Prediction model of rhomboid major and pleura depth based on anthropometric features to decrease the risk of pneumothorax during dry needling

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Abstract

Background: Although mostly common adverse events associated to dry needling can be considered minor, serious adverse events including induced pneumothorax cannot be excluded, and safety instructions for reducing the risk of pleura puncture are needed. Objective: To investigate if anthropometric features can predict the rhomboid major muscle and pleura depth in a sample of healthy subjects to avoid the risk of pneumothorax during dry needling. Methods: A diagnostic study was conducted on 59 healthy subjects (52.5 % male) involving a total of 236 measurements (both sides in maximum inspiration and expiration), to calculate the accuracy of a prediction model for both pleura and rhomboid depth, as assessed with ultrasound imaging, based on sex, age, height, weight, body mass index (BMI), breathing and chest circumference. A correlation matrix and a multiple linear regression analyses were used to detect those variables contributing significantly to the variance in both locations. Results: Men showed greater height, weight, BMI, thorax circumference and skin-to-rhomboid, rhomboid-to-pleura y skin-to-pleura distances ($p<0.001$). Sex, BMI, and thorax circumference explained 51.5% of the variance of the rhomboid ($p<0.001$) and 69.7% of pleura ($p<0.001$) depth limit. In general, inserting a maximum length of 19 mm is recommended to reach the deep limit of rhomboid major decreasing the risk of passing through the pleura. Conclusion: This study identified that gender, BMI and thorax circumference can predict both rhomboid and pleura depth, as assessed with ultrasonography, in healthy subjects. Our findings could assist clinicians in the needle length election for avoiding the risk of induced pneumothorax during dry needling.

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Abstract

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Keywords: Rhomboid Muscle; Dry Needling; Ultrasound Imaging; Pneumothorax; Clinical Decision Rules

What's already known about this topic?

Although the estimated risk rate of significant adverse events during dry needling procedures is [?] 0.04%, it cannot be excluded

Different strategies including palpation of the ribs before dry needling have been proposed. However, the authors reported poor accuracy in subjects with larger muscle thickness and higher body mass index

What does this article add?

This is the first calculating the accuracy of a prediction model including multiple anthropometric features

Sex, body mass index, and thorax circumference explained 51.5% of the variance of the rhomboid major deep limit and 69.7% of pleura depth

What is the 'take-home' message for the clinician?

Clinicians should use needles no longer than 25mm to avoid an accidental pleura puncture since the lower limit of rhomboid major lower limit ranges from 11.6 mm to 16.2 mm and the pleura could be needled at 19.6-27.7 mm of depth

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Introduction

One frequent muscular impairment observed in individuals with chronic pain is myofascial pain syndrome (MPS), characterized by the presence of myofascial trigger points (MTrPs). A MTrP is defined as a hyper-irritable spot in a taut band of a skeletal muscle which is painful on stimulation (e.g., palpation, stretch, contraction, or needling), elicits referred pain, and induces motor or autonomic disturbances[1]. Active MTrPs are those which pain referral reproduces the symptoms of the patient, whereas latent MTrPs are those which referred pain does not reproduce the symptoms of the patient[1].

Myofascial trigger points have been found to be highly prevalent in spinal pain disorders[2]. Simons et al.[1] suggest that one relevant muscle for the development of thoracic spine pain is the rhomboid muscle. In fact, patients with cervical radiculopathy show a prevalence of 10.2% of active MTrPs in the rhomboid musculature[3]. In addition, up to 75% of patients with thoracic pain also exhibit active MTrPs in the rhomboid[4].

The rhomboid major is a quadrangular muscle located in the thoracic spine innervated by the dorsal scapular nerve which contributes to the positioning and motion of the scapula. The rhomboid major muscle originates from the supraspinous ligament and the spinous processes of T2-T5 vertebrae and inserts into the line between the scapular spine root and the inferior angle on the medial margin of the scapular spine[5]. It lies superficial to the posterosuperior serratus (immediately superficial to the ribs) and deeper to the middle trapezius muscle.

Manual therapy and dry needling are the most common therapeutic interventions applied for the management of MTrPs. Dry needling consists of the insertion of a solid filament needle into the muscle targeting a potential MTrP and has received increasing attention in the literature in the last years[6]. Since dry needling is an invasive technique, improving its safety is crucial[7].

Despite the fact that dry needling is declared as a safe intervention safety, several adverse events have been described in the literature. It has been reported that the most common adverse events associated to dry needling can be considered minor and include bruising, bleeding, pain during treatment and pain after treatment[8,9]. Nevertheless, serious adverse events cannot be excluded, Brady et al.[8] gave an estimated risk rate of [?] 0.04% for significant adverse events. Pneumothorax is one of the most serious adverse events occurring when dry needling the thorax or rib cage and resulting from an improper needle insertion into the pleural space during the technique. In fact, several case reports describing iatrogenic pneumothorax after the application of dry needling into posterior thoracic muscles are described[10].

Due to the anatomical location of the rhomboid musculature, a correct safety and prevention is needed due to the severity of this complication. In fact, different strategies have been proposed to ensure patient's safety and decrease relative risk during invasive procedures. Cushman et al have suggested palpation of the ribs before dry needling could prevent pneumothorax; however, these authors reported poor accuracy in subjects with larger muscle thickness and higher body mass index[11]. As conclusion of their study, they recommended the use of ultrasound evaluation during or before dry needling to ensure the correct needle length. Folli et al. recently reported, as assessed with ultrasound imaging, a mean thickness of the major rhomboid muscle of 16.3mm (males muscle thickness: 25.4mm; women muscle thickness: 20.4mm)[12]. However, the routinely use of ultrasound in clinical practice is not always possible due to its high economic costs.

Seol et al.[13] provided tentative needle lengths and safe margins based on the Body Mass Index of subjects based on a 3-group classification (BMI>25; 23<BMI<25; and BMI<23). A similar procedure including more potential predictors (e.g. age, thorax circumference, respiratory moment, gender) could help clinicians to determine the depth of the pleura and rhomboid major muscle, and, hence, determining the appropriate length of the needle. Therefore, the aim of this study was to evaluate if anthropometric features can predict rhomboid major muscle and pleura depth, as assessed with ultrasound imaging, in a sample of healthy subjects. Our hypothesis is that a prediction model based on age, height, weight, respiratory moment, thorax circumference, BMI and gender could assist during the application of dry needling into the rhomboid musculature.

Methods

Study Design

This is a diagnostic accuracy study to calculate a prediction model for the skin-to-pleura distance measured with ultrasonography in a reliable location for measuring major rhomboid thickness based on anthropometric features including age, height, weight, body mass index (BMI), gender, and thorax circumference. This study followed the Standards for the Reporting of Diagnostic Accuracy Studies (STARD) guidelines and checklist[14].

Participants

Consecutive recruitment of healthy volunteers was conducted by using local flyer announcements between October-November 2020 in Madrid (Spain). To be eligible to participate, they had to be between 18 and 65 years old. Participants were excluded if they reported thoracic pain the previous year; have been under pharmacological treatment affecting muscle tone (e.g., muscle relaxants or analgesics); have prior history of thoracic surgery, respiratory complications, or pneumothorax; and any other medical condition such as tumor, fracture or other neuromuscular condition compromising a normal skin-to-pleura distance (e.g., sarcopenia, myasthenia gravis, amyotrophic lateral sclerosis, or multiple sclerosis). This study was approved by the Institutional Ethics Committee of Rey Juan Carlos University. Prior to their inclusion in the study, all participants read and signed a written informed consent.

Based on a previous study conducting a prediction model based on anthropometric features[15], a sample size of at least 96 measurements were considered as appropriate. Considering this as a prognostic study, a range from 10 to 15 subjects per potential predictor, with no more than five predictor variables, is recommended to obtain proper sample size for prediction models and for avoiding overestimation of the results[16]. Based on this sample size estimation, a sample size of 50 subjects would be required given the maximum cut-off of five predictors included in the final model. Since we originally included seven potential predictors in the model (age, gender, height, weight, BMI, thorax circumference and respiratory moment), we determined a sample size of at least 70 measurements, giving a total of 35 participants.

Procedure

Anthropometric data included age, gender, height, weight and BMI. Further, thorax circumference (measured horizontally at the xiphoid process) was also calculated at maximum inspiration and expiration in standing position with 90o of arms abduction[17].

For ultrasound imaging, participants were in prone with their arms in abduction of 90o and elbows flexed. The assessment point was selected following the procedure as described by Folli et al.[12]which has been found to be highly reliable. Firstly, the spinous process and the inferior angle of the scapula was identified by manual palpation, and the half distance between these points was calculated. Second, a horizontal projection was traced medially to the spinous process of the thoracic spine. The transducer was therefore placed in the middle-distance between these points (**Fig. 1**).

The following distances skin to pleura, skin to the lowest limit of major rhomboid, and lowest limit of major rhomboid to pleura were calculated by using an ultrasound equipment Alpinion Ecube 8 (Gyeonggi-do, Korea) with a linear transducer E8-PB-L3-12T 3-12 MHz (**Fig. 2**). The mean of three repeated trials performed by the same clinician with more than 10 years of experience using ultrasound imaging was calculated for the main analysis at two moments, maximum inspiration and maximum expiration.

Statistical Analysis

Data analysis was conducted with the Statistical Package for the Social Science (SPSS) V.21 (Armonk, NY, USA) for Mac OS. A Kolmogorov-Smirnoff test was done to analyze the normal distribution of the data (normal if $p>0.05$). After checking the sample homogeneity, student t-tests for independent samples were used to assess gender differences for age, height, weight, BMI, thorax circumference during maximum inspiration and expiration, or respiratory moment differences for ultrasonographic features.

Multiple linear regression analyses were conducted to determine variables significantly contributing to the variance within the pleura depth. First, a correlation analysis between pleura depth with anthropometric features and respiratory moment was performed using Pearson's correlation coefficients (r) for normal distributed variables. Values ranging 0-0.3 were considered as poor correlation, 0.3-0.5 as fair, 0.6-0.8 as moderate and 0.8-1.0 as strong[18]. Those statistically significant variables ($p<0.05$) were included in a step-wise multiple linear regression model to estimate the proportion of variance explaining the pleura depth. To avoid risk of bias during the regression model, a multicollinearity and shared variance analyses between the variables (defined as $r>0.80$) were also calculated.

Hierarchical regression models were conducted to determine those variables that contributed significantly to pleura depth determination. The significance criterion of the critical F value for entry into the regression equation was set as $p<0.05$. The adjusted changes in R^2 were reported step by step in the regression model to determine the association of each additional variable.

Results

From a total of 60 volunteers responding to the announcements, one was excluded due to respiratory complications. Fifty-nine asymptomatic subjects (52.5% males) were included. After assessing both sides on each subject in both maximum inspiration and expiration, we analyzed a total of 236 measurements. **Table 1** provides sociodemographic and anthropometric data of the total sample, and divided by gender, respiratory moment, and side. In general, men exhibited higher age, height, weight, BMI, thorax perimeter, rhomboid depth, pleura depth, and rhomboid-to-pleura distance (all, $p<0.001$). No side-to-side differences were found in any feature. Differences were found between inspiration and expiration for thorax perimeter ($p<0.001$), rhomboid to pleura distance ($p<0.001$) and pleura depth ($p<0.001$), but rhomboid depth showed no differences ($p>0.05$).

Table 2 summarizes Pearson's correlation coefficients of rhomboid and pleura depth with anthropometric features. Pleura depth was correlated with respiratory moment, age, perimeter, weight, height, BMI, and gender. Rhomboid depth was correlated with perimeter, weight, height, BMI, and gender, not age. In addition, significant correlations also existed among the anthropometric variables with no multicollinearity (except height with BMI and perimeter); therefore, height was excluded from the regression analysis.

Table 3 describes the hierarchical regression analysis conducted in this study for determining pleura depth. BMI contributed with 55.9% of the variance ($p<0.001$), gender contributed an additional 13.3% ($p<0.001$), and thorax circumference the last 0.5% of variance ($p<0.05$). When combined, anthropometric features explained a total of 69.7% of variance of pleura depth.

Table 4 shows the hierarchical regression analysis conducted for rhomboid major depth. BMI contributed the 42.2% of the variance ($p<0.001$), gender contributed an additional 8.7% ($p<0.001$), and thorax circumference the last 0.6% of variance ($p<0.05$). Therefore, the combined model explained 51.5% of variance for predicting the rhomboid depth.

Discussion

This study found that anthropometric features were able to predict rhomboid and pleura depth in asymptomatic subjects. These findings could help clinicians in the use of dry needling or acupuncture by determining the most appropriate needle length to avoid an accidental pleura puncture and a potential pneumothorax.

Although this is not the first study assessing the optimal needle insertion in this location, it is the first calculating the accuracy of a prediction model including multiple anthropometric features. Seol et al. [13] provided needle length recommendations based on the BMI and providing safety margins (which consist in a range between the mean + 1 SD of rhomboid muscle depth and the mean - 1 SD of rib depth). This recommendation could be acceptable if clinicians cannot use ultrasound imaging, but several features with moderate correlation with rhomboid-pleura depth (e.g., perimeter, and gender) identified in our study were not considered. Current results would support that the first parameter to be considered for selecting the needle length is the BMI, explaining a great percentage of variance in both rhomboid and pleura depth. This is an expected finding since higher weight is associated with higher proportion of fat and, therefore, more skin-to- underlying tissues distance. Interestingly, in the descriptive analysis, we observed gender differences for all the anthropometric measures, supporting that men show higher anthropometric scores (i.e., height, age, weight, and BMI) than women. These gender differences would explain the relevance of gender in the prediction model.

The identified variables determining rhomboid and pleura depth were consistent, where BMI, gender or thorax circumference were the most relevant predictors in both prediction models. Although respiratory moment and age were associated with pleura depth, they were not included in the regression model due to their poor significance. Thus, respiratory moment was not associated with rhomboid lower limit. Since the rhomboid major is not a ventilatory muscle, its depth did not show differences between maximum inspiration and expiration; explaining the lack of association of respiratory moment. Nevertheless, although the role of serratus posterior superior in the breathing is controversial[19], the safety margin is greater during maximum expiration due to the intercostal and serratus posterior superior activation, which should be considered during application of invasive procedures.

Our data revealed a more explained model for pleura depth than for rhomboid muscle depth (explaining 69.7% and 52.7% of variance, respectively). Even if rhomboid deep limit cannot be accurately predicted, the combination of both models could be potentially useful to decrease the risk of pneumothorax during dry needling.

Perhaps the most relevant findings from the current study are the results from the hierarchical regression analysis used to determine pleura depth, which explained almost the 70% of variance. Clinicians can use, in absence of ultrasound equipment and inability to manual identification of the ribs, the BMI and thorax circumference to decrease the risk of an accidental puncture of the pleura. Based on the current results, clinicians should use needles no longer than 25mm to avoid an accidental pleura puncture since the lower limit of rhomboid major lower limit ranges from 11.6 mm to 16.2 mm and the pleura could be needled at 19.6-27.7 mm of depth.

Although this study has shown promising results, potential limitations should be recognized. First, this prediction model was based on a sample of healthy subjects, with several demographic differences. Larger sample sizes are needed to determine normative values of rhomboid and pleura depth. Second, we only assessed one measurement point, which could not be the exact location of the MTrP; therefore, different locations could have different depths. Further research assessing depth differences between segments is needed. Finally, this model can be applied just in healthy subjects with no neuromuscular conditions.

Conclusion

This study found that some anthropometric features can explain 69.7% of the variance of pleura depth, as assessed with ultrasound, in healthy subjects. BMI, gender, and thorax circumference were the most relevant features for pleura depth, and BMI, gender, weight, and respiratory moment the most relevant for rhomboid lower limit depth. Our findings could assist clinicians for selecting an appropriate needle length during insertion of rhomboid major and decreasing the risk of pneumothorax.

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Conflicts of Interest: None

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Legend of Figures

Figure 1. (A) *Location of the examination point; 1: Spinous process of the scapula; 2: Inferior angle of the scapula; 3) Middle distance between 1 and 2 in the medial border of the scapula; 4) Spinous process of the vertebra; (B) Probe placement during the assessment

Figure 2. (A) Ultrasound assessment imaging; (B) Location of muscle layers: middle trapezius, rhomboid major, serratus posterior superior and intercostalis; (C) Measurement of A) skin-to-rhomboid, B) rhomboid-to-pleura, and C) skin-to-pleura distances

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