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Artigo Original

Efeitos da alta demanda inspiratória no equilíbrio e risco de quedas em idosos

Effects of high inspiration demand on balance and fall risk index in elderly

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Resumo: Objetivo: Analisar o efeito da alta demanda inspiratória sobre o equilíbrio e o risco de queda em idosos. Métodos: Os participantes realizaram o Modified Clinical Test of Sensory Interaction and Balance (m-CTSIB) na plataforma Biodex Balance System (BBS) com aumento da demanda respiratória e imediatamente após o teste. O m-CTSIB foi realizado em três condições: avaliação basal com respiração livre; com aumento da demanda inspiratória; e após o término do teste. A análise dos dados foi realizada por meio do teste de Shapiro-Wilk, utilizando o teste de Levene e Análise de Variância para medidas repetidas (ANOVA). Resultados: Treze homens idosos (73 ± 7,25 anos) foram selecionados nos quais a pressão inspiratória máxima (PImáx) foi avaliada. No protocolo m-CTSIB, a comparação pré e durante mostrou diferenças significativas em Olhos Abertos em superfície firme e instável e em Risco de Queda. Quando essas condições foram comparadas durante e após os testes, houve diferenças significativas em todas as condições. Quando comparados pré e pós, apenas a superfície instável Olhos Fechados mostrou diferença significativa. Conclusão: A sobrecarga na demanda inspiratória foi capaz de causar alterações em variáveis do equilíbrio, principalmente quando o voluntário é exposto à sobrecarga.

Palavras-chaves: Respiração; Biodex Balance System; Idoso; Biomecânica.

Abstract: *Objective***:** Analyze the effect of high inspiratory demand on balance and risk of falling in the elderly. *Methods***:** The participants performed the Modified Clinical Test of Sensory Interaction and Balance (m-CTSIB) on the Biodex Balance System (BBS) platform with increased respiratory demand and immediately after the test. m-CTSIB was performed under three conditions: baseline assessment with free breathing; with an increase in the inspiratory demand and after the end of the test. For data analysis, the Shapiro-Wilk test was performed using the Levene test, and Analysis of Variance for repeated measures (ANOVA). *Results*: Thirteen elderly men (73 ± 7.25 years) were selected in whom the maximum inspiratory pressure (PImax) was evaluated. In the m- CTSIB protocol, pre and during comparison showed significant differences in Eyes Open in firm and unstable surface and in Fall Risk. When these conditions were compared during and after the tests, there were significant differences in all conditions. When pre and after were compared, only the Eyes Closed unstable surface showed a significant difference. *Conclusion***:** The overload in the inspiratory demand was able to cause changes in the balance variables, especially when the volunteer is exposed to overload.

Key-words: Breathing; Biodex Balance System; Elderly; Biomechanics.

1. Introduction

Currently in Brazil there are approximately 28 million elderly people, which represents more than 13 % of the population. According to projections, it is estimated that by the year 2040 Brazil will have 55 million elderly people, which will represent 27 % of the population, with 13 million being over 80 years old[1]. Therefore the country must prepare for the arrival of a large part of the population to old age, aiming at improving the quality of life and preventive methods in processes that affect this age group[2].

Some studies point out that aging is a process that can lead to changes in various body systems, especially in musculoskeletal structures and their functions[3, 4]. Aging also causes physiological changes, influencing the decline of functional capacity, which can compromise autonomy and mobility, thus increasing the risk of falls[5].

Falls are considered highly prevalent events among the elderly, even in active and healthy elderly people, and characterize one of the great predictable geriatric syndromes. Approximately 30 % of the elderly fall each year, and half have recurrent falls, with the majority of falls occurring at home[6,7]. Falls and fractures in elderly people can be greater in men when talking about the number of spinal cord injuries and head trauma[8]. Another factor that is also associated with aging is the biological change that compromises the inspiratory muscle function[9].

The strength of inspiratory muscles gradually decreases from 65 years of age[10]. Studies show that the stabilizing action of the diaphragm muscle works indirectly, increasing intra-abdominal pressure, and directly by continuous co-contraction with the rectus abdominis muscle, contributing to postural stabilization[11, 12].

In contrast, when inspiratory pressure overloades the diaphragm's role in postural balance, this causes people to adopt less efficient postural control strategies than in the free-breathing state[13], demonstrating that respiratory muscles play an important role in balance. High inspiratory demand can also lead to an increased risk of injuries and falls or loss of balance[14]. This imbalance is simultaneously related to the increased risk of falls[15].

However the identification of elderly fallers, and all the mechanisms that may globally influence this process, prevention, and treatment for this topic, still deserve further investigation in order to prevent all the harm that may be caused by the imbalance that causes falls.

According to Hodge's theory, age-related declines in respiratory function can directly and indirectly alter the contribution of inspiratory muscles to balance. Therefore, this raises the question of whether the increased demand on the inspiratory muscle system using a pressure threshold device can negatively interfere with the balance of elderly people, and thus influence the increased risk of falling.

Among the alternatives for measuring postural stability on a static or unstable surface, are platforms capable of moving freely in the anteroposterior and medial-lateral axes at the same time, such as the Biodex Balance System (BBS) (New York, USA)[16, 17,18]. This device assesses balance through 12 different levels of stability, with level 1 being more stable and 12 being more unstable[19] and can be programmed according to the degree of difficulty that one wants to cause[20]. This equipment also allows the assessment of the patient's neuromuscular control, quantifying their ability to maintain dynamic postural stability on a stable or unstable surface[17].

The BBS device is linked to software (Biodex, Version 1.08, Biodex, Inc.) that allows the device to measure the degree of inclination on each axis, providing an average swing score. Eight springs located at the bottom and outside of the platform provide greater or lesser resistance to movement[21]. The reliability of this type of equipment for the balance test was also found using the Bland-Altman method.

With this type of equipment, balance and postural stability can be assessed through various protocols by combining various degrees of platform instability, changing the position of the arms (crossed or free), uni or bipedal posture, and eyes open or closed[21].

When active elderly people were evaluated with this platform[20] a good stability index (0.80) and a low percentage of error variation was found. In this sense, balance measures with these platforms have been shown to be reliable and can be useful in determining the risk of falls and monitoring programs for the prevention of falls in the elderly. In this study one test of the BBS device was performed: the Modified Clinical Test of Sensory Interaction and Balance (m-CTSIB).

The m-CTSIB test in contrast, aims to provide information on the individual's ability to adapt and maintain balance on a static surface, in view of the sensory conflicts imposed by the test, and reveals the sensory system in which the individual is most dependent for postural control[25]. The result of the m-CTSIB test is the patient swing index, which represents the mean absolute deviation from the patient's mean position during a test. The higher the sway index, the more unstable the person was during the test. The test changes a sensory condition and measures how well the patient compensates.

Since balance is considered essential during the practice of physical activity as well as in the daily quality of life, and its lack can negatively impact healthy aging; and that the deficiency of respiratory muscles can reduce postural control strategies[13] in elderly individuals; and that aging can lead to declines in the respiratory system[9]; and that the elderly population is visibly increasing, it is necessary to develop preventive methodologies and physical activity promotion programs aimed at this population[2]. In this way, the present had the objective of to verify the influence of increased inspiratory demand on balance and risk of falling in the elderly. And to check whether the variables of the CTSIB test on the BBS platform is different in the elderly when performed under three different conditions: during free breathing; during the increase in respiratory demand; and immediately after, to verify the recovery of the inspiratory muscles and the influence of recovery on balance.

2. Methods

Population

The volunteers were 13 physically active elderly men (over 60 years old). The present study was approved by the local Ethics and Research Committee (Report number:

3.800.531). The inclusion criteria for this study were: being aged 60 years or above, participants should practice physical activities for at least 6 months with a weekly load of 150 to 300 minutes of moderate-intensity aerobic physical activity; or at least 75 to 150 minutes of vigorous-intensity aerobic physical activity[22]; being male, and walking.

The exclusion criteria were: respiratory problem of any type; walking with an aid device (cane, crutches, walker); presence of neurological disease; orthopedic involvement in the last 6 months in lower limbs (sprains, ligament tears, muscle injuries, fractures and surgeries), low back pain; vestibular impairment (presence of vertigo or labyrinthitis); visual impairment not corrected by lenses;

Instruments

Stadiometer, Scale, BBS, Manovacuometer (measures maximum inspiratory pressure (IPmax) in cmH^2O), and PowerBreathe (Respiratory Exerciser for training High Resistance Inspiratory Muscles (HaB Latin America)).

Procedures

After signing the consent form, the volunteers were invited for the sample characterization assessments (age, gender, mass, height, IPmax), and then referred to BBS assessments under the following conditions: Free breathing; with increased respiratory demand; and immediately after to check the recovery of the inspiratory muscles and its influence on balance.

Description of Test

The participants initially performed the IPmax assessment (to calculate the percentage that would be used in carrying out the test with an increase in inspiratory demand) at the level of the mouth with a digital manuvacuometer Globalmed® Model MVD300.

a) m-CTSIB Protocol (BBS):

This test was also carried out with the BBS, for which the platform is stable and allows the analysis of the ability to maintain stability under four conditions of sensory conflict, with the goal of staying for 30 seconds in each condition. In condition 1 (eyes open on a firm surface), all senses are present; in condition 2 (eyes closed on a firm surface), the visual system does not provide information; in condition 3 (eyes open on an unstable surface), there is inaccurate information from the proprioceptive system; and in condition 4 (eyes closed on an unstable surface), there is inaccurate information from the proprioceptive system and absence of the visual system.

To start, the volunteers were positioned on the BBS in the orthostatic position, with eyes open and arms free, with an on-screen feedback display[24]. The same test was then performed, with the volunteer breathing through the Power Breathe® equipment (with an increase of 50 % in IPmax), and repeated for the third time to assess recovery.

The unstable surface is a patterned indexed foam pad that matches the size of the provided Balance System SD platform. The foam pad is used for the m-CTSIB test conditions.

During the test, the voluntaries were performed with the volunteers barefoot, and the feet positions were recorded using coordinates on the platform grid to ensure the same posture throughout the test.

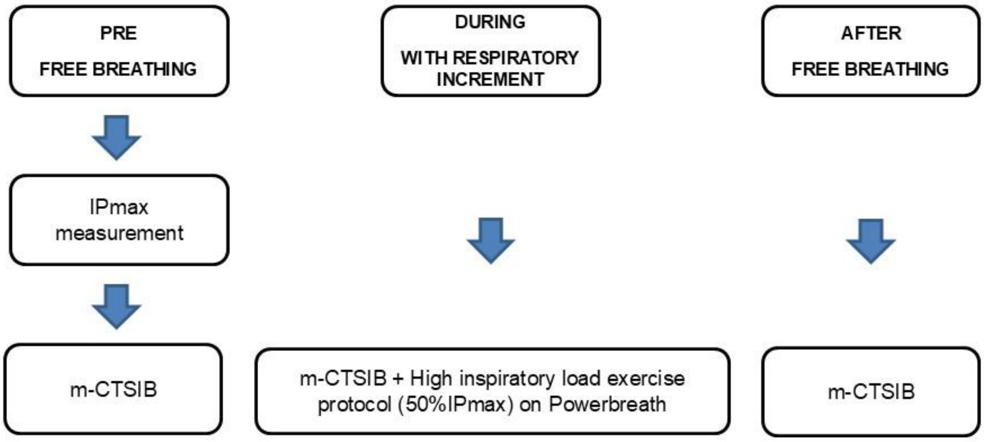

Figure 1 – Test organization chart.

Variables

a) Variables of the m-CTSIB Protocol: this protocol provides the Sway Index against the four sensory conditions:

Condition 1 (eyes open on a firm surface); Condition 2 (eyes closed on a firm surface); Condition 3 (eyes open on an unstable surface); and Condition 4 (eyes closed on an unstable surface);

Data processing

Stability variables: the degrees of general stability, anteroposterior stability, mediolateral stability, and the balance index were collected by Biodex software, Version 1.08, Biodex, Inc.

Statistics

After checking normality using the Shapiro-Wilk test and homogeneity using the Levene test, a one-way analysis of variance for repeated measures (ANOVA) and post-hoc with Bonferroni correction was performed. Thus, a comparison was made between before, during, and after the increase of 50 % in IPmax, verifying the influence of the increase in inspiratory demand on the risk of falls in the elderly. All analyzes were performed using SPSS 21.0, adopting $p<0.05$.

3. Results

Table 1 shows the anthropometric and IPmax description of the volunteers (n=13).

Age	Weight	Height	BMI	IPMax (PRE)
73 ± 7.26	68.23 ± 13.62	1.68 ± 6.35	24.93 ± 3.41	103 ± 36.77

Table 1: *Age (years); Weight (kilograms); Height (meters); BMI (weight/height²); Inspiratory Pressure (centimeters of water);*

Table 2 presents the mean values and SD of the Eyes Open Firm Surface and Eyes Closed Firm Surface in the m-CTSIB obtained before, during, and after respiratory demand.

Eyes Open Firm Surface			Eyes Closed Firm Surface	
CONDITION	MEAN AND SD	p	MEAN AND SD p	MEAN AND SD p
PRE	1.03 ± 0.53	0.003*	1.72 ± 0.90	1.72 ± 0.90
DURING	1.70 ± 0.57	0.000**	1.93 ± 0.75	1.93 ± 0.75
AFTER	1.00 ± 0.33	0.807***	1.48 ± 0.54	1.48 ± 0.54

* Difference between pre and during conditions (p=0.003) (p=0.456)

** Significant difference between during and after conditions (p=0.000) (p=0.001)

*** Difference between pre and after conditions (p=0.807) (p=0.301)

Table 3 presents the mean values and SD of the Eyes Open Foam Surface and Eyes Closed Foam Surface in the m-CTSIB obtained before, during, and after respiratory demand.

Eyes Open Foam Surface			Eyes Closed Foam Surface	
CONDITION	MEAN AND SD	p	MEAN AND SD	p
PRE	1.73 ± 0.50	0.000*	5.09 ± 1.27	0.197*
DURING	3.08 ± 0.80	0.007**	5.63 ± 1.80	0.004**
AFTER	2.08 ± 1.24	0.304***	4.43 ± 1.3	0.040***

* Difference between pre and during conditions (p=0.000) (p=0.197)

** Significant difference between during and after conditions (p=0.007) (p=0.004)

*** Difference between pre and after conditions (p=0.304) (p=0.040)

Table 4 presents the mean values and SD of the Fall Risk Test (AVG) in the m-CTSIB obtained before, during, and after respiratory demand.

Fall Risk (AVG)

CONDITION	MEAN AND SD	p
PRE	2.39 ± 0.57	0.001*
DURING	3.09 ± 0.72	0.000**
AFTER	2.25 ± 0.57	0.332***

* Significant difference between conditions pre and during (p=0.001)

** Significant difference between during and after conditions (p=0.000)

*** Difference between pre and after conditions (p=0.332)

4. Discussion

Hodges studies[24] have already stated that the phasic contractions of the diaphragm help to maintain postural stability in situations where externals destabilize a spine. We believe that a similar mechanism occurs in dynamic tasks and that the increase in inspiratory muscle demand results in the worsening of balance skills.

Possibly the deficits caused in practically all the variables analyzed are due to the combination between the physiological changes that occur in aging and the use of the Power Breathe® device. The trunk musculature works together with the function of protecting the spine and preserving postural control, and opposes the automatic form in anticipation of actions that destabilize or overload postural stability[11, 12]. Diaphragm contractions occur in the same way, but the role of the diaphragm in breathing always takes precedence over postural function[25].

Studies on the relationship of respiratory muscles, especially the diaphragm, in trunk stabilization point out that the increase in intra-abdominal pressure during inspiration is capable of stimulating proprioception during postural control[11]. In this study, the results show that the exercise with high inspiratory load generated an increase in the values in the test, indicating an increase in the balance index, and thus increasing the risk of falls.

Studies comparing the PST protocol before, during, and after the increase in inspiratory demand were not found in the literature, thus the present study is a precursor on the association of respiratory increment with balance in the BBS. The PST protocol was used as it is important data to be studied and applied in the literature. Although we did not find relevant differences, this could be due to the need for a larger sample.

The increase in the variables may be the result of a change in the postural control strategy, already studied[13], explaining that when there is inspiratory muscle fatigue, proprioception and the emerging postural control of the trunk muscles are directed, with the intention of compensating for postural imbalances.

Age-related declines in respiratory function can directly and indirectly alter the contribution of inspiratory muscles to body balance; recent evidence suggests that inspiratory muscle weakness can contribute to deficits in balance during daily activities.

Based on the results obtained, it is concluded that the overload on inspiratory demand was able to cause changes in the risk of falling in the elderly (Fall Risk) and in the balance variables of the CTSIB (Eyes Open Firm Surface, Eyes Open Foam Surface, and Eyes Closed Foam Surface) under different conditions. Therefore, we consider that the strength of the inspiratory muscles and activities with high respiratory demand must be taken into account in the treatment, prescription, and prevention of activities involving the elderly.

5. Conclusion

With this study, we conclude that the increase in inspiratory demand provided by the Power Breathe® device was able to change the balance of elderly people. Thus, it is important to emphasize the attention in the practice of physical activities that increases respiratory demand. Furthermore, further studies are needed to investigate the positive influence of inspiratory muscle training on improving postural balance and trunk muscle control.

Author Contributions: MG and KPPP had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Concept and design: Gonçalves, KPPP and TAMP. Acquisition, analysis, or interpretation of data: all authors. Drafting of the manuscript: KPPP and TAMP. Critical revision of the manuscript for important intellectual content: All authors. Statistical analysis: KPPP and TAMP. Obtained funding: MG. Administrative, technical, or material support: Gonçalves. Supervision: MG.

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