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Original Research

Clarifying acromial distance: Standardisation and association between supine and sitting positions

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ABSTRACT

Objectives: To define a standardised acromial distance (AD) in relaxed, supine position and its cut-point with sensitivity and specificity for classifying pectoralis minor (PMI) shortness. To clarify a predictive value of AD while relaxed, supine (AD2) from AD while sitting (AD1), adjusted by the effect of body mass index (BMI).
Design: Cross-sectional;
Setting: Laboratory of Physical Therapy Faculties.
Participants: Eighty-five participants aged 18–38 years.
Main outcome measures: A standardised-AD was proportionate of AD at scapular retraction (AD3) to AD2. AD1 was clarified as a predictive variable for AD2 in circumstances of adjusted BMI.
Results: The cut-point of standardised-AD for PMI shortness was equal to or above 0.61. The sensitivity and specificity were 75.64% and 85.71%. AD2 was 0.355 time of AD1 when adjusted for effect of BMI. This cumulative effect may be able to explain AD2 for 41.4% of the variation in the AD1 and BMI around its mean.
Conclusions: Standardised-AD may be suitable to reflect PMI shortness while supine. Application for clinical practise may estimate AD2 from AD1 by summation of the effect of BMI. When designing postural education for correcting PMI shortness while lying, efficacy may be a concern in transfer to upright or functional position.

1. Introduction

The pectoralis minor (PMI) line runs from the third, fourth, and fifth ribs to the coracoid process of the scapula. Shortening of the PMI is one of the causes of scapular dysfunction, rounded shoulder or forward shoulder posture (Kibler, 2009; Lee, Cynn, Yi, Kwon, & Yoon, 2015). It also causes an increase of the scapular internal rotation and anterior tilting (Borstad & Ludewig, 2002, 2005, 2006; Borstad, 2006; Ludewig & Reynolds, 2009). Two major methods to define shortness of PMI in clinical practise have been purposed. The first method is measuring the pectoral muscle, on the anatomical surface of the pectoralis minor (Borstad, 2008; Borstad & Ludewig, 2005). The second method is inferred from acromial distance (AD) in relaxed, supine position with arms placed by the side and elbows flexed (Sahrmann, 2002) or in an upright position (Peterson et al., 1997; Struyf et al., 2009). The AD is more relevant in clinical practise for both sexes than the first method.

In the upright position, AD is a horizontal distance between the posterior border of the acromion and the wall. This position has been approved for validity and reliability. For validity of AD while standing, moderate correlation to radiographs that used the bony landmarks of the spinous process of the seventh cervical vertebra and the anterior tip of the left acromion process as reference points has been confirmed (Peterson et al., 1997). The acceptable reliability of AD measured in upright standing or sitting positions was previously presented (Laudner, Wenig, Selkow, Williams, & Post, 2015; Struyf et al., 2009; Viriyatharakij, Chinkulprasert, Rakthim, Patumrat, & Ketruang, 2016). For PMI shortness, only a cut-point for AD while supine was defined and was at least 25.4 mm (Sahrmann, 2002). However, a limitation found in clinical

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application of this cut-point is the high possibility for individuals to have AD more than 25.4 mm (Lewis & Valentine, 2007; Struyf et al., 2009, 2013). As reported, the sensitivity and specificity following the cut-points were 100% and 0%, from participants diagnosed with and without symptoms (Lewis & Valentine, 2007). The next concern was the variety of average ADs reported when derived from different actions (Lewis & Valentine, 2007; Struyf et al., 2013), such as AD at scapular retraction (Nijs, Roussel, Struyf, Mottram, & Meeusen, 2007; Struyf et al., 2009, 2013). Another notification was that AD derived while sitting consistently presented higher distances as compared to AD while supine. However, the association of AD while sitting has not been certified with the conventional method or AD while supine. Other than position and action, some variations in body dimensions may affect AD. One example of this was shown by the PMI index that adjusted PMI length by height (Borstad & Ludewig, 2005). Because the PMI attaches to the ribs, significant correlations between body mass index (BMI) and chest area (Ghoshhajra et al., 2011), and between weight and chest circumference (Wells, Treleaven, & Cole, 2007), were found. Though, AD may also be affected by BMI. The next factor to be of concern is change in the PMI length from the resting position. A shorter PMI may cause more difficulty to move into retraction position from resting position than the lengthened one. Then, clarifying PMI shortness by adjusted AD retraction based on resting AD may be more suitable than a definite value from one static position. Clinical application of PMI shortness may qualify the effect of different positions, actions, BMI and change of PMI length based on resting. A new cut-point for classifying PMI shortness should be defined. This study had two objectives: the first was to define a standardised-AD while supine and a cut-point for classifying PMI shortness that represented both high sensitivity and specificity. The second was a predictive value of AD while supine from sitting position as clarified by adjusting the effect of BMI as a potential confounding factor of AD. The relevance of the results will provide a practical application for AD for assessment or implementation of intervention.

2. Materials and methods

Eighty-five participants were recruited by purposive sampling and signed informed consent to join in this cross-sectional study. The inclusion criterion was participants who had no pain in the upper extremities and neck by active movement screening. The exclusion criterion was participants that had scoliosis. The setting of this study was the laboratories in the Physical Therapy Faculties. Participant characteristics and ADs of the dominant arm were recorded. ADs were defined as the distance of the acromion angle perpendicular to the reference surface. Three ADs were measured from two starting positions: AD1 was measured while upright sitting on a chair in the first sequence. While, AD2 and AD3 were measured while supine lying in bed, and sequentially measured from relaxation to scapular retraction. Participants were instructed to retract both scapulars as much as possible and maintain normal breathing during measurements. All of the AD measurements were performed in inhaled position by a standard L-square ruler with a water level. Two well-trained physical therapists (WT and CS) independently conducted AD measurements. Accordingly, they were blinded to each other. Minimising the measurement error was also controlled by assigning a specific physical therapist to process measurements for only one position of ADs in this study. Two measurements for each AD were averaged. Upright sitting on a chair was controlled by hip-knee angle flexion at 90° and feet flat on the floor. Furthermore, participants were not allowed to lean their trunk against the wall. For lying, all participants lied with no pillow and placed both forearms and hands on their tummy to decrease the tension on the short head of the biceps brachii (Lewis & Valentine, 2007). The standardised-AD, a cut-point, sensitivity and specificity of standardised-AD and an association between AD1 and AD2 as a predictive model were analysed in sequence.

2.1. Statistical analyses

All characteristics of participants are presented as mean and 95% confidence interval (CI). Intra-tester reliability of all AD measurements was analysed by intraclass correlation (ICC 3, 1). Standard error of measurement (SEM) $= SD\sqrt{(1 - ICC)}$ and minimal detectable change at 95% CI (MDC95 $= 1.96$*SEM) were clarified for the error of measurement of each AD. Sample size was calculated from alpha was 0.05, power was 80, expected R^2 was at least 0.2 and effect size was 0.25. Therefore, at least 65 participants were deemed appropriate for multiple regression analysis with two predictors (Erdfelder, FAul, Buchner, & Lang, 2009). The standardised-AD or proportion of AD3 to AD2 was calculated by dividing AD3 by AD2. A cut-point for defining PMI shortness as analysed by receiver operating characteristic (ROC) analysis, based on the definition of AD2, was at least 25.4 mm. Sensitivity, specificity, and likelihood ratio (LR) were analysed. The association of AD1 and AD2 as clarified by regression analysis and the predictive value of AD while supine (AD2) from sitting position (AD1) delivered in the circumstance of multiple regression analysis was adjusted for the effect of BMI as a potential confounding factor. Standardised beta coefficient (beta) was analysed to compare the strength of the effect of each individual independent variable (AD1 and BMI) to the dependent variable (AD2). A stronger effect will correspond to a higher absolute value of the beta coefficient.

3. Results

All characteristics of the 85 participants, aged between 18 and 38 years, are presented in Table 1. Intra-rater reliability of all AD measurements presented excellent reliability as shown in Table 2. In the sitting position, the 95% CI of ICC was 0.879–0.998. In the supine position, the 95% CI was 0.976–1.00, and for the supine position with scapular retraction it was 0.998–1.00 (Table 3). The upper boundary of MDC95 for AD1 and AD2 were 2.49 and 2.34 mm. While that of the AD3 was 0.65 mm.

According to the standardised-AD, a cut-point less than 0.61 (or 0.605) was an acceptable change of PMI length. If the standardised-AD was equal to or above 0.61 (or 0.605), the participants were defined as having PMI shortness. The sensitivity and specificity were 75.64% and 85.71%. LR+ was 5.295 and LR-was 0.284 as shown in Fig. 1. The ranges of 95% CI of areas under the curve (AUC)

Table 1
Characteristics of all participants.

Characteristics	n	Mean	SE	95% CI (lower - upper boundary)	
Sex: female, male; n (%)	73(85.9), 12(14.1)				
Age; yrs	85	24.4	0.6	23.1,	25.6
Weight; kg	84	57.0	1.2	54.6,	59.5
Hight; cm		159.8	0.6	158.5,	161.1
BMI; kg/m^2		22.3	0.4	21.4,	23.2
Acromial distance	85				
AD1; mm		71.3	1.4	68.5,	74.1
AD2; mm		41.8	1.3	39.2,	44.3
AD3; mm		28.2	1.1	26.0,	30.4
Standardised-AD		0.67	0.01	0.64,	0.70

Abbreviations: AD - acromial distance; position of AD1 was sitting, AD2 was relaxed, supine and AD3 was supine with scapular retraction; SE - standard error; CI - confidence interval.

Table 2
Intraclass correlation coefficient, standard error of measurement and minimal detectable change of the acromial distance while sitting, supine, relaxed and supine with scapular retraction.

Acromial distance	ICC	95% CI (lower – upper boundary)		SEM	95% CI (lower – upper boundary)		MDC95	95% CI (lower – upper boundary)	
AD1	0.983	0.879	0.998	0.48	0.18	1.27	0.93	0.35	2.49
AD2	0.997	0.976	1.000	0.42	0.17	1.20	0.83	0.33	2.34
AD3	1.000	0.998	1.000	0.07	0.05	0.33	0.14	0.09	0.65

Abbreviations: AD - acromial distance; position of AD1 was sitting, AD2 was relaxed, supine and AD3 was supine with scapular retraction; ICC - intraclass correlation; SEM - standard error of measurement; MDC95 - minimal detectable change at 95% confidence interval; CI - confidence interval.

Table 3
Multiple regression analysis for predicting association of AD1 and BMI to AD2.

Acromial distance in relaxed, supine (AD2)	Coefficient	95% CI (lower – upper boundary)		Standardised (beta) coefficient	Adjusted R^2
AD1 in sitting; mm	0.355	0.193	0.517	0.388	0.414
BMI; kg/m^2	1.195	0.684	1.705	0.414	
Constant	−10.045	−23.482	3.392		

Abbreviations: AD - acromial distance; position of AD1 was sitting, AD2 was relaxed supine; BMI - body mass index; CI - confidence interval.

Cut-point	equal to or above 0.61
Sensitivity; %	75.64
Specificity; %	85.71
Likelihood ratio	
LR+	5.295
LR-	0.284
Area under curve	0.808
95% CI (lower; upper boundary)	0.634; 0.982

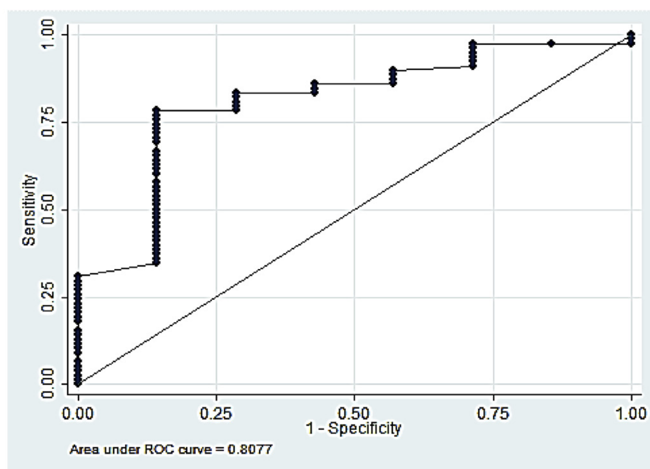

Fig. 1. Receiver operating characteristic (ROC) analysis for defining PMI shortness.

were 0.634–0.982.

Multiple regression was analysed based on 84 participants as one participant did not fill out weight and height information. The predictive value of AD2 was estimated as 0.355 times AD1 when BMI was constant in the predictive model in Table 3. The predicted value of AD2 was 1.195 times BMI when AD1 was constant. After adjusting for the effect of BMI, the R^2 in a simple regression analysis increased from 0.272 to 0.428 and the adjusted R^2 was 0.414. Thus, the cumulative effect of AD1 and BMI may be fit to explain AD2 for 41.4% of the variation in AD1 and BMI around its mean. The beta coefficient presented contribution of AD1 and BMI on AD2 was that AD1 shared 38.8% and BMI shared 41.4%.

4. Conclusions

This study evaluated ADs in different positions and actions. When in retraction, the scapula will be rotated externally and moves more parallel to the bed. Thus, leading to AD3 being less than AD2, in accordance with previous studies (Struyf et al., 2009, 2013). By taking the baseline into account, the relative change of PMI length or standardised-AD may be suitable to reflect shortness of PMI and be more appropriate for comparison between individuals. Based on a classical shortness of PMI as AD2 $\geq$ 25.4 mm (Sahrmann, 2002), the ROC analysis presented a standardised-AD cut-point less than 0.61 as acceptable to determine no shortness of PMI. Alternatively, participants would be defined as having PMI shortness if the standardised-AD was above or equal to 0.61 (or 0.605). This cut-point reflected high sensitivity and specificity and was acceptable for both LR+ and LR-. LR + showed the probability that an individual with PMI shortness and standardised-AD positive (true positive) in reference to the probability that an individual would not have PMI shortness but a standardised-AD positive (false positive). While LR-presented the probability that an individual with PMI shortness but standardised-AD negative (false negative) in reference to the probability that an individual would not have PMI shortness and a standardised-AD negative (true negative). In addition, the results showed a high average for AUC that was 0.808 and the range of lower to upper boundaries was 0.634–0.982. A previous study predicted forward scapular posture by including PMI length in multiple regression analysis (Lee et al., 2015). However, the PMI length was measured on the anatomic pectoral area, and the cut-point for forward scapular posture was referenced from

AD in the upright position. No sensitivity and specificity were presented.

Comparison between positions should consider the effect of this potential confounder. Although, this effect can by identified by adjusting for potential confounders in the multiple regression model. After being adjusted, AD1 and BMI had positive significant correlation to AD2 and the association presented by the adjusted R^2 was approximately 41%. The range of AD2 was approximately 0.2–0.5 times for each increasing unit of AD1 as BMI was constant. While the range of AD2 was approximately 0.7–1.7 times for each increasing unit of BMI as AD1 was constant. BMI was a confounder as it improved the adjusted R^2 from 0.263 to 0.414. For comparing the strength of the effect, the beta coefficient of BMI shared a slightly stronger effect (0.414) than that of AD2 (0.318). The additional variable age did not contribute meaningfully to the predictive value in the model. Application for clinical practise based on the estimation of AD2 may be one-third of AD1 by summation with 1.2 times BMI. For further studies, standardised-AD less than 0.61 may be used to evaluate no PMI shortness while supine. When designing stretching or postural education for correction of PMI shortness while lying, efficacy may concern the transfer to upright or functional position from length of PMI, as lying on a bed is a position with less effect of gravity than the upright position. The generalisability of this study is the scope of determining PMI shortness by AD measurement.

4.1. Limitation of this study

This study presented the association between factors that affect PMI shortness based on participants that BMI were less than 30 kg/m^2 and gender proportions were not balanced. For predicting association of AD1 and BMI to AD2, a prediction interval may be an optional exploratory for clinical implication.

Ethical approval

The study was approved by Ethical approved by Ethic Committee for Human Research of Srinakharinwirot University (PTPT2017-007) and Saint Louis College, Thailand (47/2560).

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Declaration of interest

None declared.

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