; Cloth tape measure; Electromagnetic sensor; Laser displacement sensor; Concurrent validity;

1.0 INTRODUCTION

Chest wall expansion examination is one of the crucial assessments for respiratory function. It can be considered as an indicator of respiratory muscle function in rheumatological [1] and neuromuscular diseases [2]. Besides, pulmonary conditions such as obstructive and restrictive diseases have an effect on chest wall expansion [3]. Decreased thoracic chest wall expansion results in increased oxygen consumption, fatigue exacerbation and shortness of breath [4]. Reduced lateral rib movements in obstructive lung disease have also been reported [5]. It is important to assess chest wall expansion in order to determine efficacy of physiotherapy intervention. It is normally performed by comparing the measurements to the person's baseline measurements [6].

Chest expansion measurement is the subtraction of thoracic circumference at end of forced inspiration and thoracic circumference at the end of forced expiration [7]. Human chest rib movements can be divided into upper and lower ribs in terms of biomechanical differences. Upper rib movement (Pump-handle motion) increases in anteroposterior diameter of the chest, while lower rib movement (Bucket-handle motion) increases in transverse diameter of the chest [8]. Hence, clinical assessment of the chest wall expansion is based on these two levels, with different measurements on both upper and lower regions of the chest wall. The most common anatomical marker for upper chest measurement is third intercostal space at midclavicular line parallel to the level of fifth thoracic spinous process [7]. Lower chest measurement marker is at the tip of xiphoid process parallel to the level of the tenth thoracic spinous process [7].

The traditional instrument tool to measure chest expansion is cloth tape measure (CTM) through circumferential measurements at specific points on the chest wall [9]. The tape should be conformed to the chest wall by ensuring there is no compression on the underlying soft tissues [10]. CTM chest expansion measurements is performed in medical settings for monitoring lung function in conditions such as ankylosing spondylitis [3], chronic obstructive pulmonary disease [11] and cystic fibrosis [12]. It is reported to be reliable in obtaining chest wall measurements among healthy individuals [13] with intra-class correlation coefficient (ICC) ranging from 0.90-0.97 for upper and lower thoracic regions [14].

In recent years, skin attached electromagnetic sensors (EMS) has been tested for the use of clinical measurements. Measurement tools that produce magnetic field such as EMS are known to affect the accuracy of the results if there are metals in the feild [15]. Nevertheless, this instrument has been used to measure head movements [16], [17], body sways [18] and thoracolumbar curvatures [19]. Respiratory movement measuring instrument (RMMI) has also been used for measuring changes in anteroposterior thoracic and abdominal diameters during breathing [20].

Another potential chest expansion measurement tool is laser displacement sensor (LDS). It is a contactless tool that uses 650nm of laser light source that is capable of measuring reliable rough surface with a measuring range from 250 to 1,000mm [21]. Respiratory activity usually happens with small displacement of the chest cavity and this instrument is suitable to detect this small motion, such as respiratory rate [21]. LDS is deduced to have better measurement speed and is more comfortable in cases with infectious disease [21]. However, whether it can be used to measure chest expansion is not known.

There are a few devices used for measuring chest wall expansion via circumference [22]-[25] and anteroposterior measurements [15], [20]. However, information regarding correlation between chest wall expansion measurements using CTM, EMS and LDS is not available. Since both EMS and LDS are known to be able to measure movement displacement on the human body, there is a potential for these instruments to be used for measurement of anteroposterior chest wall expansion. The aim of the present study was to determine the concurrent validity of chest wall expansion using cloth tape measure (CTM), electromagnetic (EMS) and laser displacement (LDS) sensors.

2.0 METHODOLOGY

Study Procedure

This cross-sectional study was conducted at Universiti Kebangsaan Malaysia, Kuala Lumpur Campus. Ethical approval was obtained from UKM Research Ethics Committee (UKM1.5.3.5/244/NN-100-2015) prior to conducting the study.

Male participants aged between 18 to 30 years old were invited through flyers that were distributed around the university residential area. Participants with history of pulmonary diseases such as asthma, pneumonia, tuberculosis, chest deformity (such as barrel chest, pigeon chest, funnel chest), spinal deformities (kyphosis, kyphoscoliosis, scoliosis), and those who have had any injury or surgery at the thoracic region (thorax injury, rib fracture) were excluded from the study.

The sample size was calculated using Bonett's open source R function CIcorr [26]-[28]. 95% confidence interval half-widths with estimated Pearson correlation values |r|=0.90 was used. 62 participants were required for this study.

Participants who fulfilled the inclusion criteria of the study were given written and verbal information regarding the study prior to obtaining their informed written consent. Participants' demographic information was obtained.

Prior to the measurement of chest wall expansion using these three different devices, all the participants were taught to perform correct breathing technique [29]. Participants were instructed to "breath in/out as maximum as possible, make yourself as big/small as possible" [30].

Participants were required to expose their upper body for marking measurement reference points using a skin marker pencil in upright sitting position with knees and ankles at 90° with arms relaxed on the thighs. Two anatomical surface markings were palpated and marked by the researcher for upper chest measurements that included third intercostal space at the midclavicular line for anterior region and the level of fifth thoracic spinous process for the posterior region. For the lower chest measurements, the tip of the xiphoid process and the level of the tenth thoracic spinous process was palpated and marked for anterior and posterior region respectively.

For all tests, participants were required to perform three chest wall expansion by breathing in and out in erect sitting position on a wooden chair with back and arm rest with hands resting on the thighs. A 3-minute-interval was provided between each test. The average of the three chest wall expansion measurements' score were recorded and used for further analysis. All three tests were performed in random order by the participant to reduce bias

Instrumentations

Cloth Tape Measure (CTM)

CTM was held circumferentially around the upper chest wall according to the marking reference points by the researcher (as in Figure 1). Three chest wall expansion measurements were performed and measurement readings recorded. The procedure was repeated at the lower chest wall according to the marking reference points as described previously.

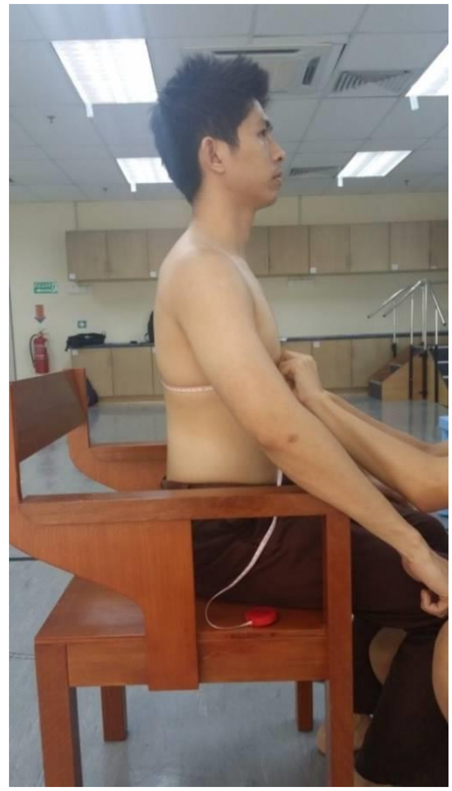

Fig. 1. Chest Wall Expansion using CTM

Electromagnetic Sensor (EMS) (Patriot, Polhemus, 40 Hercules Dr, Colchester, Vermont, USA)

The sensors were placed on the marking reference points of the upper chest wall by using double-sided adhesive tape on the anterior and posterior aspects of chest wall. The receiver was fixed on an adjustable chair approximately 30cm (12 inches) at the same height in line with the sensors at the anterior aspect of chest region (as in Figure 2 and 3). Three chest wall expansion measurements were taken. The procedure was repeated by placing the sensors on the marking reference points of lower chest wall. All data collected was recorded for further analysis using Matlab.

Fig. 2. Chest Wall Expansion using EMS and its Sensor Placement

Fig. 3. Chest Wall Expansion using EMS and its receiver placement

Laser displacement sensor (LDS)

LDS (LK-G507, Keyence, Corp. USA) was fixed on an adjustable chair approximately 500mm away from the participant's chest wall at the same height of the marking reference points of the upper chest wall (as in Figure 4). During the three chest wall expansions, the laser was irradiated continuously on the chest wall. The procedure was repeated by adjusting the sensor onto the marking reference points of lower chest wall. All data collected was recorded for further analysis using Matlab.

Fig. 4. Chest Wall Expansion using LDS

Data Analysis

Data was analyzed using Statistical Package for Social Sciences (SPSS) version 22.0 (IBM Corp., Armonk, New York). Descfigure 100riptive analysis was used to determine demographic characteristic and chest wall measurements using cloth tape measure (CTM), electromagnetic sensor (EMS) and laser displacement sensor (LDS). Spearman's rho correlation test was used to determine the correlation between of chest wall expansion using CTM, EMS and LDS.

3.0 MAIN RESULTS

A total of 62 males between the ages of 18 to 30 years with ideal BMI participated in this study. The summary of participants' characteristics are as shown in Table 1. Median chest measurement for upper and lower chest expansions using the three measurement tools are as in Table 2.

Social-Demographic Characteristics	**Total Mean ± SD Total n = 62**
Age (years)	21.97 ± 1.70
Weight (kg)	65.35 ± 12.97
Height (m)	1.71 ± 0.06
Body Mass Index (BMI) (kg/m^2)	22.15 ± 3.69

Table 1. Characteristics of Participants.

Device	CTM (Circumference)		EMS (Anteroposterior)		LDS (Anterior)	
	Upper Chest (cm)	Lower Chest (cm)	Upper Chest (cm)	Lower Chest (cm)	Upper Chest (cm)	Lower Chest (cm)
Median (Range)	3.52 (1.63-8.53)	3.82 (1.40-9.00)	2.82 (1.27-6.40)	2.47 (1.18-5.26)	2.60 (0.67-6.41)	2.18 (0.79-4.67)

Table 2. Chest wall measurement using cloth tape measure, electromagnetic sensor and laser displacement sensor.

There was significant moderate positive correlation ($p<0.05$) between chest expansion measurements using CTM, EMS and LSD ($r= 0.46-0.60$).

	Upper Chest				Lower Chest			
	EMS		LDS		EMS		LDS	
	r	p value	r	p value	r	p value	r	p value
CTM	0.53	< 0.001	0.60	< 0.001	0.46	< 0.001	0.51	< 0.001

Table 3. Correlation of chest wall expansion using cloth tape measure, electromagnetic sensor and laser displacement sensor.

4.0 DISCUSSION

Our study results showed that there was a significant moderate positive correlation between cloth tape measure (CTM), electromagnetic sensor (EMS) and laser displacement sensor (LDS) in measuring chest wall expansions. In the best of the authors' knowledge, this is the first study to correlate chest wall expansion measurements between CTM, EMS and LSD.

The average chest expansion circumference for upper and lower chest were 3.52cm (1.63-8.53cm) and 3.82cm (1.40-9.00cm) respectively. It was lower compared to measurements from a previous study involving healthy adults [31]. Lower level of chest wall expansion may be related to lower lung function [32] and levels of physical fitness [33]. Participants in our present study were office workers and university students who had sedentary lifestyle with low to moderate level of physical activity levels. Greater cranio-caudal direction expansion compared to other directions during deep breathing could have been due to lower average anteroposterior chest expansion values [34].

Correlation results were better at upper chest (0.53-0.60) compared to lower chest (0.46-0.51). This could be due to the normal biomechanics of the rib cage during breathing. Upper thoracic region, is mainly anterior-posterior direction expansion ("pump-handle" motion), whereas, lower thoracic region is lateral direction expansion ("bucket-handle" motion). There is also greater rib cage dominance in deep breathing that may have led to larger measurement values [35]. The overall correlation results showed a significant moderate positive correlation ($r = 0.46-0.60$). This may be due to more ventral direction chest movements compared to dorsal direction during breathing [36].

We would also like to highlight that LDS has a visual image was displayed concurrently during chest wall expansions. This special feature may be of interest to therapist as it can be used as a biofeedback system during chest wall expansion training. Effectiveness and advantage of biofeedback systems for re-education of dysfunctional muscles have been suggested previously [37].

The limitation of our study was that only male participants were involved and this limits generalization of study results. However, it is known that there is greater chest wall expansion in males compared to females during deep breathing in sitting position [15]. The study was limited to males to minimize variability in results that can be affected by gender. Next, the chest wall measurements of two levels (upper and lower thoracic) may be insufficient to quantify the overall correlation between circumference, that included anteroposterior or anterior approaches only. This was due to the constraints of the skeletal structures itself at the lateral abdominal wall and the normal breathing biomechanics. Hence, restriction of the lateral expansion and tendency of more ventral direction expansion is possible [36].

Chest wall measurement may also be complicated with the difference due to positions and postures. A difference between supine lying and standing position was reported but no difference between supine lying and sitting position was noted in chest wall measurements [38]. Significant greater thoracic expansion was demonstrated in sitting compared to supine lying position [15]. For example in intensive care unit (ICU), patients who are immobilized or bed-ridden will be prevented from changing to sitting position due to unstable vital signs [39]. Therefore, it will be beneficial in future studies to measure chest wall expansion in both lying and sitting positions using these tools and determine if there are any differences in the measurements.

5.0 CONCLUSION

Our study presents concurrent validity of chest wall expansion between cloth tape measure (circumference), electromagnetic sensor (anteroposterior) and laser displacement sensor (anterior) among young male participants. Our study also demonstrated feasibility of electromagnetic sensor and laser displacement sensor in measuring chest wall expansion in either anteroposterior or anterior approach.

6.0 ACKNOWLEDGEMENT

We would like to thank all participants and support staffs at School of Rehabilitation Sciences, UKM for their support and cooperation throughout this study. This study is supported using a grant from Universiti Kebangsaan Malaysia (AP-2014-014).

References

[1] Şahin G, Çalikoğlu M, Özge C, Incel N, Biçer A, Ulşubaş B, et al. Respiratory Muscle Strength but Not BASFI Score Relates to Diminished Chest Expansion in Ankylosing Spondylitis. Clinical Rheumatology. 2004; 23(3): 199-202.

[2] Feldman D, Ouellette M, Villamez A, Massery M, Cahalin L. The Relationship of Ventilatory Muscle Strength to Chest Wall Excursion in Normal Subjects and Persons with Cervical Spinal Cord Injury. Cardiopulmonary Physical Therapy Journal. 1998; 9(4): 20.

[3] Sharma J, Senjyu H, Williams L, White C. Intra-Tester and Inter-Tester Reliability of Chest Expansion Measurement in Clients with Ankylosing Spondylitis and Healthy Individuals. Journal of the Japanese Physical Therapy Association. 2004; 7(1): 23-28.

[4] Ando T, Kawamura K, Fujitani J, Koike T, Fujimoto M, Fujie MG. Thoracic ROM Measurement System with Visual Bio-Feedback: System Design and Biofeedback Evaluation. 2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, hlm. 2011; 1272-1274.

[5] Gilmartin J, Gibson G. Abnormalities of Chest Wall Motion in Patients with Chronic Airflow Obstruction. Thorax. 1984; 39(4): 264-271.

[6] Adedoyin RA, Adeleke OE, Fehintola AO, Erhabor GE, Bisiriyu LA. Reference Values for Chest Expansion among Adult Residents in Ile-Ife. Journal of Yoga & Physical Therapy. 2012; 1-4.

[7] Bockenhauer SE, Chen H, Julliard KN, Weedon J. Measuring Thoracic Excursion: Reliability of the Cloth Tape Measure Technique. The Journal of the American Osteopathic Association. 2007; 107(5): 191-196.

[8] Hillegrass EA, Sadowsky HS. Essentials of Cardiopulmonary Physical Therapy. Philadelphia, PA: W.B. Saunders Company. 2001.

[9] Clarkson HM. Joint Motion and Function Assessment: A Research-Based Practical Guide. Lippincott Williams & Wilkins. 2005.

[10] Marriott BM, Grumstrup-Scott J. Body Composition and Physical Performance: Applications for the Military Services. National Academies Press. 1992.

[11] Malaguti C, Rondelli RR, De Souza LM, Domingues M, Dal Corso S. Reliability of Chest Wall Mobility and Its Correlation with Pulmonary Function in Patients with Chronic Obstructive Pulmonary Disease. Respiratory Care, 2009; 54(12): 1703-1711.

[12] Custers J, Arets H, Engelbert R, Kooijmans F, Van Der Ent C, Helders P. Thoracic Excursion Measurement in Children with Cystic Fibrosis. Journal of Cystic Fibrosis. 2005; 4(2): 129-133.

[13] Lapier TK, Cook A, Droege K, Oliverson R, Rulon R, Stuhr E, et al. Intertester and Intratester Reliability of Chest Excursion Measurements in Subjects without Impairment. Cardiopulmonary Physical Therapy Journal. 2000; 11(3): 94-98.

[14] Mohan V, Dzulkifli NH, Justine M, Haron R, Leonard JH, Rathinam C. Intrarater Reliability of Chest Expansion Using Cloth Tape Measure Technique. Bangladesh Journal of Medical Science. 2012; 11(4): 307.

[15] Kaneko H, Horie J. Breathing Movements of the Chest and Abdominal Wall in Healthy Subjects. Respiratory Care. 2012; 57(9): 1442-1451.

[16] Chow YW. Low-Cost Multiple Degrees-of-Freedom Optical Tracking for 3D Interaction in Head-Mounted Display Virtual Reality. International Journal of Recent Trends in Engineering. 2009; 1(1): 52-56.

[17] Mason R, Kim C, Brookes T. Taking Head Movements into Account in Measurement of Spatial Attributes. Proceedings of the Institute of Acoustics Reproduced Sound Conference, hlm. 2008; 239-246.

[18] Varela DG, Carneiro JaO, Colafêmina JF. Static Postural Balance Study in Patients with Vestibular Disorders Using a Three Dimensional Eletromagnetic Sensor System. Brazilian Journal of Otorhinolaryngology. 2012; 78(3): 7-13.

[19] Singh DK, Bailey M, Lee R. Biplanar Measurement of Thoracolumbar Curvature in Older Adults Using an Electromagnetic Tracking Device. Archives of Physical Medicine and Rehabilitation. 2010; 91(1): 137-142.

[20] Ragnarsdóttir M, Kristinsdottir EK. Breathing Movements and Breathing Patterns among Healthy Men and Women 20–69 Years of Age. Respiration. 2006; 73(1): 48-54.

[21] Gan KB, Yahyavi ES, Zahedi E, Mohd. A. MA. Performing Contactless Respiration Rate Measurement Using an Optical Displacement Sensor and LabVIEW. National Instruments. 2012; http://sine.ni.com/cs/app/doc/p/id/cs-14796.

[22] Wang HK, Lu TW, Liing RJ, Shih, TTF, Chen SC, Lin KH. Relationship between Chest Wall Motion and Diaphragmatic Excursion in Healthy Adults in Supine Position. Journal of the Formosan Medical Association. 2009; 108(7): 577-586.

[23] Leino K, Nunes S, Valta P, Takala J. Validation of a New Respiratory Inductive Plethysmograph. Acta Anaesthesiologica Scandinavica. 2001; 45(1): 104-111.

[24] Merritt CR, Nagle HT, Grant E. Textile-Based Capacitive Sensors for Respiration Monitoring. IEEE Sensors Journal. 2009; 9(1): 71-78.

[25] Tawa H, Yonezawa Y, Maki H, Ogawa H, Ninomiya I, Sada K, et al. A Wireless Breathing-Training Support System for Kinesitherapy. 2009 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, hlm. 2009; 5179-5182.

[26] Moinester M, Gottfried R. Sample Size Estimation for Correlations with Pre-Specified Confidence Interval. Quant Methods Psychol. 2014; 10:124-130.

[27] Bonett DG. CIcorr.R and sizeCIcorr.R. 2014.

[28] R Foundation for Statistical Computing. R: A Language and Environment for Statistical Computing. 2011.

[29] Page P, Frank C, Lardner R . Assessment and Treatment of Muscle Imbalance: The Janda Approach. Human Kinetics. 2010.

[30] Olsén MF, Lindstrand H, Broberg JL, Westerdahl E. Measuring Chest Expansion; A Study Comparing Two Different Instructions. Advances in Physiotherapy. 2011; 13(3): 128-132.

[32] SN Syazwani SA. Nilai Rujukan untuk Pengembangan Dada di kalangan Dewasa yang Sihat: Kajian Keratan Rentas. Degree Thesis, Program Fisioterapi, Pusat Pengajian Sains Rehabilitasi, Universiti Kebangsaan Malaysia. 2015.

[33] Chanavirut R, Khaidjapho K, Jaree P, Pongnaratorn P. Yoga Exercise Increases Chest Wall Expansion and Lung Volumes in Young Healthy Thais. Thai J Physiol Sci. 2006; 19(1): 1-7.

[34] Rosenthal M, Bain S, Cramer D, Helms P, Denison D, Bush A, et al. Lung Function in White Children Aged 4 to 19 Years: I--Spirometry. Thorax. 1993; 48(8): 794-802.

[35] Leong J, Lu W, Luk K, Karlberg E. Kinematics of the Chest Cage and Spine During Breathing in Healthy Individuals and in Patients with Adolescent Idiopathic Scoliosis. Spine. 1999; 24(13): 1310.

[36] Verschakelen JA, Demedts MG. Normal Thoracoabdominal Motions. Influence of Sex, Age, Posture, and Breath Size. American Journal of Respiratory and Critical Care Medicine. 1995; 151(2): 399-405.

[37] De Groote A, Wantier M, Chéron G, Estenne M, Paiva M. Chest Wall Motion during Tidal Breathing. Journal of Applied Physiology. 1997; 83(5): 1531-1537.

[38] Nishigaki Y, Mizuguchi H, Takeda E, Koike T, Ando T, Kawamura K. Development of New Measurement System of Thoracic Excursion with Biofeedback: Reliability and Validity. Journal of neuroengineering and rehabilitation. 2013; 10(1): 1.

[39] Harris J, Johansen J, Pedersen S, Lapier TK. Site of Measurement and Subject Position Affect Chest Excursion Measurements. Cardiopulmonary Physical Therapy Journal. 1997; 8(4): 12-17.