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Proposal of standardization of *Horus®* computerized posturography in adults

Proposta de normatização da posturografia computadorizada Horus® *em adultos*

Keywords

Dizziness
Postural Balance
Vestibular Function Tests
Posture
Vertigo

ABSTRACT

Purpose: To propose a normalization model of a posturography platform in adults without changes in body balance, through descriptive analysis by age group and sex. **Methods:** Cross-sectional observational study. Adults, with no changes in body balance and no vestibular complaints were submitted to 6 sensory conditions on the Horus® posturography platform. The following variables were analyzed: stability limit area and confidence ellipse area, trajectory length and average velocity for each condition tested. The variables were analyzed by age group and sex. The equilibrium score, the sensory integration test and the equilibrium index were calculated on the conditions. **Results:** Sixty-one subjects (38.3%) and 23 (37.7%) were male, 40 (65.57%) between the ages of 20 and 40 and 21 (34.43). %) between 41 and 59 years. The area of the stability limit and pressure center variables for 6 sensory conditions tested - confidence ellipse area, trajectory length, total mean velocity and confidence ellipse ratio by the area of the stability limit were described. There was a statistically significant difference in the comparison between the area of the stability limit between sexes and between age groups, being a higher value in males and in younger patients. Regarding the analysis of the variables by each condition, there was no difference of results between the sexes and age groups. **Conclusion:** Subjects of different sexes and age groups should be considered separately only in the analysis of the stability limit.

Palavras-chave

Tontura
Equilíbrio Postural
Testes de Função Vestibular
Postura
Vertigem

RESUMO

Objetivo: Propor um modelo de normatização de uma plataforma de posturografia em adultos sem alterações do equilíbrio corporal, através da análise descritiva por faixa etária e sexo. **Método:** Estudo observacional transversal. Adultos sem alterações do equilíbrio corporal e sem queixas vestibulares foram submetidos a seis condições sensoriais na plataforma de posturografia Horus®. Foram analisadas as variáveis: área do limite de estabilidade e área de elipse de confiança, comprimento da trajetória e velocidade média para cada condição testada. As variáveis foram analisadas por faixa etária e sexo. Sobre as condições foram calculados o escore de equilíbrio, teste de integração sensorial e índice de equilíbrio. **Resultados:** Foram avaliados 61 sujeitos, 38 (62,3%) do sexo feminino e 23 (37,7%) do sexo masculino; 40 (65,57%) na faixa etária de 20 a 40 anos e 21 (34,43%) entre 41 a 59 anos. Foram descritas a área do limite de estabilidade e as variáveis do Centro de Pressão para seis condições sensoriais testadas – área da elipse de confiança, comprimento da trajetória, velocidade média total e razão da elipse de confiança pela área do limite de estabilidade. Houve diferença estatisticamente significante na comparação da área do limite de estabilidade entre sexos e entre faixas etárias, sendo o valor maior no sexo masculino e em pacientes mais jovens. Quanto à análise das variáveis por condição, não houve diferença de resultados entre os sexos e faixas etárias. **Conclusão:** Sujeitos de sexos e faixas etárias distintas devem ser considerados separadamente somente na análise do limite de estabilidade.

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INTRODUCTION

The vestibular system is not the only source of sensorial information used to guide and maintain posture. Visual and somatosensory information, as well as the correct sensory integration originating in the brainstem, participate actively in maintaining body balance. This representation is compared with a map of prior knowledge of postural situations and efferences are then emitted for a postural adjustment[1]. Thus, the importance of a diagnostic method to evaluate these data individually becomes evident. This way, each system supplies diverse and equally important information.

Posturography complements the classic series of tests for diagnosis of vestibular impairment, which was redundant in the investigation of the vestibular ocular reflex (VOR)[2]. It is a complementary test for individuals presenting complaints related to body balance not diagnosed by conventional tests, such as electro-oculography with rotational and caloric testing and vestibular evoked myogenic potential (VEMP). Its clinical relevance consists primarily of diagnosing the presence of a disorder in body balance and, later, establishing if this disorder results from a problem in sensory input or integration, inefficient motor response, or a combination of both. It provides complementary information to the other tests, since it assesses, through different conditions, the participation of the visual, vestibular, and somatosensory systems in maintaining body balance. On the other hand, even patients who have posturography within normal limits may experience oculographic changes. Therefore, posturography is not a substitute for conventional vestibular tests, but it complements their findings and is prescribed in specific situations where investigation of the vestibulospinal reflexes (VSR) and sensory analysis of the balance disorder are relevant[3].

Posturography analyzes the center of pressure (CoP) using a force platform. The CoP corresponds to the vertical projection of the center of body mass[2]. When a healthy individual remains erect and static on a force platform, small CoP oscillations are observed[4,5]. Quantification of these oscillations is essential to determine the parameters of normality[5].

Anthropometric factors of each individual (weight and height), age, the position of the feet, and distance between the patient and the visual field can influence the CoP[4]. Elderly people present decreased proprioception and muscle strength, which directly affect balance and can increase the chance of falls[6]. The individual's 40 cm visual field is associated with better postural stability concerning the visual target positioned 3 meters away[4]. The closer the feet are, the smaller the area of the stability limit, and the greater the difficulty in standing upright[4]. Thus, it is vitally important to establish normality parameters considering these variations.

Therefore, this study aims to describe a proposal for standardizing the Horus® computerized posturography platform for adults without alterations in body balance, through descriptive analysis by age group and sex.

METHODS

This is a cross-sectional observational study approved by the Research Ethics Committee of Universidade Estadual de Campinas (number 78240017.0.0000.5404). All participants were informed about the procedure and signed the Informed Consent Form. The sample consisted of 61 adult individuals between 20 and 59 years old, with no complaints regarding body balance. All participants were submitted to the clinical evaluation protocol of the Otoneurology Sector of the Discipline of Otorhinolaryngology, Head and Neck of Universidade Estadual de Campinas, which includes anamnesis, ENT (Ear, Nose, and Throat) physical examination and cranial nerve exams, static and dynamic balance tests (Romberg and Fukuda respectively), coordination tests (diadochokinesis with alternate pronation and supination of the upper limbs and index-nose test), research for spontaneous and semi-spontaneous nystagmus, head impulse test, and head-shaking nystagmus. All participants were evaluated by the same team. The participants were chosen randomly among hospital staff, students, and passers-by in the previously set 12-month period between July 2017 and July 2018. The study included individuals without vestibular diseases and able to collaborate with the performance of posturography, which requires the integrity of vision and the ability to fix one's gaze at a predetermined point. Individuals with vestibular, neurological, or orthopedic diseases, using medication that could influence vestibular function, individuals who did not agree to sign the Informed Consent Form, or did not wish to participate in the study were excluded. Athletes, dancers or any individual potentially presenting balance performance well above average were also excluded.

Participants were submitted to six sensory conditions on the Horus® dynamic posturography platform (chart 1). This device, consisting of a force platform containing four sensors, arranged in a rectangular position at the four corners, was developed and is marketed in Brazil by Contronic[7]. It provides information from the center of pressure (CoP), mediolateral stabilogram, anteroposterior stabilogram, statokinesigram, and rehabilitation module, and is useful for diagnosis and vestibular rehabilitation. However, it still does not have known parameters of normality for the conditions tested. The stable surface corresponds to the platform surface itself, on which the patient stands barefoot and without support, and the unstable surface is tested using a medium-density pad. A 42-inch LED TV set was positioned 1 meter away from the patient's eyes, on the same horizontal plane of vision, following the manufacturer's orientation, with the projection of a fixed point and optokinetic tunnel to provide visual conflict. The stability limit area (SL) and 95% confidence ellipse area (CE), path length (PL), and average speed (AS) variables were analyzed.

Figure 1 shows the equipment and the way the test is carried out, always by two examiners to avoid the risk of falling.

The Horus® posturography platform is a static type, as it allows measuring the anteroposterior and lateral excursion of the body in individuals standing in an orthostatic position, stationary on a force platform. As the CNS uses a combination of sensory modes in maintaining posture and since the vestibular system responds more to changes in acceleration and orientation in space, posturography is believed to be a limited method for analysis of the spinal vestibular function[8,9]. However, it enables analysis of the patients' SL area - their ability to voluntarily move the center of mass with precision, speed, and velocity in all directions until their maximum body displacement limit is reached. Moreover, this posturography system allows dynamic tests to be performed by using a medium-density pad on the platform to simulate a proprioceptive conflict and simulates a visual conflict through visual stimulation using image projections on a widescreen.

Force platforms are currently indispensable in the study of balance and posture, especially for patients with dizziness complaints. Although there are several devices available in the market, the parameters analyzed are usually similar and equally useful for diagnosis and vestibular rehabilitation (VR)[10].

The protocol employed by our service used configurations available in the platform software and others established by the service in particular, based on other protocols already described[11].

Initially, the stability limit was marked. The participant was instructed to move their body in an anteroposterior and lateral direction using the ankle strategy, without moving their feet or trunk. The movement happened slowly until the individual reached his/her limit of stability, respecting the following sequence: forward and return to the starting position; to the right and return to the starting position; to the left and return to the starting position; backward and return to the starting position. Participants were instructed to perform the complete sequence of movements only once. If there was any movement of feet or torso, the test was restarted. After that, the six conditions were tested for 30 seconds each. Only one record of each condition was made, as allowed by the equipment.

The variables were also analyzed by age and sex and the equilibrium score (ES) and sensory integration test (SIT) were calculated for each condition and balance index (BI). The ES analysis considered that the goal in each of these conditions is the maintenance of static equilibrium. The participant was instructed to remain as stationary as possible on the platform, even in the face of cushion instability and visual conflict. Quantification of the results obtained ranged from 100% (no displacement recorded by the platform's sensors) to 0%, which corresponded to a fall in either direction. Based on the ES for each condition, the SIT was performed, consisting in the quantitative analysis of body equilibrium calculated using the ratio between the ES of two conflicting situations, to establish the most requested equilibrium functions in these situations, and the ES was found by the calculations described below:

- somatosensory function: average of condition 2/average of condition 1
- visual function: average of condition 4/average of condition 1
- vestibular function: average of condition 5/average of condition 1
- visual dependency: average of condition 3 + 6/average of condition 2 + 5
- equilibrium index: arithmetic mean of conditions 1 to 6

In eyes-open conditions, there is the contribution of visual information. In situations where the cushion is used, proprioceptive information is distorted, requiring more from visual and vestibular information. When using the cushion with eyes closed, maintaining posture fundamentally depends on vestibular information[11]. The visual conflict with an optokinetic tunnel provides distorted, but not absent, visual information[12,13,14,15].

The Horus® software generated reports containing information about the SL area, the 95% CE area, PL, and AS in the six sensory conditions. The 95% confidence ellipse area is defined as the 95% distribution area of the samples from the Center of Pressure. The length of the trajectory corresponds to the average displacement of the individual in the anteroposterior and latero-lateral directions. The average oscillation speed is determined by the total distance divided by the 30 seconds of each test, according to information provided in the manufacturer's manual.

Posturography results were collected using data from the Center of Pressure by the balance platform for each stimulus, aiming to establish limits of normality for posturography parameters. Each parameter was analyzed both separately and jointly, to observe the performance of participants.

The descriptive analysis involved the presentation of frequency tables for categorical variables and position and dispersion measures for numerical variables. The Chi-square test was used for comparison of proportions. The Mann-Whitney test was used to compare measures between genders and age groups. The level of significance adopted for statistical tests was 5%. All confidence intervals constructed throughout the survey were defined with 95% statistical confidence. The SAS (Statistical Analysis System) System for Windows program, version 9.4 (SAS Institute Inc., 2002-2012, Cary, NC, USA.) was used for statistical analysis.

Chart 1. Posturography protocol

Stability limit area
Condition 1: Eyes open with fixed target on firm surface
Condition 2: Eyes closed on firm surface (Romberg)
Condition 3: Eyes open with visual conflict (*) on a firm surface
Condition 4: Eyes open with fixed target on unstable surface
Condition 5: Eyes closed on unstable surface
Condition 6: Eyes open with visual conflict (*) on unstable surface

(*) Visual conflict: optokinetic tunnel

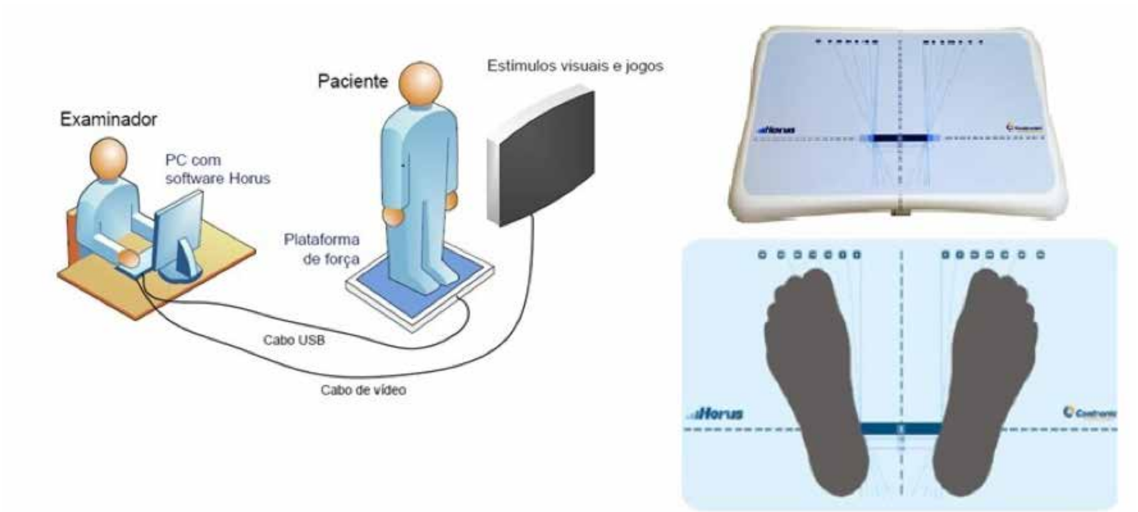

Figure 1. Schematic illustration of the functional diagram and positioning of the feet on the platform

Source: User Manual - Horus - System for Posturography and Postural Rehabilitation. Pelotas: Contronic; 2016.

RESULTS

Sixty-one patients without vestibular complaints or changes in body equilibrium and chosen in the period set for the study were evaluated, 38 (62.3%) female and 23 (37.7%) male, 40 (65.57%) in the 20 to 40 years age group and 21 (34.43%) in the 41 to 59 years age group. The proportions of the groups by sex and age group were homogeneous, with a p-value of 0.1047 by the Chi-square test.

Tables 1 and 2 present anthropometric data.

Table 3 describes the stability limit area discriminated by gender and age group. Table 4 shows the description of the CE, PL, and AS variables area for the six conditions tested.

Figure 2 describes possible normal values of the equilibrium score for the six conditions tested and the balance index, and figure 3 describes normal values of the sensory integration test. The minimum value would be the cutoff point between the healthy and the sick and can be useful for clinical analysis. The maximum value is not relevant for this analysis, as it represents an above-average performance.

Table 1. Descriptive values of height and body mass by gender

Descriptive value	Sex	Average	Mean	Minimum value	Maximum value	Standard deviation	P value
Height (cm)	M	175.1	175	156	193	7.9	p<0,05*
	F	162	161	150	174	6	
Body mass (kg)	M	76.6	73	57.6	116.3	14.8	p<0,05*
	F	63.9	61.6	40.9	102.6	13.4	

*Mann-Whitney Test (p<=0,05). Captions: M: male. F: female.

Table 2. Descriptive values of height and body mass by age group

Descriptive value	Age group	Average	Mean	Minimum value	Maximum value	Standard deviation	P value
Height (cm)	F1	169.1	170	150	193	10.1	p<0,05*
	F2	163.3	162	155	176	6.4	
Body mass (kg)	F1	68.9	67.9	40.9	116.3	17.2	P=0,91
	F2	68.6	65.5	49.8	100.7	11.2	

*Mann-Whitney Test (p<=0,05). Captions: F1: 20 to 40 years old. F2: 41 to 59 years old.

Table 3. Descriptive values of the Horus® stability limit (SL) area by gender

Descriptive value	Sex	Average	Mean	Minimum value	Maximum value	Standard deviation	P value
SL area (mm^2)	M	28356.8	27218.3	14664.9	39109.1	6841.6	0.0016*
	F	22167.5	21438.5	8709.6	36392.7	6351.5	
	F1	26248.5	26055.8	9181.6	39109.1	6679.9	0.0061
	F2	21772.8	20204.7	6986.7	36392.7	6968.7	

*Mann-Whitney Test (p<=0,05). Captions: M: male. F: female. F1: 20 to 40 years old. F2: 41 to 59 years old.

Table 4. Descriptive values of the 95% confidence ellipse area (EC), the path length (CT) and the average speed (VM) of the Horus® conditions for both genders and age groups

Descriptive value	Condition	Average	Mean	Minimum value	Maximum value	Standard deviation
CE area (mm^2)	C1	163.9	139.4	21.8	477.8	100.2
	C2	190.1	151.1	20.9	643.2	148.2
	C3	158.4	127.9	11.9	499.8	117.7
	C4	284.3	252.3	36.6	876.6	175.6
	C5	441.8	211.6	59.7	2436	381
	C6	253.6	197.4	25.7	1115.3	190.6
PL (mm)	C1	254.2	233	145.2	515.5	84.8
	C2	331.4	306.6	132.5	664.2	122.2
	C3	271.9	255	142	528.1	89.4
	C4	385.7	353.6	153.9	833.9	133.3
	C5	491.4	467.4	216	1206	186.6
	C6	360	328	195.3	669.1	122.3
VM (mm/s)	C1	8.6	7.3	4.6	39.7	4.9
	C2	10.5	9.9	4.3	21.2	3.9
	C3	8.7	8.1	4.5	15.8	2.8
	C4	12.1	11.1	5	26.9	4.3
	C5	15.8	14.4	7	39.1	6
	C6	11.4	10.5	6.4	21.7	3.9

Captions: C1 - Condition 1: Eyes open with fixed target on firm surface. C2 - Condition 2: Eyes closed on firm surface (Romberg). C3 - Condition 3: Eyes open with visual conflict on a firm surface. C4 - Condition 4: Eyes open with a fixed target on an unstable surface. C5 - Condition 5: Eyes closed on an unstable surface. C6 - Condition 6: Eyes open with visual conflict on an unstable surface.

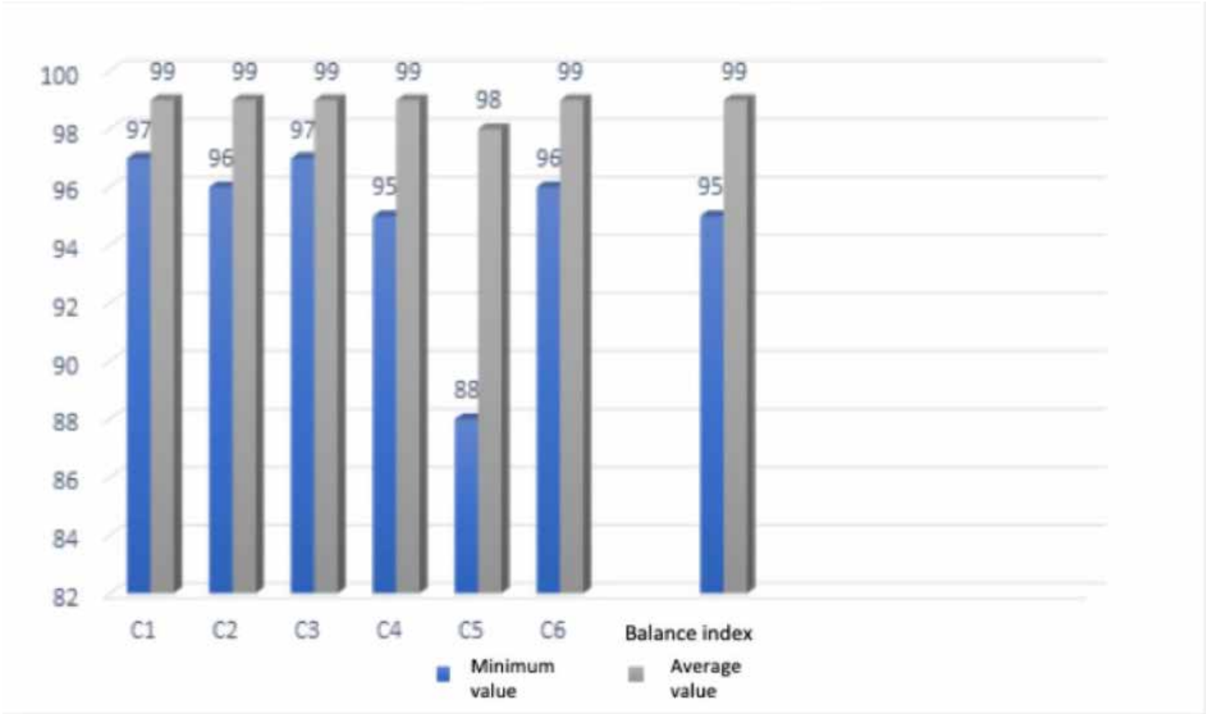

Figure 2. Normality values of the balance score for the tested conditions and balance index in both genders and age groups

Caption: C1 - Condition 1: Eyes open with fixed target on firm surface. C2 - Condition 2: Eyes closed on firm surface (Romberg). C3 - Condition 3: Eyes open with visual conflict on a firm surface. C4 - Condition 4: Eyes open with a fixed target on an unstable surface. C5 - Condition 5: Eyes closed on an unstable surface. C6 - Condition 6: Eyes open with visual conflict on an unstable surface.

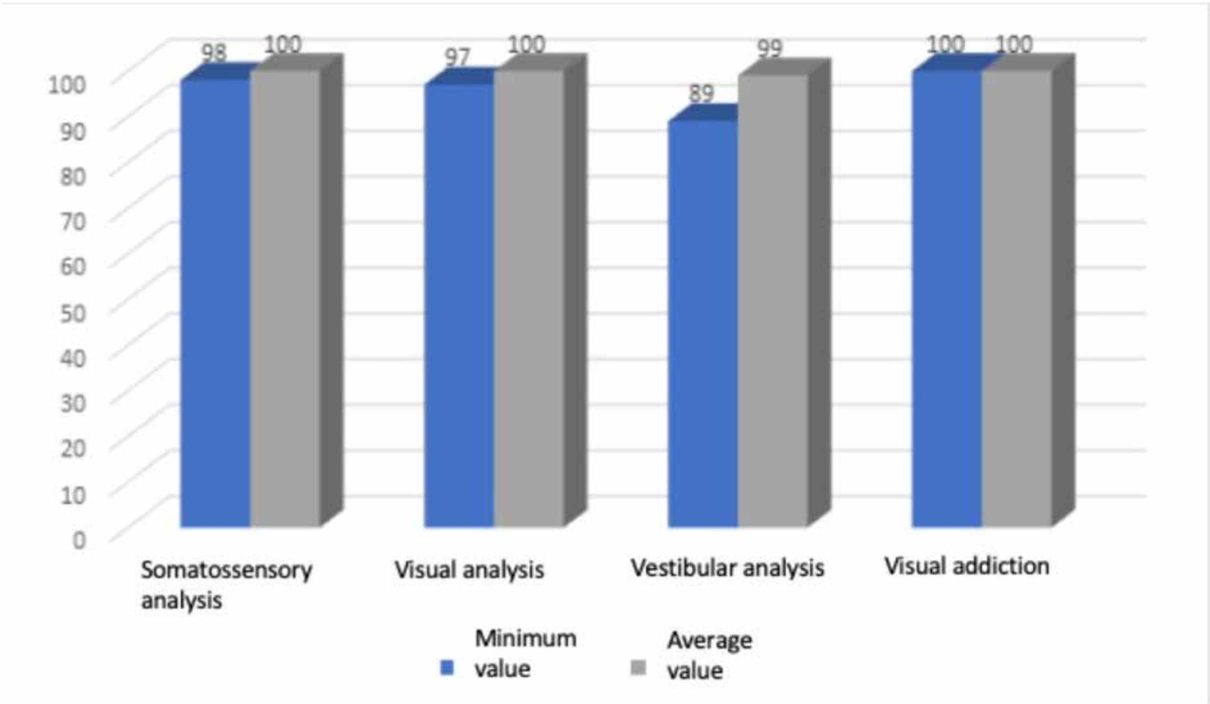

Figure 3. Normality values of the sensory integration test for both genders and both age groups

DISCUSSION

The stability limit area is equivalent to the individual's ability to voluntarily move his center of mass, with precision and speed. This test uses the ability to integrate thinking and cognition. To perform it, the individual needs observation, memory, and quick response, in addition to postural control[16,17]. In this study, the stability limit (SL) area was significantly larger in male participants and younger individuals. Also, male and younger participants were taller, which provides a greater support base. The difference in the SL area in men is well documented in the literature in publications using other platforms[18,19,20]. In addition, women tend to have reduced lean mass and muscle strength compared to men of the same age[21]. Regarding the age group, other publications corroborate that younger individuals tend to have a greater area of stability than older ones, due to the relationship between sensory information and motor capacity, which tends to be lower with advancing age[22]. When the SL area is below the minimum variation of the standard deviation, we can infer that the individual has a limitation of body movement due to some deficiency in one of the systems that make up sensory integration. However, when this value exceeds the maximum variation of the standard deviation, there is no pathological significance, as well-conditioned individuals (athletes, dancers, etc.) may perform better than the general population. This study excluded participants with this profile from the analysis.

In all conditions tested, specifically in static conditions either with eyes open or closed (Romberg), on a fixed surface or not, the absence of a statistically significant difference between sexes and age groups below 60 years old agrees with the studies by Freitas PB and Moreira DA et al[22,23].

In this study, we have chosen to calculate the equilibrium score for each condition tested, as well as the ES and SIT, like Equitest®, Balance Master®, SwayStar®, STATITESTTM, among other dynamic platforms[24,25,26]. Many differences between posturography stimuli and protocols are explicit in the results found in this study when compared to others. However, they are similar ideas, and the data generated are important for comparison with future analyses to be made with Horus®, as well as for future standardization work or clinical applicability. It is worth mentioning that SIT is the only test that provides quantitative information regarding the functionality of the three systems which report on equilibrium, evidently with limitations regarding sensitivity and specificity[19].

The main limitation of this study is that the calculation of ES and SIT is different from that found in conventional dynamic platforms due to the limitations of the equipment itself as to how the data are obtained. While dynamic platforms are equipped with an oscillating surface and a wide and mobile visual scenario that involves the individual, the Horus® platform simulates these conditions through the use of a cushion and a virtual reality image projected on a television monitor. These factors make comparisons between equipment's difficult, but do not prevent them.

CONCLUSÃO

Esta proposta de normatização evidenciou que a área do limite de estabilidade apresenta diferença entre os sexos e faixas etárias, devendo ser considerada separadamente na análise e em futuros protocolos de normatização e na prática clínica. O escore de equilíbrio e o teste de integração sensorial não apresentaram diferenças entre sexos e faixas etárias.

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Authors’ contributions

ECMFF – participated in the study design, data collection, analysis and interpretation and writing of the paper; RM – participated in the study design, data collection, analysis and interpretation and writing of the paper; GS – participated in the study design and writing of the paper; VBCR – participated in the study design and data collection; CTC – participated, as a supervisor, in the study design, data analysis and interpretation and writing of the paper; JRP – participated, as a supervisor, in the study design, data collection, analysis and interpretation of the data and writing of the paper.