

Body power center, maximum phonation time and sound pressure of healthy women

Centro de força corporal, tempos máximos de fonação e pressão sonora de um grupo de mulheres saudáveis

Letícia Fernandez Frigo¹, Carla Aparecida Cielo², Joziane Padilha de Moraes Lima², Melissa Medeiros Braz²

ABSTRACT

Introduction: Muscle recruitment is essential for the maintenance of the respiratory system, which under pathophysiological conditions reduces its muscular strength, leading to a decrease in respiratory pressures and subglottal air pressure. **Purpose:** To investigate the correlation among muscle activation that makes up the center of physical force, the maximum phonation time and the sound pressure of adult women. **Methods:** Collection of maximum phonation time of /a/ and modal sound pressure; assessment of muscle activation transversus, multifidus, pelvic floor and maximal expiratory pressure of ten women (19-28 years old) without vocal complaints and without laryngeal disorders diagnosed by otolaryngologist. The Spearman test was applied. **Results:** A hundred per cent satisfactory activation of the transversus belly, no significant positive correlation among sound pressure, maximum phonation time and the maximal expiratory pressure values; majority of women with maximum phonation time of /a/ slightly below expectations and sound pressure values within the expected activation and satisfactory the multifidus, perineal muscles and Oxford scale, with positive correlation, but not significant. **Conclusion:** Among adult women without vocal complaints and no laryngeal disorders studied, no correlation was found among the activation of the muscles that make up the center of physical force, maximum phonation time and the sound pressure, although most women has made satisfactory muscle activation and while slightly below normal values for maximum phonation time and normal sound pressure.

Keywords: Voice; Phonation; Women's health; Respiration; Exhalation

RESUMO

Introdução: O recrutamento muscular é essencial para a manutenção do sistema respiratório e, em condições fisiopatológicas, reduz sua força muscular, levando à diminuição das pressões respiratórias e pressão aérea subglótica. **Objetivo:** Verificar e correlacionar a ativação da musculatura que compõe o centro de força corporal, os tempos máximos de fonação e a pressão sonora de mulheres adultas. **Métodos:** Coleta do tempo máximo de fonação de /a/ e pressão sonora modal; avaliação da ativação do músculo transverso do abdome, multifídeo, assoalho pélvico e da pressão expiratória máxima de dez mulheres de 19 a 28 anos, sem queixas vocais e sem afecções laríngeas diagnosticadas por otorrinolaringologista. Foi aplicado o teste de Spearman. **Resultados:** Cem por cento de ativação satisfatória do transverso do abdome; correlação positiva não significativa entre a pressão sonora, o tempo máximo de fonação e os valores de pressão expiratória máxima; maioria das mulheres com tempo máximo de fonação de /a/ discretamente abaixo do esperado e pressão sonora com valores dentro do esperado; ativação satisfatória do multifídeo, musculatura do assoalho pélvico e escala de Oxford, com correlação positiva, mas não significativa. **Conclusão:** Neste grupo de mulheres adultas sem queixas vocais e sem afecções laríngeas, não foi verificada correlação entre a ativação da musculatura que compõe o centro de força corporal, os tempos máximos de fonação e a pressão sonora. No entanto, a maioria das mulheres apresentou ativação muscular satisfatória e, ao mesmo tempo, valores discretamente abaixo da normalidade para tempo máximo de fonação e normais, para pressão sonora.

Palavras-chave: Voz; Fonação; Saúde da mulher; Respiração; Expiração

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(1) Centro Universitário Franciscano, Santa Maria (RS), Brazil.

(2) Universidade Federal de Santa Maria – UFSM – Santa Maria (RS), Brazil.

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Corresponding author: Letícia Fernandez Frigo. E-mail: Letícia_frigo@hotmail.com

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INTRODUCTION

For correct vocal production, the structural integrity and functionality between the respiratory, laryngeal or phonatory levels and the resonance cavities are fundamental⁽¹⁾. The sound pressure (SP), measure that depends on complete glottic adduction and control of laryngeal movements is influenced by the increase in subglottal air pressure and expired airflow, as well as the maximum phonation times (MPT), which are related to support/duration of phonation and evaluate the coordination between levels of vocal production⁽²⁾.

The muscle recruitment is essential for the maintenance of the respiratory system's mechanics that, under pathophysiological conditions in which muscle strength is altered, leads to a decrease in respiratory pressures, chest movement and subglottal air pressure^(3,4,5). Studies indicate that vocal production deficit may originate from respiratory capacity disorders, since this function is a source of energy for vocalization, especially in the expiratory phase^(6,7).

The respiratory muscular support and postural adequacy contribute to a more stable voice, with greater projection and control of laryngeal hyperfunction⁽⁴⁾. The respiratory muscles and their insertions should act synergistically and recruitment of the body power center (BPC) may increase the neuromuscular control⁽⁸⁾, strength and resistance of the abdominal support to the voice. Postural changes may interfere on the breathing by altering the activation of the respiratory muscles and resulting in consequences on voice production^(1,9).

The BCP is described as the set of stabilizing muscles of the spine, important for a proper maintenance of the posture. It consists by a central muscle groups, such as the multifidus, pelvic floor, transverse abdomen and diaphragm, which is essential to phonation. The main aim of BCP recruitment is to maintain the stability of the spine, favoring body posture, with increased neuromuscular control, strength and resistance of the central muscles^(8,10,11,12). These structures are also fundamental for the expiration and maintenance of the abdominal breathing support for voice production, mainly in its aspects of support MPT and SP⁽¹⁾.

The development of respiratory control is important for the maintaining air pressure, during phonation⁽¹³⁾. The abdominal respiratory support provides a significant improvement in vocal extension rates⁽³⁾ *loudness* (subjective sensation of SP) e *pitch* (subjective sensation of frequency)⁽¹⁴⁾.

Parameters such as SP, duration and frequency can also be altered, according to the vocal fold vibration pattern and its interrelationship with the expiratory flow and pressure. The vocal fold resistance, determined by the completeness and strength of its adduction, is fundamental in the control of SP and MPT, being decisive for these variables⁽²⁾.

No studies were found in the literature that relate BCP to voice production, affirming only theoretically, the relationship between respiratory and glottic levels of vocal production.

Therefore, the investigation of the correlation between the activation of the BCP muscle groups, which directly influences the respiratory level with the MPT and SP vocal measures, in women without vocal complaints and laryngeal affections, can bring initial results to a new research line, generate scientific evidence to support the established theory and create parameters of normality for the foundation of the clinical practice of phonoaudiology and physiotherapy. Therefore, the investigation of the correlation between the activation of the BCP muscle groups, which directly influences the respiratory level with the MPT and SP vocal measures, in women without vocal complaints and laryngeal affections, can bring initial results to a new reserach line, generate scientific evidence to support the established theory and create parameters of normality for the foundation of the clinical practice of phonoaudiology and physiotherapy.

In view of the above, the present study aimed to verify the activation of the BCP musculature, MPT and SP values of adult women without vocal complaints and laryngeal affections, as well as to verify the existence of a correlation between these variables.

METHODS

Observational, analytical and quantitative research, approved by the Research Ethics Committee of the *Universidade Federal de Santa Maria* (23081.016945/2010-76). The target population was consisted by adult women of childbearing age, who received clarification about the study and were invited to read and sign the Free and Informed Consent Term (FICT).

All the volunteers were submitted to a interview and the otorhinolaryngological and audiological evaluations, for the application of the inclusion and exclusion criteria.

Inclusion criteria: to be female, since women are more engaged in health care practices and are more vulnerable to musculoskeletal changes, due to specific anatomical and functional characteristics, besides evaluation of the perineal musculature is performed by the vaginal cavity⁽¹³⁾; being in the adult age range from 19 to 40 years, since the woman, at age 19, has already passed the changes of adolescence and at 40, has not yet experienced the significant hormonal changes of the climacteric phase^(13,15); to make a continuous contraceptive use to avoid possible influences on physical and laryngeal fitness, influenced by the phases of the menstrual cycle⁽¹⁶⁾; Have a body mass index (BMI) classified as normal (between 18,5 and 24,9 kg/m²); have adhered to the FICT.

Exclusion criteria: have a history or complaint of cognitive deficit, due to the possible influence about the understanding the orders; be multiparous or pregnant; being in premenstrual period, menstrual period or allergies, colds or flu, in the interview day; to present alterations of perineal sensitivity; have made orthopedic or abdominal surgeries; refer to neurological, psychiatric, gastric, respiratory, laryngeal and/or any surgical

procedures of the head and neck; to present organic and/or functional alteration at the laryngeal level in the medical exam of laryngoscopy; to report being smoker and/or consuming alcohol in excess (four doses at the same time)⁽¹⁷⁾; to present vocal complaints for at least 15 days; to present hearing loss because it influences vocal quality.

To apply the inclusion and exclusion criteria were performed a anamnesis, otorhinolaryngological evaluation, including visual inspection of the larynx, and auditory screening. The volunteers who passed these criteria formed the study group (SG). From then on, at previously scheduled times, data collection was performed, which consisted of muscular and vocal evaluations. The evaluations of BCP musculature were done by a physical therapist and the MPT and SP collections, by a speech therapist.

The target population was invited to participate in the survey, by direct contact and by e-mails of disclosure. There were 17 volunteers, but one of them was excluded because of laryngeal involvement (vocal nodules), 4 because they presented BMI considered above normal, and 2 because they did not attend all the evaluations. Thus, the EG was constituted by ten women. It is important to note the difficulty of capturing subjects in this type of study, probably due to the need for an intracavitary vaginal procedure, in one of the tests.

To evaluate the activation of the abdominal musculature, was used a sphygmomanometer as the unit of pressure *biofeedback*. Placed on supine, volunteers were instructed to activate the deep abdominal muscles, with verbal instructions such as “shrink the abdomen taking the navel towards to the spine while releasing the air”. For this evaluation, must to assume the neutral position of the spine and try to maintain it, while the abdominal muscles gently shrink and become depressed. To begin the test, was assumed the prone position on the pressure biofeedback unit. The sphygmomanometer was leveled to the center of the abdominal wall; the pressure gauge was inflated to 70 mmHg⁽¹⁸⁾ and volunteers were instructed to “pull” the abdomen inward, to achieve total activation of the abdominal musculature, including the transverse abdomen. The expected result was that, after contraction, the pressure dropped from 4 mmHg to 10 mmHg and was maintained for 10s⁽¹⁹⁾. In this test, the variation of the pressure generated by the contraction was recorded, as well as the time of its maintenance.

To evaluate the ability multifidus muscle to stabilize the trunk during dynamic movements of the extremities, the volunteers were placed in the four-position, with the pelvis in a neutral position, using the muscular control to remain in position. The following maneuvers were carried out: flex an upper limb up to 90° and hold it in that position; to elevate the lower limb extended and maintain it; to associate the 2 movements in a contralateral manner. The scores considered were: a) normal = able to perform the elevation of the contralateral lower and upper limbs on both sides, while keeping the pelvis neutral for 20s to 30s; B) good = able to maintain the pelvis neutral while

performing simple elevation of the lower limb and maintains for 15s to 20s; C) regular = able to perform simple elevation of the upper limb while maintaining the pelvis neutral for 15s to 20s; D) weak = unable to keep the pelvis neutral while performing simple elevation of the upper limb; E) trait = unable to raise the arm or leg of the stretcher to the extended position⁽²⁰⁾.

To evaluate the strength of the pelvic floor musculature, was adopted the gynecological position, in litter located in a private room, with the pelvic floor and lower limbs. The latex rod of the device (Perina, branded Quark®), previously coated with a disposable condom, was introduced into the vagina. The level of pressure on the numerical scale was zeroed and, to evaluate the isolated contraction of the pelvic floor, the volunteers were asked to perform perineal contraction with maximum effort, with verbal commands such as “prevent urine passage” until was observed the contraction of the perineal musculature. The volunteers were instructed to perform a perineal contraction in expiratory time of respiration. A sequence of five contractions was performed, with an interval of 1 min between each, considering, as a result, the mean contractions. This measure indicates the recruitment capacity of muscle fibers and the closure of the urethral sphincter⁽²¹⁾, showing the activation of the pelvic floor musculature.

With a lubricated disposable glove, the physical therapist performed the vaginal palpation. As a standard, the second and third fingers are introduced into the vaginal canal and, at this stage, the strength and functionality of the pelvic floor muscles are evaluated by means of the Oxford scale, which depended on the contraction and voluntary maintenance of the perineal musculature⁽²¹⁾.

The activation values of the perineal musculature, multifidus and transverse abdomen were classified according to the literature^(19,20), on satisfactory or unsatisfactory activation.

The maximal expiratory pressure (EpMAX) that indicates the activation of the expiratory muscles, such as the abdomen, a component of the BCP, was performed with an analogical manovacuometer of the brand Support® and with the volunteers in the orthostatic position, with nostrils occluded by a nasal clip. The volunteers were instructed to inhale to the total lung capacity, before being stimulated to exhale with maximum effort inside the mouthpiece, to measure EpMAX. They were also advised to avoid collapse of the cheeks during measurement, so as not to raise the pressure of the oral cavity, generated exclusively by contraction of the facial muscles with closure of the glottis. Were performed three maximum, acceptable and reproducible maneuvers (difference of 10%, or less, between the efforts), with rest interval between the efforts of approximately 1 min, with the highest value recorded in mmHg⁽²²⁾.

At the same time, were evaluated the MPT. The volunteers remained in orthostatic position with the Behringer ECM 8000 microphone (frequency response from 15 kHz to 20 kHz) join it to professional digital recorder (Zoom H4n; 96 kHz, 16 bits, with 50% of the recorder signal level), Fixed in a pedestal and

positioned in front and at 90° angle of the mouth⁽²³⁾, keeping the distance of 4 cm between the microphone and the mouth, to capture the emissions of the vowel^(24,25,26). They were instructed to, after a maximum inspiration, sustain during an entire expiration, with a normal *pitch* and *loudness*, the vowel /a/, which was recorder and measured by seconds. The vowel was sustained three times, the highest value being chosen in seconds, such as MPT⁽⁶⁾.

IT was realized the measure of normal SP, in dB, of vowel emissions /a/, with the Instrutherm sound pressure gauge (Dec-480 model), Positioned in front and at 30 cm from the mouth and adjusted in the “A” weighting circuit and “slow” response circuit, in a room with a noise level below 50 dB, considering it, as a result, the modal SP obtained⁽²⁶⁾.

After checking the normality of the variables, the Spearman test was applied to perform the correlations between the variables of muscle activation of the BCP, MPT/a/ and SP, with a significance level of 5%.

RESULTS

The entire sample studied had satisfactory transverse abdomen activation, as well as, for the most part, satisfactory activation of multifidus, maximal expiratory pressure and pelvic floor strength (Table 1).

The descriptive values of SP and MPT/a/ variables are shown in Table 2.

Regarding the variables mentioned, it was not possible to perform the correlation calculation with the results of the muscular evaluation of the transverse abdomen muscle, since there was no variation among the volunteers, that is, 100% of the studied group obtained satisfactory activation of this musculature. The correlations of the cited variables, without significant results, are presented in Table 3.

Table 1. Descriptive analysis of the results of the muscular activation tests

	Satisfactory	Unsatisfactory
EpMÁX	60%	40%
Multifidus	90%	10%
Pelvic floor	90%	10%
Oxford	90%	10%
Transverse	100%	-

Subtitle: EpMÁX = Maximum expiratory pressure; Multifidus = Activation of multifidus muscles; Pelvic floor = Activation of the pelvic floor through the perineometer; Oxford = Perineum muscle activation assessed through the Oxford scale; Transverse = Activation of the transverse abdomen

DISCUSSION

In this study, were measured the MPT/a/ and the modal SP of adult women without vocal complaints and without laryngeal affections and the measures were correlated to the results of the muscular activation of the muscles that make up the BCP.

The BCP, muscular strap that stabilizes the spine and trunk⁽¹⁰⁾, also helps the formation of positive expiratory pressure for phonation. When the BCP components act synergistically, they result in better diaphragm performance, resulting in greater airflow, SP and MPT, and may interfere with vocal quality⁽²⁶⁾. Authors⁽²⁾ Authors report that the shortening of the diaphragm and intercostal muscles causes pulmonary volume changes, influencing neither MPT and voice quality, mainly SP.

The vocal fold resistance, determined by the completeness and strength of its adduction, is also fundamental in the control of SP and MPT. This level of vocal production, the phonatory level, was controlled in the present study because the group did not present vocal complaints nelaryngeal affections, trying to

Table 2. Descriptive analysis of the variables sound pressure and maximum phonation times/a/

	Minimum group value	Maximum group value	Group average	Median	Standard deviation
SP modal (dB)	62	73	66.48	65.5	3.694
MPT/a/ (s)	6.33	18.66	12.326	12.16	4.12038

Subtitle: SP = sound presssure; MPT = maximum phonation times

Table 3. Correlation between the muscle groups of the center of corporal strength, maximum times of phonation /a/ and sound pressure, by the Spearman test

Tests	Muscle activation			
	EpMÁX	Multif.	Pelvic floor	Oxford
MPT/a/	r= 0.1963 p=0.5867	r=0.2171 p=0.5468	r=-0.2874 p=0.4240	r=0.3618 p=0.3042
SP	r=0.1975 p=0.5844	r=-0.0728 p=0.8416	r=-0.0587 p=0.8719	r=0.,2359 p=0.5116

Subtitle: EpMÁX = Maximum expiratory pressure; Multif. = Activation of multifidus muscles; Pelvic floor = Activation evaluated through the perineometer; Oxford = Activation of the perineum muscle through the Oxford scale; MPT = Maximum phonation time; SP = Modular sound pressure

determine the role of BCP, part of the respiratory level, in the MPT and SP vocal variables.

It was verified that all volunteers demonstrated satisfactory activation of the transverse abdomen muscle (Table 1). In a study of the respiratory strategies of singers, professional singers who used the oblique and transverse muscles of the abdomen more often performed greater rib enlargement and longer expiration⁽³⁾. Thanks to the horizontal orientation of the transverse fibers of the abdomen, this muscle acts as a band, sustaining and providing dynamic stabilization during static posture, gait⁽²⁷⁾ and expiration support⁽³⁾. Authors suggest that the large abdominal support required in the expiratory phase for adequate vocal projection is obtained by increasing the activation of the abdominal muscles⁽³⁾.

The abdominal musculature plays an important role in the initiation, regulation and production of the voice, apparently there is a direct relation between vocal extension and the relative increase in total lung capacity, being the abdominal musculature fundamental in the expansion of this capacity⁽¹²⁾.

The modal SP was presented as expected for adult women (64 dB), which is related to the satisfactory activation of the transverse abdomen, in its role of prolonging expiration⁽⁵⁾ and to improve SP, the projection and, consequently, vocal loudness (Tables 1 and 2).

Even excluding the influence factors on the vocal parameters, the analyzed group showed values of MPT discretely below the normal range (Table 2), A result that may be associated with the portion of the sample that presented an unsatisfactory activation of EpMAX, which evaluates the abdominal and intercostal muscles (Table 1), highlighting the role of muscle strength and coordination over the MPT values. Even though slightly below normal, the mean value of MPT found in the group is not considered suggestive of vocal alteration⁽²⁾. Thus, it is observed that even women without vocal or laryngeal alterations may present a slight reduction of MPT and unsatisfactory activation of the respiratory muscles, a component of the BCP, but satisfactory activation of the transverse abdomen.

It was observed that most of the women had satisfactory activation of the pelvic floor muscles and, at the same time, values considered normal for SP (Tables 1 and 2). The pelvic floor muscles have the function of sustaining the pressure exerted by the abdominal viscera and its contraction increases the intra-abdominal pressure by projecting the diaphragm upwards and favoring expiration for phonation (MPT) e a SP^(2,3,5,28).

The BCP muscles are the only active muscles during all movements of the trunk and, when activated satisfactorily, favor postural stability and a more energetic breathing, with effects on the voice^(2,3,5,7,28,29). High yield vocal emission requires more adapted and complex breathing and the lack of respiratory support causes poor vocal projection impairment. If there is a distance between the respiratory support and the laryngeal

mechanisms, the vocal fold vibration remains unchanged. A study carried out with popular singers verified an increase in MPT after seven speech-language intervention sessions with vocal and respiratory exercises, evidencing the benefits of respiratory and vocal synergy⁽³⁰⁾.

According to the results obtained, it is inferred that the BCP muscles evaluated by EpMAX, abdominal and intercostal, are more related to MPT measures. In order to perform the expiration, the rectus abdominis is required, as well as internal intercostals that perform the depression of the ribs. The result obtained may be due to the incoordination of these groups at forced expiration. The transverse abdomen increases the intra-abdominal pressure and stabilizes the spine. A satisfactory activation of this muscle by the volunteers may be associated with SP measurements, since they are related to the maintenance of expiratory air column pressure for phonation⁽⁴⁾.

As a limitation of the study, the reduced number of subjects is highlighted, and considering that, in the literature studied, no similar studies were found, the discussions and inferences about the findings of this research become restricted. It is important to expand this area of research with a greater number of subjects, to establish parameters of normality, and also to include the male gender, other age groups, as well as subjects who present changes in the different levels of vocal production, in order to better establish the relations between BCP muscles and different measures of voice.

It is noted that the importance of this study for the multiprofessional vision and the relationship between speech therapy and physiotherapy in the integral evaluation of vocal production.

CONCLUSION

In this group of adult women without vocal complaints and without laryngeal affections, no correlation was verified between the activation of the musculature that composes the body strength center, the maximum phonation times and the sound pressure. However, most of the women presented satisfactory muscular activation and, at the same time, values discretely below normal for maximum phonation times and normal for modal sound pressure.

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