Manual Testing of Respiratory Muscles in Adults with Asthma: A Intra and Interrater Reliability and Validity Study

Yannely Serrano-Villar (✉ yannely.serrano.villar@gmail.com)

Universidad Industrial de Santander

Eliaana-Isabel Rodríguez-Grande

Universidad del Rosario

María Solange Patiño Segura

Universidad Industrial de Santander

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Abstract

Background: Manual Muscle Testing (MMT) is a useful tool to evaluate ventilatory mechanics in adults with asthma. However, in the reviewed literature, there are few studies that report psychometric features of this test. Therefore, the present study aimed to evaluate MMT reliability and validity in respiratory muscles in adults with asthma.

Methods: It was a cross-sectional study. Muscle strength (MMT and static respiratory pressures), sociodemographic and anthropometric variables related to the disease were evaluated. Measurements were carried out by two independent evaluators. The reliability of MMT was analyzed with the weighted kappa and the convergent validity was evaluated by comparing the MMT and the respiratory pressure measurements using Pearson's correlation coefficient. The level of significance was $p < 0.05$.

Results: Twenty-six adults with stable asthma participated in the study. The intrarater reliability for MMT was between moderate and substantial ($\kappa = 0.45-0.88$) for all evaluated muscles while the interrater reliability was slight and fair for intercostal muscles ($\kappa = 0.07-0.24$), and fair and substantial ($\kappa = 0.36-0.75$) for other muscles. The convergent validity of MMT and respiratory pressures was low ($r = 0.20-0.48$).

Conclusions: MMT is a reliable measurement that can be used to evaluate respiratory muscle strength in adults with asthma. This study supports MMT application for respiratory muscles at clinical settings when more objective measures such as MIP and MEP are not available.

Considering that the MMT is a useful, practical, low-cost tool commonly used by physiotherapists, future studies could evaluate the convergent validity compared with dynamometry or electromyography of the respiratory muscles.

Background

Worldwide, asthma is considered the most common chronic respiratory disease. It affects as many as 334 million people reaching the 14th place among the most important diseases in terms of extent and time period of disability.¹ Asthma is characterized by chronic inflammation of the airways accompanied by airflow obstruction;² causing an intermittent load on respiratory muscles and muscle overload during acute exacerbations³. The resulting muscle dysfunction is evidenced by the decrease of the muscle strength,⁴ and in the reduced net excitation of inspiratory motor neurons.³

To know the respiratory muscle function state is valuable to determine functional consequences and level of asthma control. Consequently, several technological strategies have been developed for its assessment, namely, measurement of maximal inspiratory and maximal expiratory pressures (MIP and MEP),⁵ spirometry⁶ and electromyography.⁷ Nonetheless, since these procedures are not available in all clinical settings, monitoring of breathing pattern, costal mobilization, and assessment of muscle contraction with palpation⁵ are traditionally used as part of the Manual Muscle Testing (MMT). The latter

has been recognized as a simple, economical and accessible tool.⁸ In spite of the advantages, the MMT psychometric features have only been evaluated on limb musculature as the reviewed literature shows.⁹

The availability of reliable and valid measuring tools within the clinical ambit, allows to make an unbiased assessment, suggest a diagnosis, and implement treatments oriented to improve ventilatory mechanics compromised by the asthma.³ Additionally, for research, it can be useful to support outcomes derived from physiotherapeutic interventions by reducing the likelihood that results be affected by measurement variability.

According to the aforementioned, it is necessary to assess the psychometric properties of tools used in clinical practice and compare them with tests and measurements of proven validity and reliability. In that sense, MMT reliability, and validity against MIP and MEP should be evaluated. In this way, ventilatory function assessment of patients with asthma can be complemented for monitoring disease control, providing support to therapeutical programs to control symptoms, preventing complications, and improving function and life quality of this population.² Therefore, the research question of present study were: What is the intra and interrater reliability of MMT of the diaphragm, external intercostal and abdominal muscles in a population of patients with asthma?, and What is the convergent validity of MTT against MIP and MEP in a population of patients with asthma?.

Methods

The reliability and validity evaluation of the diagnostic tests were carried out using a cross-sectional sampling.¹⁰

Subjects: The study group included adults with asthma in stable phase of disease, according to the criteria proposed by the GINA, which include the control of signs and symptoms, and the result of functional tests.² Patients were excluded if comorbidities such as heart diseases, uncontrolled arterial hypertension, recent lung biopsy, spinal cord injury, ocular lesion, tracheotomy, surgery or trauma of upper airways, hemodynamic instability, pregnancy, respiratory infections¹¹ were present. Also, in case of sequelae of musculoskeletal or neurologic disorders compromising thoracic mobility and muscle control;¹² or a lack of voluntary effort during spirometry, defined by a Peak Expiratory Flow (PEF) or by a Forced Expiratory Flow at 25% (FEF_{25%}) under 60% of the predicted value (13). Measurements were taken in the Laboratory of Movement Analysis, School of Physiotherapy, Universidad Industrial de Santander.

Evaluators: Two clinical-experienced physiotherapists participated in the study. They standardized verbal commands and hand contacts and were trained in the application of tests, in order to avoid classification bias.

Procedures:

The protocol comprised measurements that should be done in three days (2 and 8 days apart). On day 0 screening and familiarization were carried out; anthropometric, spirometric, sociodemographic, disease-related and monitoring-related variables were measured, and familiarization with muscle strength variables were attained. On the second day, MMT was measured independently by two evaluators. On the third day, MMT was measured again by the two evaluators; additionally, one of the evaluators always measured the Maximal Inspiratory and Expiratory Pressures (MIP and MEP). All variables were measured at a random order. Vital signs were monitored by one of the evaluators at the beginning and end of each session. Both evaluators were blinded for the previous measurements and for those from each other. Additionally, evaluations were done at the same time of day. Patients were requested to continue the medical treatment during the study (Figure 1).

Measurements

Spirometry. A spirometer (Spirobank G., MIR SRL) was used following technical procedures recommended by the American Thoracic Society and the European Respiratory Society.^{6,13} Subjects completed at least three maximal forced expiratory maneuvers and PEF and FEF_{25%} were recorded; if these variables fell below 60% of the predicted value^{6,13} the participant was excluded from the study. The forced expiratory volume during the first second (FEV₁), the forced vital capacity (FVC) and the FEV₁/FVC ratio were also recorded.

Anthropometric variables. Corporal weight (Kg) was measured using a portable, digital, and calibrated scale; size (m) was measured with an inextensible metric tape of 1 mm precision; and the Body Mass Index (BMI=weight/size²) was calculated. Recommendations from the Anthropometry Procedures Manual of the National Health and Nutrition Examination Survey, elaborated by the Centers for Disease Control and Prevention,¹⁴ were followed.

Monitoring variables. Heart rate (beats/min), rate of breathing (respirations/min), arterial blood pressure (mm Hg), and oxygen saturation (SaO₂; percentage) with 2% precision were recorded. Additionally, lung auscultation findings, breathing difficulty assessed through the Borg Scale, and signs of respiratory distress, were also recorded.^{15,16}

Variables of muscle strength. Muscle strength was assessed by MMT and static respiratory pressures measurement. MMT was based on palpation, thoracic mobility observation, and manual resistance applied against a contracting muscle, in accordance with the ordinal grading system from the Medical Research Council (MRC).¹⁷ The protocol implemented for this study took into account evaluator and subject postures, the applied hand contacts, the muscle palpation pressure, and the verbal command emitted. The grading scale was different for the inspiratory and the expiratory musculatures. A “normal /good /fair /poor /trace /null” scale was used for diaphragm and external intercostal muscles, taking into account the thoracic expansion, expulsion of the hand, and the respiratory function. The terms functional, slightly functional, non-functional and null were used for abdominal muscles, according to the characteristics of the coughing mechanism.^{8,18} The evaluator began the test by emitting the

corresponding verbal command while observing the muscle contraction; then placed his/her hands on the indicated muscle points for palpating its contraction without resistance; and finally, applied manual resistance against the muscle movement.^{8,18} Tests for every muscle were made twice with 1-min interval between each effort, and the higher value was recorded. Images of diaphragm, external intercostal, and abdominal muscles evaluation are shown in Figures 2, 3, and 4 respectively.

MIP and MEP measurements were done using a manometer with nozzle and valves for sensing pressure changes. MIP is considered the maximal subatmospheric pressure generated against an occluded airway from residual volume (Müller maneuver), sustained for one second. MEP was measured from the total lung capacity (TLC) and exerting the maximal expiratory pressure against the occluded airway (Valsalva maneuver) for one second.¹⁹

Statistics. A25-35 individual-sample was calculated to be suitable for determining MMT psychometric features after considering the use of two replicates and assuming 80% power, a significance level of 5% and a loss of 20%.²⁰

Measures of central tendency and dispersion were calculated to characterize the population according to nature and distribution of variables. Both, intrarater and interrater reliability of MMT were evaluated using weighted kappa.¹⁰ Landis and Koch guidelines²¹ for interpreting kappa values, were implemented as follows, slight ($\kappa=0.0-0.2$), fair ($\kappa=0.21-0.40$), moderate ($\kappa=0.41-0.60$), substantial ($\kappa=0.61-0.80$), and almost perfect ($\kappa=0.8-1.00$) agreement. Convergent validity of MTT and static pressures was established by Pearson correlation coefficient; the expected level of correlation was classified in accordance with data from Carter *et al.*²² as follows, small ($r=0.0-0.25$), low ($r=0.26-0.49$), moderate ($r=0.50-0.69$), high ($r=0.70-0.89$), and very high ($r=0.90-1.00$).

Results

Flow of participants. Twenty-nine adults with stable asthma were enrolled for the study; three did not complete the programmed evaluations; therefore, only 26 patients were included in the study (Figure 1); 16/26 (61.54%) were female. Table 1 describes general, disease-related and spirometric characteristics of the patients. Spirometric pattern was normal in all participants as evidenced by FEV₁ and FVC, and FEV₁/FVC that were respectively above 80% and 70% of the predicted values.⁶

Table 1
Characteristics of sample (N=26)

Variable	Data
Age, years (percentile 25;75)	24.5 (20;32)
Weight, kg (SD) ^a	69.4(16.11)
Size, m (SD)	1.6 (0.08)
BMI ^b , Kg/m ² (SD)	25.5 (5.24)
Schooling, approved years (SD)	14.6 (3.43)
Asthma Features	
Time of disease evolution, years (SD)	18.1 (9.31)
Time after last acute exacerbation, months (percentile 25;75)	7 (4;36)
Spirometric values	
PEF ^c (SD)	93.3 (20.88)
FEF _{25%} ^d (SD)	74.1 (23.66)
FEV ₁ ^e (SD)	82.8 (13.82)
FVC ^f (SD)	91.2 (9.79)
FEV ₁ /FVC (SD)	89.8 (10.92)

a: Standard Deviation; b: Body Mass Index; c: Peak Expiratory Flow; d: Forced Expiratory Flow at 25% of FVC; e: Forced Expiratory Volume during the first second; f: Forced Vital Capacity

Reliability of MMT. Intrarater reliability was similar in both evaluators; the agreement was substantial (kappa=0.78-0.88) for external superior intercostal and abdominal muscles, and moderate (kappa=0.45-0.59) for anterior and posterior diaphragm. Confidence intervals were wide for all musculature evaluated. The intrarater reliability findings are shown in Table 2.

Table 2
MMT Intrarater Reliability (N=26)

Muscle	Agreement (%)	Expected agreement (%)	Kappa	95%CI ^a Normal
Evaluator 1				
Anterior diaphragm	90.38	76.18	0.59	0.26 – 0.925
Lateral diaphragm	95.19	76.70	0.79	0.57 – 1.00
Posterior diaphragm	92.31	81.36	0.58	0.28 – 0.89
Superior ICs ^b	96.15	66.57	0.88	0.61 – 1.00
Inferior ICs ^b	76.92	50.30	0.53	0.21 – 0.85
Rectus abdominis	92.31	64.20	0.78	0.46 – 1.00
Oblique ones	92.31	64.20	0.78	0.46 – 1.00
Evaluator 2				
Anterior diaphragm	93.16	87.44	0.45	0.08 – 0.83
Lateral diaphragm	94.87	88.76	0.54	0.18 – 0.90
Posterior diaphragm	91.35	80.10	0.56	0.27 – 0.85
Superior ICs ^b	98.08	89.64	0.81	0.50 – 1.00
Inferior ICs ^b	96.15	90.98	0.57	0.12 – 1.00
Rectus abdominis	96.15	82.54	0.77	0.22 – 1.00
Oblique ones	96.15	82.54	0.77	0.22 – 1.00
a: Confidence Interval; b: Intercostal				

The interrater reliability was between slight and substantial during the second and third evaluation days. Confidence intervals were wide, but reduced for lateral diaphragm. The findings of interrater reliability for each muscle is shown in Table 3.

Table 3
MMT Interrater Reliability of (N=26)

Muscle	Agreement (%)	Expected agreement (%)	Kappa	95%CI ^a Normal
Measurement 1				
Anterior diaphragm	94.87	87.57	0.58	0.28 – 0.88
Lateral diaphragm	94.23	76.63	0.75	0.53 – 0.97
Posterior diaphragm	88.46	78.11	0.47	0.09 – 0.84
Superior ICs ^b	82.69	80.92	0.09	-0.05 – 0.24
Inferior ICs ^b	86.54	84.91	0.10	-0.17 – 0.39
Rectus abdominis	80.77	69.53	0.36	-0.03 – 0.76
Oblique ones	80.77	69.53	0.36	-0.03 – 0.76
Measurement 2				
Anterior diaphragm	94.23	77.07	0.74	0.48 – 1.00
Lateral diaphragm	97.01	88.79	0.73	0.49 – 0.97
Posterior diaphragm	93.27	83.80	0.58	0.25 – 0.91
Superior ICs ^b	81.73	80.25	0.07	-0.05 – 0.20
Inferior ICs ^b	88.46	84.76	0.24	0.03 – 0.45
Straight abdominal	92.31	73.67	0.70	0.26 – 1.00
Oblique ones	92.31	73.67	0.70	0.26 – 1.00
a: Confidence Interval; b: Intercostal				

Additionally, the overall interrater reliability was analyzed considering both assessments results as well as the overall reliability between the two evaluation days (Table 4). The interrater reliability was substantial for diaphragm, moderate for abdominal and slight for intercostal muscles; while the intermeasurement reliability was substantial for all muscle groups.

Table 4
Overall Reliability (N=26)

Muscle	Agreement (%)	Expected agreement (%)	Kappa	95% CI Normal
Interrater reliability				
Diaphragm	95.19	80.10	0.75	0.49 – 1.00
Intercostal ones	42.31	33.43	0.13	-0.01 – 0.28
Abdominal ones	80.77	66.42	0.42	0.06 – 0.79
Inter-measurement reliability				
Diaphragm	95.19	79.36	0.76	0.54 – 0.98
Intercostal ones	88.46	50.00	0.76	0.51 – 1.00
Abdominal ones	92.31	64.20	0.78	0.46 – 1.00

Convergent validity of MMT and static respiratory pressures. Overall, correlation between static respiratory pressures and MMT was between small and low for both, inspiratory and expiratory muscles (Table 5).

Table 5
Correlation between static respiratory pressures and MMT (N=26)

Muscle group	R	95%CI
Inspiratory (absolute average)		
MIP and diaphragm	0.25	-0.15 – 0.58
MIP and external intercostal	0.48	0.12 – 0.73
MIP and inspiratory	0.39	0.01 – 0.67
Expiratory (absolute average)		
MEP and abdominal	0.20	-0.19 – 0.55
r= Pearson's correlation coefficient		

Discussion

MMT intrarater reliability, was substantial for diaphragm, external intercostal and abdominal muscles (Table 4). These results could be attributed to standardization of the protocol. Unfortunately, it was not possible to compare the observed results with other studies since MMT reliability in respiratory muscles has not been previously assessed.^{9,23,24}

The intrarater reliability level was different when analyzing specifically each muscle group according to subgroups; it varied from almost perfect to moderate. These variations cannot be attributed to changes in muscle strength since the elapsed time between measurements is not enough to show significant changes in muscle strength. Such variations can be explained by analyzing biomechanics of respiratory muscles. Then, the almost perfect agreement for superior external intercostal muscles and the substantial result for abdominal muscles, can be explained owing that palpation of these muscles is a simple task due to their superficial anatomical disposition.^{18,25,26}

Moderate to substantial reliability for diaphragm should be analyzed taking into account its function and anatomical disposition. When the diaphragm contracts, its central tendon moves downwards and the dome tends to flatten.^{18,26,27} Such behavior makes diaphragm palpation a complex task during the test. Additionally, the pathologically flattened diaphragm, resultant from chronic respiratory diseases, pulls the ribs laterally instead of up and outwards, decreasing the capacity to enlarge thorax dimensions. This difference in diaphragm function can hinder participant's performance during evaluation becoming an uncontrolled issue for the evaluator.^{25,28} On the other hand, the lower reliability observed in the inferior external intercostal muscles can be related to diaphragm interference. Diaphragmatic action depends on the union to the six lower ribs and the zone of apposition, an area where the muscle juxtaposes to the inner surface of the costal margin.²⁸

The overall interrater reliability is influenced by the evaluators' training and standardization of the measurement protocol. Although these factors were controlled in the present study, the evaluated construct (muscle strength) by MMT involves a subjective assessment. Consequently, the variability in the observations can be attributed to differences in the resistance applied to the muscle and the grade given to the perceived performance.

Despite hand contact standardization, manual resistance was not quantified; therefore, it could differ between evaluators. These differences may affect the external intercostal muscles since the forces exerted on the ribs are transmitted to the rib cage through the joints.^{25,29,30} On the other side, the fair interrater reliability observed on the first day in abdominal muscles can be attributed to the lack of differentiation between the two levels of evaluation ("functional" and "weakly functional") in the grading scale used. This could cause a difference in the criteria of evaluation between both raters.

When comparing measurements of the two days, interrater reliability was greater in the second measurement for the majority of muscles (Table 3). This can be attributed to the effect of participants' test evaluation learning. In this context, Laviertes³¹ described a training-derived outcome when repeated measurements of MIP were done in adults with acute asthma. Possibly the same factor is present in MMT since both methods assess respiratory muscle strength. Therefore, in every new measurement, muscle performance improves as a result of previous experience.

The confidence intervals of kappa coefficients calculated for both days were wide, reflecting the typical variability of the construct evaluated and the MMT subjectivity on respiratory muscles. Variability of

measurements can be explained by features of these groups of muscles; namely, localization within the thoracic cavity,^{18,25,27} and influences that costal and pulmonary biomechanics may have over them.¹² Strength of muscle contraction is determined by muscle length-tension, force-velocity, and stimulating strength-frequency relationships; as well as by the contractile apparatus integrity.²⁷ Therefore, small changes in the aforementioned factors would result in variations of muscle strength perceived through palpation.

Reliability variations in the diaphragm fibers data could be influenced by the extent of the abdominal muscles relaxation, posture at the moment of testing, and modifications in ventilatory mechanics.^{8,18,25} For external intercostal muscles, the test is based on the horizontalization and verticalization extent of the ribs, changes in intercostal spaces, enlargement of the chondrosternal angle during the breathing cycle, and the diaphragm relaxation; any change in these conditions increases measurement variability. Additionally, abdominal muscles are evaluated considering their capacity to generate expiratory flows and their localization in the thoracic wall.^{8,18,32}

In addition to the variability of the measurements due to physiological characteristics, it is important to mention the sample size. Although the calculated sample size was reached, perhaps it was not enough to have a greater accuracy in the reliability measurements.

The convergent validity of MMT and the static respiratory pressures was low. The correlation analysis was done between MIP and the average score of diaphragm and external intercostal muscles; as well as between MEP and the average score of abdominal muscles. The analysis was not done specifically for each subgroup of muscles because respiratory pressures do not differentiate the strength per muscle group.¹⁹ Therefore and for the reasons that will be explained below, the MIP and MEP may not be the best comparison standard.

The low overall correlation should be analyzed considering the measurement protocol of both variables. Patients for MMT are in supine position while for measuring pressures are seated. Posture has an effect on performance of respiratory muscles, mainly, in the inspiratory ones working against resistance to surpass elasticity of the rib cage, elastic resistance of lungs, gravity force, and abdominal content.^{18,27}

Recruitment of respiratory muscles depends on breathing type, posture and thoracic wall features^{18,27}. Particularly, the work of diaphragm and intercostal muscles can be identified in different positions. In vertical position, during an inhalation, the diaphragm pulls phrenic center down, causing an increment of the thoracic cavity vertical. During exhalation, diaphragm relaxes, its dome lifts and the thoracic volume is reduced. In decubitus position, used for MMT, the diaphragm continues working according to the pressures it receives; specifically, in lateral decubitus position, the hemidiaphragm at the lying side is pushed by the intra-abdominal pressure, and has a more expiratory role than in other positions²⁹. Intercostal muscles work is influenced by the ribs posture, since the strength the muscles produce is transmitted through joints and cartilage to other bones.^{18,25,27}

The expiratory action of abdominal muscles can be explained by the trunk position, as its flexion facilitates the egress of air;¹⁸ and by muscle activation specificity, since at the end-inspiration and onset-expiration, the more activated (minor oblique, transversus abdominis, lateral fibers of major oblique) muscles are the ones participating less at the trunk flexion.¹⁸ Additionally, diaphragm inspiratory action at the standing and sitting postures is complemented by abdominal muscles tension facilitating an increase of abdominal pressure and avoiding abdominal protrusion during inspiration.²⁵

Another difference between the maneuvers for testing the respiratory pressures and MMT was the resistance applied. The manometer used for evaluating the pressures, provides an occlusion to the air flow that imposes a fixed resistance to muscle work¹⁹ while in MMT, the evaluator manually imposes a resistance that was not quantified. Low correlation between static respiratory pressures and MMT can also be explained by activation of muscle groups during the maneuvers. The effort measured through MIP results from joint activation of inspiratory muscles³³ while MMT discriminates the effort of each muscle group. Therefore, the low correlation can show an advantage of MMT over measurement of respiratory pressures. Unfortunately, this advantage could not be corroborated in the present study because the electromyographic activity was not evaluated.

A constraint in the study was its restriction to adults with stable asthma because MMT psychometric properties were established only for such patients. Therefore, it is recommended that psychometric features be evaluated at different asthma phases and in different age groups, as well as in other pathologies. Another study limitation was that the manual resistance applied by evaluators during MMT was not quantified. Although this parameter can be measured precisely through dynamometry, the application of this measurement for respiratory muscles (mainly, the intercostal) is difficult due to their anatomical disposition. Additionally, dynamometry is restricted in the clinical practice because of shortages of equipment. Muscle strength data measured by static respiratory pressures are difficult to compare with other studies because of the use of different scales. Consequently, reporting the measured effort as percentage is advisable because it contributes to compare different results.

According to the aforementioned, it can be concluded that MMT is a reliable measurement to evaluate respiratory muscles strength of patients with asthma. This assessment can be applied by health professionals during thorax physical examination, widening the analysis of ventilatory mechanics in each case. In spite of its subjectivity, is a useful, practical, low-cost, and easy to perform tool to assess muscle groups differentiating their fibers. When correctly applied, MMT is an efficient procedure within the clinical survey of muscle work, provided that the basic conditions for efficacy of the test are fulfilled; namely, evaluator specific training, adjacent musculature relaxation, posture, adequate hand contacts, and standardized verbal commands.

Conclusions

Intra and interrater reliability for MMT was between substantial and moderate, except for interrater reliability for superior external intercostal muscles on the second day of measurements graded as slight.

Correlations between MMT and MIP, and MEP were low.

Results from this study support MMT application for respiratory muscles at clinical settings when more objective measures such as MIP and MEP are not available. In spite of its subjectivity, is a useful, practical, low-cost, and easy to perform tool to assess muscle groups differentiating their fibers provided that the basic conditions for efficacy of the test are fulfilled; namely, evaluator specific training, adjacent musculature relaxation, posture, adequate hand contacts, and standardized verbal commands that facilitate the touch sensitivity for muscle contraction.

According to the aforementioned, it can be concluded that MMT is a reliable measurement to evaluate respiratory muscles strength of patients with asthma. Future studies could evaluate the convergent validity compared with dynamometry or electromyography of the respiratory muscles.

Abbreviations

BMI: Body Mass Index. CI: Confidence Interval. FEF_{25%}: Forced Expiratory Flow at 25%. FEV₁: Forced expiratory volume during the first second. FVC: Forced vital capacity. ICs: Intercostal. MEP: maximal expiratory pressure. MIP: maximal inspiratory pressure. MMT: Manual Muscle Testing. MRC: Medical Research Council. PEF: Peak Expiratory Flow. R: Pearson's correlation coefficient. SD: Standard Deviation. TLC: Total lung capacity.

Declarations

Ethics approval and consent to participate

The project was approved by the Scientific Research Ethics Committee of the School of Health of Universidad Industrial de Santander with code 7083, and it was carried out in accordance with Good Clinical Practice rules and the Ethics Principles for Medical Research Involving Human Beings that are defined in the latest revision of the Declaration of Helsinki. All of the participants voluntarily agreed to be enrolled in the study and signed an informed consent form.

Consent for publication

All of the participants voluntarily agreed to be enrolled in the study and signed an informed consent form.

Availability of data and material

Data relating to this study are available from the corresponding author on request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

All authors contributed to study conception and design. All authors are accountable for all aspects of the work and for the integrity of the data and the accuracy of the data analysis. All authors read and approved the final manuscript.

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Author details

¹MSc in Physiotherapy, Universidad Industrial de Santander.

²MSc in Physiotherapy, MS (c) in Clinical Epidemiology, Pontificia Universidad Javeriana. Teaching Professor, Universidad del Rosario, School of Medicine and Health Sciences, GI Rehabilitation Sciences: Bogotá, Cundinamarca, Colombia, PhD student in Clinical Epidemiology, Pontificia Universidad Javeriana.

³MSc in Physiotherapy. Teaching Professor, Universidad Industrial de Santander, Faculty of Health, School of Physiotherapy: Bucaramanga, Santander, Colombia.

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Figures

Figure 1

Flow –chart of study participants

Figure 2

Evaluation of diaphragm muscle. A: Sternal fibers. B: Lumbar fibers. C: Palpation of weak fibers. D: Lateral fibers.

Figure 3

Evaluation of external intercostal muscles. A: Superior. B: Inferior. C: Posture for testing

Figure 4

Evaluation of abdominal muscles. A: Rectus abdominis. B: Oblique muscles.