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Protocol for static posturography with dynamic tests in individuals without vestibular complaints using the Horus system

Protocolo para posturografia estática com provas dinâmicas em indivíduos sem queixas vestibulares utilizando o sistema Horus

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Keywords

Postural Balance
Dizziness
Vertigo
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ABSTRACT

Purpose: To propose a protocol for investigating the body balance and determining reference values in different age groups and gender, using the methodology of static posturography with dynamic tests, in low-cost Brazilian equipment for diagnosing balance. **Methods**: The objectives of this study aimed to propose a protocol for investigating the body balance and determining reference values in different age groups and gender, using the methodology of static posturography with dynamic tests, in new low-cost Brazilian equipment for diagnosing balance. Method: 297 healthy volunteers, between 20 and 89 years old, without vestibular complaints, were divided into six groups according to age group and gender. Stability limits and seven sensory conditions named from C1 to C7 were evaluated. The work was carried out using Horus equipment, manufactured in Brazil. **Results**: The reference values of the stability limit for females and males were obtained according to the ages: from 20 to 59 (≥ 12,594 mm² and ≥ 19,221 mm²); from 60 to 69 (≥ 7,031 mm² and ≥ 12,161 mm²); from 70 to 89 (≥ 6,340 mm² and ≥ 8,794 mm²). For sensory integration tests under conditions C1 to C7, as age increased, the values of the Confidence Ellipse (CE) area also increased. Reference percentile values were established for Residual Functional Balance (RFB) and Sensory Analysis (SA). **Conclusion**: A protocol was established to investigate body balance via static posturography as well as reference values for normal individuals were determined, according to the different gender and age groups.

Descritores

Equilíbrio Postural
Tontura
Vertigem
Valores de Referência
Propriocepção

RESUMO

Objetivo: Propor um protocolo de investigação do equilíbrio corporal e determinar valores de referência para diferentes faixas etárias e gênero aplicando a metodologia da posturografia estática com provas dinâmicas em novo equipamento brasileiro de baixo custo para diagnóstico do equilíbrio. **Método**: 297 voluntários hígidos, adultos, idosos e sem queixas vestibulares foram divididos em seis grupos, segundo faixa etária e gênero. Foram avaliados os limites de estabilidade e sete condições sensoriais (C1: olhos abertos, superfície estável; C2: olhos fechados, superfície estável; C3: olhos abertos, superfície instável; C4: olhos fechados, superfície instável; C5: estimulação optocinética para a direita, superfície instável; C6: estimulação optocinética para a esquerda, superfície instável; C7: estimulação túnel, superfície instável). O trabalho foi realizado com o equipamento Horus, fabricado pela empresa brasileira Contronic Sistemas Automáticos. **Resultados**: Os valores de referência do limite de estabilidade foram obtidos para os gêneros feminino e masculino respectivamente, nas faixas de 20 a 59 anos (≥ 12.594 mm² e ≥ 19.221 mm²), de 60 a 69 anos (≥ 7.031 mm² e ≥ 12.161 mm²) e de 70 a 89 anos (≥ 6.340 mm² e ≥ 8.794 mm²). Nos testes de integração sensorial nas condições C1 a C7, conforme aumentou a idade, aumentaram também os valores da área de elipse de confiança. Foram estabelecidos valores percentis de referência para equilíbrio funcional residual e análise sensorial. **Conclusão**: Foi possível estabelecer um protocolo para investigar o equilíbrio corporal com valores de referência em função de diversas faixas etárias e gêneros.

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INTRODUCTION

For an adequate body balance, the complex integration between the sensory and motor systems is necessary, allowing the maintenance of a stable posture, defining the static balance or in movement, and constituting the dynamic balance in a harmonic and precise way. The individual's postural impairment can result from proprioceptive alteration, i.e., from the perception of posture and body movement; vestibular alteration, triggered by the position and/or movement of the head; or visual alteration, due to spatial relationships[1-9].

Posturography, also called stabilometry or stabilography, is a test in which a force platform is used for a general assessment of balance, obtaining a quantitative approximation of the oscillations of the Center of Gravity (CG) of the individual positioned in it. The Pressure Center (PC), registered by the force platform, is correlated to the CG, defined as the place of application of the resultant of all gravitational forces acting on the body[1,2,7].

The use of posturography as a tool can help the differential diagnosis, the verification of changes in the vestibulospinal system, the evaluation of the benefit of physical activity in postural control, as well as the evaluation of the reduction of postural control with aging, and the creation of strategies to prevent falls in the elderly population, among other aspects[1,4,7,10,11].

Currently, there are several force platforms used to assess body balance. However, they are equipment manufactured in other countries and difficult to access them, hindering their use in everyday clinical practice in our country[3-5,7-20]. There is also a fixed platform manufactured in Brazil, however, without sensory integration tests or sensory analysis[5,19] because it was created to use it in the biomechanics and ergonomics areas.

The Horus posturography was created for specific use in the diagnosis and rehabilitation of balance, with Brazilian engineering and manufacturing. It is an innovative fixed platform model created from the demand of professionals in the area, with a focus on portability and low cost. It includes software developed with a focus on usability and low maintenance cost, and the company offers technical assistance and calibration in the national territory, ensuring correct measurements during the life cycle of the equipment. As a differential, it also assists in rehabilitating patients by performing assisted postural exercises using computer games technology. As this equipment was recently launched in 2017, the reference values for normal individuals had not yet been established, and the protocol for carrying out the tests necessary to arrive at postural diagnosis was not clear. For this reason, this work aimed to determine a way to carry out the tests at speed and to investigate the reference values for different age groups of healthy volunteers of both genders.

OBJECTIVE

To propose a protocol for investigating body balance and determining reference values for different age groups and gender in a system of static posturography with dynamic tests.

METHODS

This is a descriptive-analytical study applied to a sample of 297 healthy volunteers aged from 20 to 89 years old in 2018. The project was sent to the Ethics Committee of the *Irmandade da Santa Casa de Misericórdia de São Paulo*, CAAE: 88284318.1.0000.5479, and approved under the number 2,713,595.

Before starting the research, all volunteers were informed about the content of the research, and those who agreed to participate signed an Informed Consent Form (ICF).

The data presented here were collected by several professionals specialized in otoneurology, in different services located in the cities of Goiânia, Rio de Janeiro, Santa Maria, and São Paulo.

Thus, the static posturography was performed with dynamic tests using Horus equipment, from the Contronic brand. Figure 1shows the set. The posturography consists of a power platform connected to a computer by a USB cable that provides digital communication and electrical power to the machine. The platform's internal circuits have the following sections: four strain gauge force sensors; an independent signal conditioning circuit for each sensor; four Analog-to-Digital Converters (ADCs) with 24-bit resolution; and a 32-bit Advanced RISC Machine (ARM) microprocessor with associated digital circuits. The associated software requires a computer with a Windows operating system. It displays and records the data provided by the platform. In addition to the force platform and the software, the system is accompanied by a pad developed in thermoplastic elastomer (TPE) material, with a height of 5 cm and the same size as the indelible label on the upper face of the platform, containing the same reference marks for positioning the feet.

The visual stimuli were generated by the same software and were designed with the aid of a 32-inch television or a projector, according to the functional diagram (Figure 1).

Sample selection

The volunteers could participate in the research according to the following exclusion criteria: diagnosis of an audio-vestibular disease considered to be the individual's self-assessment: they do not listen well, or complain of dizziness; having neurological disease, including motion sickness and migraine; presenting symptoms such as imbalance, instability, blurred vision, lightheadedness or dizziness; reporting changes that cause pain in the lower limbs or compromise strength and mobility; having a height of less than 1 meter or weight over 130 kg, having visual impairment without compensation for glasses or lenses; taking any anti-vertigo, anti-emetic medications for headache, anxiolytics or antidepressants; ingested caffeine or alcohol 48 hours before the procedure.

After the eligibility process, the volunteers put on their socks or the pro-foot offered by the evaluators.

Stabilogram

The postural oscillations were recorded to the left and the right by the Mid-Lateral (ML) stabilogram and the front and back by the Antero-Posterior (AP) stabilogram. Both parameters showed the amplitude of postural oscillation during the entire duration of the test, which allowed a detailed analysis of the amplitudes of body oscillation at any time.

The stabilograms allowed the visual identification of the periods of the test in which the individual had greater peaks of oscillation, causing a greater risk of falling.

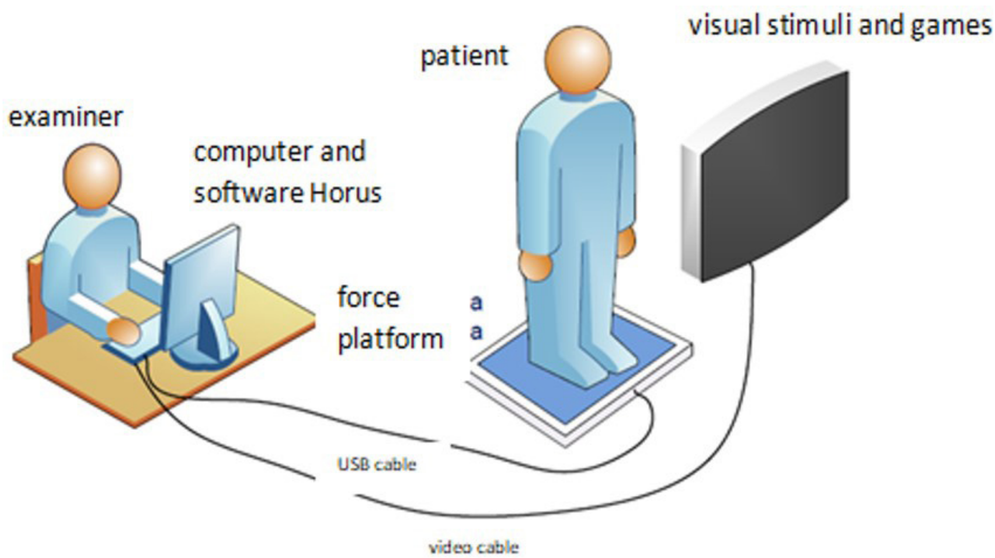

Figure 1. Functional diagram of the static platform system with Horus dynamic tests

Statocinesigram

It is the map of the displacement of the PC on the ML axis concerning the displacement of the PC on the AP axis. The patient's PC varied during the test, and each measurement generated a point in the current coordinate, resulting in a "point cloud". In the Stability Limit (SL) test, the extreme points in each direction defined the stability ellipse; in the other tests, the Confidence Ellipse (CE) was calculated to cover at least 95% of the points that made up the cloud.

Frequency spectrum graph

For the frequency graph to have adequate resolution, the signal on the stabilogram must last at least 30 seconds. Shorter signals would have fewer samples, and the frequency resolution would be less. This requirement was introduced by the use of Fast Fourier Transform (FFT) to convert signals from the time domain to the frequency domain, avoiding techniques that introduce artifacts, such as zero-padding.

The resolution of the FFT was expressed by the number of vertical bars displayed in the graphics of the frequency domain, known as bins. If the displacement of the PC is small during the race, the size of the bins in the graph may be small. The height of a bin, given in millimeters, corresponds to the signal strength at that specific frequency, given in Hertz.

The evaluation of Frequency Bands (FB) is useful as a quantitative measure of the speed at which the position of the PC varied throughout the test. The predominance of low frequencies indicated that the patient did few postural correction maneuvers during the test or that these maneuvers were slow and/or with low intensity/strength.

Quantitative parameters measured by frequency

The FB0 indicated the frequency below 70.7% of the total signal strength. FB1 indicated the frequency below 80% of the total signal strength. FB2 indicated the frequency below 85% of the total signal strength. FB3 indicated the frequency below 90% of the total signal strength. Lastly, the FB4 indicated the frequency below 95% of the total signal strength. Previous studies have shown that FB1, with 80% of the spectral power, is the parameter that best characterizes the changes in the postural control system[10], the reason why this parameter was adopted in this work.

Quantitative parameters

The average speed parameter, extracted from the stabilograms and given in mm/s indicated the average speed of the PC. In general, the lower the average PC speed is, the better the patient's body balance will be.

From the statocinesigram recorded in each test, the CE was calculated, which covers at least 95% of the points measured by the platform. Its area provides a quantitative parameter of the degree of imbalance or displacement of the PC. The area value in mm^2 is provided in the 95% CE area parameter of the Horus software.

The percentage relationship between the CE in each test and the area of the stability limit is called the CE/SL ratio. The greater the CE, i.e., the greater the displacement of the PC during the test is, the greater the CE/SL ratio in percentage will be.

Examination protocol

Orientation for the positioning of the feet on the platform

Patients were instructed to position their feet with the malleoli aligned on the horizontal dashed line of the platform and to keep them symmetrically spaced on the AP line. Participants up to 59 years old adjusted the position of the hallux by pointing between 0 and 15 degrees. Those aged 60 and over adjusted the angle of each foot between 0 and 20 degrees, in the most comfortable position. The volunteers were instructed to remain in a "standing position" throughout the exam, without bending their hips and using only the ankle strategy to maintain their balance.

Tests performed

Sensory integration test: the volunteers were instructed to remain on the platform in an orthostatic position for 30 seconds, without being distracted by questions or conversations. During the entire execution time, each individual remained silent, with their feet in the same position adopted in the stability limit test. Therefore, the platform and the volunteers were positioned one meter away from the image generated to provide visual stimulation, either by TV or a projector. The test considered the following sensory conditions:

- Condition 1 (C1): to remain in an upright position, with their eyes open, with their feet directly on the platform and without the use of a pillow, looking at a fixed point in the center of the image with a size of 10%. This percentage is related to the value adjusted in the software when programming the visual stimulus and defines the size of the point visible in the image against a black background;
- Condition 2 (C2): to remain in an upright position, with eyes closed, directly on the platform, i.e., without using the pillow;
- Condition 3 (C3): to remain in an upright position on top of the pillow on the platform, with their eyes open, looking at a fixed point with a size of 10%;
- Condition 4 (C4): to remain in an upright position on the pillow on the platform, with their eyes closed;
- Condition 5 (C5): to remain in an upright position on top of the pillow on the platform, looking at a dynamic image that displays bars that cause the optokinetic effect, moving to the right with the speed set in the software to 16%;
- Condition 6 (C6): to remain upright on the pillow on the platform, looking at a dynamic image that displays bars that cause the optokinetic effect, moving to the left with the speed set in the software to 16%;
- Condition 7 (C7): to remain in an upright position on top of the pillow on the platform, looking at a dynamic image that displays a tunnel made up of thin bars, with forwarding direction and 4% speed without rotation, all these parameters adjusted in the software, in the section that defines the visual stimulus.

After the execution of C2, if the values of the ellipse were smaller than those of C1, this condition was repeated.

The following quantitative parameters were analyzed:

- area of the stability limit, in mm^2;
- sensory integration test composed of the area of the CE in mm^2, the average speed AP in mm/s, the average speed ML in mm/s, the frequency band FB1 (80%) AP in Hz, and the band frequency FB1 (80%) ML in Hz, by Residual Functional Balance (RFB) in % and by sensory analysis (AS) in %.

The RFB values were calculated under the conditions described using equations from 1 to 7.

From the RFBs determined in the seven conditions, the parameters of the sensory analysis were calculated by Equations from 8 to 14: somatosensory (SOM); visual (VIS); vestibular (VEST); right visual dependence (RVDP); left visual dependence (LVDP); visual tunnel dependence (VTDP); and composite balance index (CBI).

$$RFB\%\ C1 = 100 - Area\ ECC1\ Area\ SL * 100 \tag{1}$$

$$RFB\%\ C2 = 100 - Area\ ECC2\ Area\ SL * 100 \tag{2}$$

$$RFB\%\ C3 = 100 - Area\ ECC3\ Area\ SL * 100 \tag{3}$$

$$RFB\%\ C4 = 100 - Area\ ECC4\ Area\ SL * 100 \tag{4}$$

$$RFB\%\ C5 = 100 - Area\ ECC5\ Area\ SL * 100 \tag{5}$$

$$RFB\%\ C6 = 100 - Area\ ECC6\ Area\ SL * 100 \tag{6}$$

$$RFB\%\ C7 = 100 - Area\ ECC7\ Area\ SL * 100 \tag{7}$$

$$SOM\% = RFB\%\ C2\ RFB\%\ C1 * 100 \tag{8}$$

$$VIS\% = RFB\%\ C3\ RFB\%\ C1 * 100 \tag{9}$$

$$VEST\% = RFB\%\ C4\ RFB\%\ C1 * 100 \tag{10}$$

$$RVDP\% = RFB\%\ C5\ RFB\%\ C4 * 100 \tag{11}$$

$$LVDP\% = RFB\%\ C6\ RFB\%\ C4 * 100 \tag{12}$$

$$VTDP\% = RFB\%\ C7\ RFB\%\ C4 * 100 \tag{13}$$

$$CBI\% = \left[\begin{matrix} (RFB\%\ C1 + RFB\%\ C2 + 3) * (RFB\%\ C3 + 3) * (RFB\%\ C4 + 3) * \\ (RFB\%\ C5 + 3) * (RFB\%\ C6 + 3) * (RFB\%\ C7) \end{matrix} \right] / 17 \tag{14}$$

Statistical analysis

The results were subjected to statistical analysis. The Kruskal-Wallis test compared the age and gender. The level of significance adopted was 5% ($p = 0.05$). Statistical confidence was set at 95%.

RESULTS

The participants of this study were 297 volunteers, of which 172 (57.9%) were female and 125 (42.1%) were male. They were divided into six groups, three female and three male groups due to the significant difference (p <0.01) in the analysis of comparisons of posturography parameters between age groups and gender, according to the Kruskal-Wallis test (Table 1 and Table 2).

Indeed, we considered normal the reference values of the stability limit when the percentile values were 5%, the values greater than or equal to 12,594 mm^2 for the range

Table 1. Comparison regarding the numerical variables between ages

AGE	VARIABELE	N	MEANS	S.D	MÍN	Q1	MEDIAN	Q3	MÁX	P*VALUE
20-59(A)	SL	141	24608.00	6247.00	8488.50	20286.00	24637.00	28603.00	42629.00	**P<0.001 -> A≠B, A≠C, B≠C**
	C1	141	91.77	65.23	8.90	48.60	71.10	71.10	71.10	**P<0.001 -> A≠B, A≠C, B≠C**
	RFB1	141	99.58	0.37	97.89	99.44	99.69	99.83	99.96	**P<0.001 -> A≠B, A≠C, B≠C**
	C2	141	136.64	91.78	17.10	71.60	119.30	181.80	447.70	**P<0.001 -> A≠(B,C)**
	RFB2	141	99.39	0.50	97.44	99.27	99.53	99.73	99.95	**P<0.001 -> A≠B, A≠C, B≠C**
	C3	141	475.12	296.19	92.70	239.80	404.70	637.00	1473.50	**P<0.001 -> A≠B, A≠C, B≠C**
	RFB3	141	97.88	1.62	92.11	97.49	98.50	98.96	99.59	**P<0.001 -> A≠B, A≠C, B≠C**
	C4	141	1209.80	672.30	310.90	751.30	1071.20	1549.2	3654.20	**P<0.001 -> A≠B, A≠C, B≠C**
	RFB4	141	94.64	3.56	81.51	93.32	95.79	97.08	98.94	**P<0.001 -> A≠B, A≠C, B≠C**
	C5	141	789.05	392.17	253.20	525.40	696.80	981.60	2211.70	**P<0.001 -> A≠B, A≠C, B≠C**
	RFB5	141	96.46	2.60	79.52	95.6	97.20	98.00	99.12	**P<0.001 -> A≠B, A≠C, B≠C**
	C6	141	818.98	451.11	194.60	488.90	704.70	1042.80	2244.10	**P<0.001 -> A≠(B,C)**
	RFB6	141	96.34	2.70	81.24	95.66	97.22	98.04	99.07	**P<0.001 -> A≠B, A≠C, B≠C**
	C7	141	763.65	406.01	191.10	452.10	662.30	954.10	2316.60	**P<0.001 -> A≠B, A≠C, B≠C**
	RFB7	141	96.63	2.35	83.01	95.77	97.23	98.14	99.40	**P<0.001 -> A≠B, A≠C, B≠C**
	SOM	141	96.63	0.65	98.37	99.71	99.88	99.96	106.67	**P<0.001 -> A≠B, A≠C, B≠C**
	VIS	141	98.29	1.44	93.05	97.90	98.85	99.25	100.17	**P<0.001 -> A≠B, A≠C, B≠C**
	VEST	141	95.03	3.37	83.01	93.87	96.13	97.23	99.04	**P<0.001 -> A≠B, A≠C, B≠C**
	RVDP	141	102.00	2.73	95.45	100.32	101.49	102.78	112.57	**P<0.001 -> A≠(B,C)**
	LVDP	141	101.87	2.78	94.47	100.35	101.44	102.52	114.01	**P<0.001 -> A≠B, A≠C, B≠C**
	VTDP	141	102.20	3.05	96.53	100.43	101.53	103.00	115.28	**P<0.001 -> A≠(B,C)**
	CBI	141	96.75	2.07	86.47	96.07	97.34	98.19	99.06	**P<0.001 -> A≠B, A≠C, B≠C**
60-69 (A)	SL	82	19097.00	7018.40	5870.40	14041.00	19160.00	23649.00	37601.00	
	C1	82	112.94	67.00	12.30	65.90	96.80	144.10	345.70	
	RFB1	82	99.34	0.45	97.86	99.13	99.43	99.68	99.92	

Caption: SL: stability limit (mm^2). N: volunteers. S.D: standard deviation. P*: P-value referring to the Kruskal-Wallis test for comparison of values between 3 groups. C1: eyes open condition, stable surface (mm^2). C2: eyes closed condition, stable surface (mm^2). C3: Confidence Ellipse (CE) area of the eyes open condition, unstable surface(mm^2). C4: eyes closed condition, unstable surface (mm^2). C5: optokinetic stimulation condition to the right, unstable surface (mm^2). C6: optokinetic stimulation condition to the left, unstable surface(mm^2). C7: unstable surface, tunnel stimulation condition (mm^2). RFB1: eyes open, stable surface(%). RFB2: eyes closed, stable surface(%). RFB3: eyes open, unstable surface(%). RFB4: eyes closed, unstable surface(%)(%). RFB5: optokinetic stimulation to the right, unstable surface. RFB6: optokinetic stimulation to the left, unstable surface(%). RFB7: tunnel stimulation, unstable surface(%). SOM: somatosensory(%). VIS: visual(%). VEST: vestibular(%). RVDP: visual optokinetic dependence to the right (%). LVDP: visual optokinetic dependence to the left(%). VTDP: visual tunnel dependence(%). CBI: composite balance index(%).

Table 1. Continued...

AGE	VARIABELE	N	MEANS	S.D	MÍN	Q1	MEDIAN	Q3	MÁX	P*VALUE
	C2	82	210.92	129.09	35.00	120.10	177.15	258.50	625.40	
	RFB2	82	98.77	0.93	94.53	98.48	99.04	99.33	99.71	
	C3	82	600.26	302.05	107.40	371.10	574.75	752.10	1948.20	
	RFB3	82	96.40	2.31	89.12	95.67	97.10	98.06	99.38	
	C4	82	1786.20	908.52	478.20	1183.10	1530.30	2112.60	4810.30	
	RFB4	82	89.53	6.20	66.72	87.18	91.07	93.43	98.45	
	C5	82	1146.30	540.62	467.60	766.80	1072.80	1335.90	3159.20	
	RFB5	82	93.27	3.63	78.80	91.20	93.86	96.00	97.96	
	C6	82	1249.00	615.37	458.50	834.80	1044.90	1451.70	3213.20	
	RFB6	82	92.56	4.38	73.86	90.43	93.79	95.46	98.59	
	C7	82	1122.00	532.16	360.30	717.80	1019.50	1354.40	2544.70	
	RFB7	82	93.46	3.58	81.95	91.36	94.24	96.35	98.29	
	SOM	82	99.42	0.74	95.75	99.26	99.62	99.77	100.41	
	VIS	82	97.03	2.14	90.88	96.28	97.59	98.44	100.09	
	VEST	82	90.11	6.09	67.39	87.54	91.70	93.85	99.25	
	RVDP	82	104.51	5.75	93.78	101.37	103.28	105.94	132.21	
	LVDP	82	103.68	5.90	93.41	100.57	102.11	104.94	132.40	
	VTDP	82	104.73	5.97	94.26	101.60	103.63	106.66	134.05	
	CBI	82	93.75	3.15	83.35	92.26	94.52	96.14	98.22	
70-89 (C)	SL	74	14738.00	5463.70	5291.50	10346.00	14453.00	19195.00	26310.00	
	C1	74	152.81	84.42	18.40	84.40	136.90	213.10	386.50	
	RFB1	74	98.83	0.70	97.14	98.36	98.96	99.43	99.91	
	C2	74	265.04	162.46	19.50	135.50	227.60	366.20	699.90	
	RFB2	74	97.78	1.41	91.97	97.20	97.93	98.84	99.90	
	C3	74	823.80	415.73	208.50	502.40	717.70	1101.6	1940.7	
	RFB3	74	93.81	3.57	78.52	92.09	94.26	96.25	98.93	
	C4	74	2136.20	934.07	117.80	1581.50	2105.90	2629.60	5845.60	
	RFB4	74	83.86	8.49	54.82	78.05	84.89	90.73	97.81	
	C5	74	1319.60	540.07	467.00	917.90	1240.30	1607.80	3006.10	
	RFB5	74	89.98	5.12	73.72	88.00	90.56	93.63	97.41	
	C6	74	1410.40	681.35	354.70	895.20	1241.00	1744.60	3953.80	
	RFB6	74	89.15	6.46	71.35	86.78	90.75	93.23	97.79	
	C7	74	1388.30	535.60	474.40	969.00	1359.70	1723.00	2960.40	
	RFB7	74	89.23	5.97	64.32	86.76	90.23	93.27	97.37	
	SOM	74	98.91	1.16	94.68	98.17	99.13	99.74	101.86	
	VIS	74	94.89	3.38	79.71	93.24	95.64	97.39	99.03	
	VEST	74	84.89	8.28	55.59	79.20	86.10	91.45	99.33	
	RVDP	74	107.32	9.63	75.37	101.56	106.97	111.31	153.32	
	LVDP	74	106.04	10.21	74.12	101.05	104.22	110.58	161.67	
	VTDP	74	106.42	10.60	84.23	101.23	104.36	109.21	162.11	
	CBI	74	90.27	4.43	76.89	88.59	90.73	93.29	97.77	

Caption: SL: stability limit (mm^2). N: volunteers. S.D: standard deviation. P*: P-value referring to the Kruskal-Wallis test for comparison of values between 3 groups. C1: eyes open condition, stable surface (mm^2). C2: eyes closed condition, stable surface (mm^2). C3: Confidence Ellipse (CE) area of the eyes open condition, unstable surface(mm^2). C4: eyes closed condition, unstable surface (mm^2). C5: optokinetic stimulation condition to the right, unstable surface (mm^2). C6: optokinetic stimulation condition to the left, unstable surface(mm^2). C7: unstable surface, tunnel stimulation condition (mm^2). RFB1: eyes open, stable surface(%). RFB2: eyes closed, stable surface(%). RFB3: eyes open, unstable surface(%). RFB4: eyes closed, unstable surface(%)(%). RFB5: optokinetic stimulation to the right, unstable surface. RFB6: optokinetic stimulation to the left, unstable surface(%). RFB7: tunnel stimulation, unstable surface(%). SOM: somatosensory(%). VIS: visual(%). VEST: vestibular(%). RVDP: visual optokinetic dependence to the right (%). LVDP: visual optokinetic dependence to the left(%). VTDP: visual tunnel dependence(%). CBI: composite balance index(%).

Table 2. Comparison regarding the numerical variables between genders

GENDERS	VARIABLE	N	MEANS	S.D	MÍN	Q1	MEDIAN	Q3	MÁX	VALOR-P*
FEMALE	AGE	172	56.90	17.80	20.00	43.00	62.00	71.00	87.00	P=0.031
	SL	172	18104.00	6864.20	5291.50	12507.00	18080.00	22608.00	37229.00	P<0.001
	C1	172	111.11	76.80	8.90	57.35	89.45	140.15	386.50	P=0.419
	VelMLC1	172	4.12	1.82	1.50	3.00	3.90	4.90	15.50	P=0.987
	VelAPC1	172	6.81	2.33	2.00	5.20	6.25	7.90	16.20	P=0.023
	RFB1	172	99.24	0.66	97.14	98.97	99.47	99.72	99.95	P=0.020
	C2	172	180.01	135.52	17.10	83.05	149.45	216.75	699.90	P=0.064
	VelMLC2	172	5.24	2.85	1.60	3.40	4.35	6.40	18.80	P=0.090
	VelAPC2	172	10.52	4.78	4.00	7.10	9.40	12.60	31.90	P=0.018
	RFB2	172	98.68	1.26	91.97	98.10	99.24	99.54	99.90	P=0.100
	C3	172	559.64	342.05	92.70	293.50	491.15	725.20	1883.00	P=0.032
	VelMLC3	172	10.68	3.88	3.20	8.10	10.00	12.80	25.60	P=0.014
	VelAPC3	172	15.12	5.34	5.10	11.25	14.50	17.25	34.80	P=0.027
	RFB3	172	96.18	2.97	83.73	94.39	97.06	98.55	99.59	P=0.075
	C4	172	1504.80	855.57	117.80	861.95	1324.90	1965.80	4507.60	P=0.033
	VelMLC4	172	18.90	7.36	5.10	13.75	17.70	23.10	43.50	P=0.006
	VelAPC4	172	29.18	19.11	11.20	20.40	26.15	33.25	242.00	P<0.001
	RFB4	172	89.73	7.83	54.82	85.49	91.99	96.00	98.94	P=0.051
	C5	172	935.91	457.61	260.30	583.25	834.40	1210.10	2394.50	P=0.005
	VelMLC5	172	15.09	5.85	3.30	10.45	14.05	18.35	38.90	P=0.003
	VelAPC5	172	21.66	7.47	9.10	16.55	19.95	25.35	52.90	P<0.001
	RFB5	172	93.52	4.79	73.72	91.19	94.84	97.24	99.09	P=0.075
	C6	172	1009.10	569.69	194.60	607.15	895.60	1245.50	3440.10	P=0.026
	VelMLC6	172	14.41	5.58	4.80	10.45	13.80	17.15	46.50	P=0.003
	VelAPC6	172	21.22	7.21	8.90	15.60	20.00	25.55	49.00	P<0.001
	RFB6	172	93.04	5.46	72.49	90.75	94.47	96.93	99.06	P=0.072
	C7	172	963.48	519.60	191.10	575.35	855.90	1258.20	2960.40	P=0.052
	VelMLC7	172	12.75	4.60	4.30	9.15	12.05	15.30	26.90	P=0.051
	VelAPC7	172	22.20	8.73	8.30	15.90	20.50	26.60	69.00	P=0.067
	RFB7	172	93.29	5.42	64.32	91.11	95.03	97.34	99.40	P=0.037
	SOM	172	99.47	1.05	94.68	99.23	99.73	99.92	106.67	P=0.821
	VIS	172	96.90	2.62	85.12	95.25	97.74	99.01	100.09	P=0.160
	VEST	172	90.41	7.49	55.59	86.70	92.31	96.23	99.33	P=0.060
	RVDP	172	104.41	7.16	75.37	100.85	102.46	106.47	153.32	P=0.160
	LVDP	172	103.77	7.57	74.12	100.38	101.97	105.54	161.67	P=0.372
	VTDP	172	104.13	7.54	84.23	100.58	102.40	106.28	162.11	P=0.732
	CBI	172	93.83	4.29	76.89	91.00	94.94	97.26	98.83	P=0.037
MALE	AGE	125	53.18	17.22	21.00	37.00	58.00	66.00	86.00	
	SL	125	24100.00	6936.20	7020.60	20286.00	24080.00	29242.00	42629.00	
	C1	125	115.18	72.44	14.20	63.40	98.90	153.50	345.70	
	VelMLC1	125	4.14	1.72	1.90	2.90	3.70	5.00	13.20	
	VeLAPC1	125	7.27	2.13	4.00	5.70	6.70	8.60	16.30	
	RFB1	125	99.46	0.41	98.03	99.23	99.58	99.74	99.96	
	C2	125	201.70	131.22	19.00	99.50	161.10	265.40	625.40	
	VelMC2	125	5.70	2.98	2.10	3.70	4.80	6.80	17.90	
	VelAPC2	125	11.44	4.70	4.90	8.60	10.40	12.90	32.90	
	RFB2	125	98.99	0.88	94.86	98.65	99.28	99.61	99.95	
	C3	125	647.33	377.04	150.00	365.70	548.20	813.40	1948.2	
	VelMLC3	125	11.99	4.65	4.20	8.70	11.40	14.90	34.00	

Caption: SL: stability limit (mm²). N: volunteers.S.D: standard deviation. P*: P-value referring to the Mann-Whitney test to compare the values between 2 groups. C1: eyes open condition, stable surface (mm²). C2: eyes closed condition, stable surface(mm²). C3: Confidence Ellipse (CE) area of the eyes open condition, unstable surface(mm²). C4: eyes closed condition, unstable surface(mm²). C5: optokinetic stimulation condition to the right, unstable surface (mm²). C6: optokinetic stimulation condition to the left, unstable surface(mm²). C7: unstable surface, tunnel stimulation condition(mm²). MLS: Medial-Lateral Speed(mm/s). APS: Antero-Posterior Speed(mm/s). RFB1: eyes open, stable surface(%). RFB2: eyes closed, stable surface(%). RFB3: eyes open, unstable surface(%). RFB4: eyes closed, unstable surface(%)(%). RFB5: optokinetic stimulation to the right, unstable surface. RFB6: optokinetic stimulation to the left, unstable surface(%). RFB7: tunnel stimulation, unstable surface(%). SOM: somatosensory(%). VIS: visual(%). VEST: vestibular(%). RVDP: visual optokinetic dependence to the right(%). LVDP: visual optokinetic dependence to the left(%). VTDP: visual tunnel dependence(%). CBI: composite balance index(%).

Table 2. Continued...

GENDERS	VARIABLE	N	MEANS	S.D	MÍN	Q1	MEDIAN	Q3	MÁX	VALOR-P*
	VelAPC3	125	17.30	7.82	7.20	12.30	15.20	21.00	62.80	
	RFB3	125	96.84	2.84	78.52	96.03	97.72	98.65	99.46	
	C4	125	1730.50	944.26	410.70	1053.00	1589.70	2241.90	5845.60	
	VelMLC4	125	21.50	8.58	7.60	15.70	20.40	25.50	59.50	
	VelAPC4	125	33.04	14.45	12.90	23.30	30.50	38.70	132.70	
	RFB4	125	91.66	6.43	65.66	89.85	93.23	96.09	98.77	
	C5	125	1135.40	590.80	253.20	696.80	1026.90	1451.00	3159.20	
	VelMLC5	125	17.41	6.86	7.60	12.90	15.70	19.90	45.40	
	VelAPC5	125	25.84	9.71	11.50	18.80	23.40	31.70	62.70	
	RFB5	125	94.58	4.02	77.36	93.63	95.85	97.29	99.12	
	C6	125	1189.60	667.32	207.90	693.50	966.30	1498.40	3953.80	
	VelMLC6	125	16.72	7.07	6.10	12.30	15.50	19.00	47.60	
	VelAPC6	125	25.02	9.79	9.80	19.10	22.90	28.70	60.10	
	RFB6	125	94.15	4.96	71.35	92.67	95.66	97.32	99.07	
	C7	125	1093.50	565.98	259.60	610.50	971.40	1390.80	2544.70	
	VelMLC7	125	14.05	5.66	1.40	9.80	13.00	16.90	36.20	
	VelAPC7	125	23.88	8.96	1.80	17.70	22.20	28.00	53.30	
	RFB7	125	94.76	3.93	80.08	93.77	96.00	97.46	99.03	
	SOM	125	99.53	0.68	95.75	99.37	99.73	99.90	100.52	
	VIS	125	97.36	2.64	79.71	96.61	98.23	98.92	100.17	
	VEST	125	92.15	6.28	66.65	90.54	93.69	96.40	99.25	
	RVDP	125	103.47	4.98	93.78	100.59	102.05	104.47	132.21	
	LVDP	125	102.93	4.50	94.04	100.46	101.69	104.03	123.26	
	VTDP	125	103.70	5.39	94.26	100.81	102.21	104.55	131.32	
	CBI	125	94.97	3.67	77.77	93.70	96.06	97.56	99.06	

Caption: SL: stability limit (mm^2). N: volunteers.S.D: standard deviation. P*: P-value referring to the Mann-Whitney test to compare the values between 2 groups. C1: eyes open condition, stable surface (mm^2). C2: eyes closed condition, stable surface(mm^2). C3: Confidence Ellipse (CE) area of the eyes open condition, unstable surface(mm^2). C4: eyes closed condition, unstable surface(mm^2). C5: optokinetic stimulation condition to the right, unstable surface (mm^2). C6: optokinetic stimulation condition to the left, unstable surface(mm^2). C7: unstable surface, tunnel stimulation condition(mm^2). MLS: Medial-Lateral Speed(mm/s). APS: Antero-Posterior Speed(mm/s). RFB1: eyes open, stable surface(%). RFB2: eyes closed, stable surface(%). RFB3: eyes open, unstable surface(%). RFB4: eyes closed, unstable surface(%)(%). RFB5: optokinetic stimulation to the right, unstable surface. RFB6: optokinetic stimulation to the left, unstable surface(%). RFB7: tunnel stimulation, unstable surface(%). SOM: somatosensory(%). VIS: visual(%). VEST: vestibular(%). RVDP: visual optokinetic dependence to the right(%). LVDP: visual optokinetic dependence to the left(%). VTDP: visual tunnel dependence(%). CBI: composite balance index(%).

Table 3. Percentile values of Medial-Lateral Speed (MLS) and Antero-Posterior Speed (APS) according to age groups and gender

AGE	VARIABLE	N	GENDER	C1	C2	C3	C4	C5	C6	C7
20-59	VelML	75	female	<5,80	<7,80	<15,70	<27,50	<19,50	<18,50	<15,80
	VelML	65	male	<6,30	<8,50	<16,20	<28,80	<22,80	<19,50	<17,50
60-69	VelML	45	female	<5,50	<10,40	<15,70	<33,30	<28,10	<23,10	<21,30
	VelML	37	male	<8,20	<14,20	<21,80	<40,20	<31,10	<32,30	<27,70
70-89	VelML	51	female	<8,20	<16,20	<20,60	<34,90	<28,10	<28,10	<25,90
	VelML	23	male	<8,30	<14,70	<22,70	<40,20	<33,70	<37,00	<28,90
20-59	VelAP	75	female	<9,60	<17,40	<19,60	<40,80	<26,50	<26,10	<26,30
	VelAP	65	male	<10,80	<15,70	<23,70	<44,70	<34,90	<30,10	<38,00
60-69	VelAP	45	female	<11,30	<21,10	<25,80	<47,50	<33,70	<39,40	<43,90
	VelAP	37	male	<38,00	<23,50	<27,40	<58,50	<42,30	<48,60	<46,20
70-89	VelAP	51	female	<12,10	<21,60	<30,80	<57,80	<46,20	<39,80	<42,90
	VelAP	23	male	<12,50	<23,30	<44,80	<64,00	<52,10	<57,70	<45,70

Caption: N: volunteers. C1: eyes open condition, stable surface (mm^2). C2: eyes closed condition, stable surface(mm^2). C3: Confidence Ellipse (CE) area of the eyes open condition, unstable surface(mm^2). C4: eyes closed condition, unstable surface(mm^2). C5: optokinetic stimulation condition to the right, unstable surface (mm^2). C6: optokinetic stimulation condition to the left, unstable surface(mm^2). C7: unstable surface, tunnel stimulation condition(mm^2).

of 20 to 59 years old in the female gender and greater than or equal to 19,221 mm^2 in the male. In the range of 60 to 69 years old, the normal values were 7,031 mm^2 in females and 12,161 mm2 in males; and in the range of 70 to 89 years old, the normal values were 6,340 mm2 in females and 8,794 mm2 in males.

The percentile values of 95% lower or equal in the conditions C1, C2, C3, C4, C5, C6, and C7 in Medial-Lateral Speed (MLS) and Antero-Posterior Speed (APS) were according to age groups and gender (Table 3).

We considered the percentile values of posturography parameters in the female gender in the different age groups in the reference values P95 (Table 4).

In addition, the percentile values of posturography parameters in the male gender in the different age groups in the reference values P95 were also considered (Table 5).

Table 4. Percentile values regarding posturography parameters for females in different age groups

AGE	VARIABLE	N	P1	P5	P10	P25	P50	P75	P90	P95	P99
20-59	SL	76	8488.50	12594.00	15117.00	18217.00	22162.00	26016.00	30723.00	32615.00	37229.00
	C1	76	8.90	18.10	26.80	46.30	67.20	109.45	155.10	203.90	345.20
	RFB1	76	97.89	98.42	99.06	99.44	99.69	99.82	99.90	99.92	99.95
	C2	76	17.10	30.20	38.60	63.25	110.20	169.70	215.00	313.70	414.50
	RFB2	76	97.44	98.08	98.48	99.25	99.49	99.74	99.85	99.88	99.90
	C3	76	92.70	164.00	184.40	211.85	328.10	626.75	865.20	964.10	1185.20
	RFB3	76	92.11	94.14	94.51	97.01	98.56	99.02	99.26	99.43	99.59
	C4	76	310.90	361.10	467.70	636.90	932.10	1301.60	1734.60	2496.50	3654.20
	RFB4	76	81.51	86.00	89.07	93.35	96.05	97.42	98.27	98.48	98.94
	C5	76	260.30	271.30	326.10	451.15	635.80	881.75	1171.10	1442.30	2165.00
	RFB5	76	79.52	92.06	92.94	95.52	97.27	98.17	98.68	98.94	99.09
	C6	76	194.60	284.10	345.70	404.65	619.40	893.25	1315.70	1592.10	1699.90
	RFB6	76	81.24	91.69	92.68	95.62	97.41	98.24	98.60	98.86	99.06
	C7	76	191.10	233.40	294.80	414.30	621.75	908.55	1056.70	1363.00	2316.60
	RFB7	76	83.01	91.43	94.35	96.05	97.40	98.27	98.70	98.81	99.40
	SOM	76	98.37	99.20	99.55	99.66	99.88	99.96	100.07	100.23	106.67
	VIS	76	93.63	94.72	95.28	97.67	98.99	99.28	99.43	99.72	99.83
	VEST	76	83.01	87.25	89.64	93.83	96.40	97.73	98.46	98.79	99.04
	RVDP	76	95.45	98.82	99.48	100.26	101.40	102.62	105.54	108.70	112.34
	LVDP	76	94.47	98.99	99.31	100.16	101.43	102.66	105.74	108.48	111.56
	VTDP	76	96.53	98.64	99.22	100.34	101.58	102.97	106.60	109.74	115.28
	CBI	76	86.47	92.67	93.86	96.11	97.41	98.34	98.70	98.78	98.83
60- 69	SL	45	5870.40	7031.00	8703.10	11875.00	14674.00	19762.00	23649.00	27114.00	31011.00
	C1	45	12.30	22.90	33.40	62.00	91.50	139.20	186.50	222.40	310.40
	RFB1	45	97.86	98.15	98.60	99.12	99.37	99.60	99.77	99.84	99.92
	C2	45	35.00	61.80	68.30	98.50	162.10	206.70	302.90	494.60	606.10
	RFB2	45	94.53	96.99	97.25	98.32	99.12	99.33	99.51	99.55	99.71
	C3	45	107.40	190.70	247.30	368.60	491.90	700.00	951.40	1011.90	1283.10
	RFB3	45	90.24	90.85	92.23	95.10	96.36	97.91	98.39	98.66	99.38
	C4	45	478.20	647.60	840.30	1183.10	1508.00	2112.60	2714.30	3312.80	4391.40
	RFB4	45	69.86	73.01	79.51	85.51	89.85	92.88	94.34	95.07	97.01
	C5	45	482.40	560.80	569.30	735.80	952.00	1234.10	1903.00	2132.40	2394.50
	RFB5	45	78.80	86.50	87.39	90.93	92.66	95.73	96.90	97.17	97.95
	C6	45	458.50	586.40	711.50	840.10	991.20	1372.20	2389.70	2629.10	3213.20
	RFB6	45	73.86	83.86	85.68	88.94	92.62	95.04	96.13	96.42	97.13
	C7	45	360.30	482.10	509.50	717.80	931.70	1228.10	1620.60	1906.60	2147.50
	RFB7	45	81.95	85.84	88.43	91.13	93.20	95.93	96.57	96.89	97.46
	SOM	45	96.51	97.90	98.37	99.25	99.65	99.78	99.98	100.04	100.35
	VIS	45	91.36	91.45	92.55	95.54	97.22	98.46	99.25	99.95	100.09
	VEST	45	70.43	74.05	79.80	87.10	90.48	93.45	94.72	95.65	97.16
	RVDP	45	99.92	100.24	100.27	101.97	103.65	106.94	110.07	114.66	130.40
	LVDP	45	93.41	97.87	98.67	100.49	102.77	105.72	110.53	111.87	132.40
	VTDP	45	98.12	98.94	99.68	102.36	104.47	108.41	113.12	117.30	134.05
	CBI	45	83.35	87.57	88.83	91.08	93.55	95.47	96.59	96.72	97.34
70-89	SL	51	5291.50	6340.20	8194.10	9644.30	12842.00	17132.00	20133.00	21262.00	23878.00
	C1	51	18.40	42.50	57.80	84.90	136.40	213.70	273.00	327.10	386.50
	RFB1	51	97.14	97.24	97.57	98.21	98.83	99.41	99.61	99.66	99.91
	C2	51	19.50	61.40	79.70	122.20	218.50	350.30	487.30	633.30	699.90
	RFB2	51	91.97	94.64	96.06	96.88	97.92	98.68	99.48	99.64	99.90

Caption: N: volunteers.SL: stability limit (mm^2). C1: eyes open condition, stable surface (mm^2). C2: eyes closed condition, stable surface(mm^2). C3: Confidence Ellipse (CE) area of the eyes open condition, unstable surface(mm^2). C4: eyes closed condition, unstable surface(mm^2). C5: optokinetic stimulation condition to the right, unstable surface (mm^2). C6: optokinetic stimulation condition to the left, unstable surface(mm^2). C7: unstable surface, tunnel stimulation condition(mm^2). RFB1: eyes open, stable surface(%). RFB2: eyes closed, stable surface(%). RFB3: eyes open, unstable surface(%). RFB4: eyes closed, unstable surface(%)(%). RFB5: optokinetic stimulation to the right, unstable surface. RFB6: optokinetic stimulation to the left, unstable surface(%). RFB7: tunnel stimulation, unstable surface(%). SOM: somatosensory(%). VIS: visual(%). VEST: vestibular(%). RVDP: visual optokinetic dependence to the right(%). LVDP: visual optokinetic dependence to the left(%). VTDP: visual tunnel dependence(%). CBI: composite balance index(%).

Table 4. Continued...

AGE	VARIABLE	N	P1	P5	P10	P25	P50	P75	P90	P95	P99
	C3	51	208.50	338.30	421.20	482.10	594.50	964.80	1350.10	1576.50	1883.00
	RFB3	51	83.73	86.90	90.05	92.04	94.32	96.25	97.50	97.80	98.93
	C4	51	117.80	765.40	847.10	1196.50	1839.20	2535.30	2930.10	3501.80	4507.60
	RFB4	51	54.82	70.60	71.54	78.42	84.77	90.87	94.40	95.40	97.81
	C5	51	467.00	574.00	628.10	782.10	1177.70	1458.60	1680.60	2082.80	2160.40
	RFB5	51	73.72	79.18	84.04	88.00	90.59	93.31	95.90	96.73	97.41
	C6	51	354.70	519.50	698.70	889.10	1118.00	1504.30	1975.00	2234.80	3440.10
	RFB6	51	72.49	75.02	81.35	87.39	90.70	93.86	95.63	96.74	97.79
	C7	51	474.40	537.30	774.20	946.40	1309.80	1692.60	1959.50	2351.20	2960.40
	RFB7	51	64.32	73.95	82.38	86.42	89.70	92.30	95.05	96.32	97.37
	SOM	51	94.68	96.29	97.44	98.16	99.07	99.74	100.00	100.41	101.86
	VIS	51	85.12	89.46	91.84	93.18	95.26	97.63	98.01	98.77	99.03
	VEST	51	55.59	71.46	72.99	80.06	85.69	91.71	94.85	95.79	99.33
	RVDP	51	75.37	92.96	99.45	101.59	107.50	110.80	118.94	122.25	153.32
	LVDP	51	74.12	91.23	98.28	101.31	104.46	108.71	116.20	122.24	161.67
	VTDP	51	84.23	93.37	94.11	99.38	103.50	108.71	116.74	121.53	162.11
	CBI	51	76.89	81.88	84.84	88.59	90.72	93.27	95.69	96.13	97.77

Caption: N: volunteers.SL: stability limit (mm^2). C1: eyes open condition, stable surface (mm^2). C2: eyes closed condition, stable surface(mm^2). C3: Confidence Ellipse (CE) area of the eyes open condition, unstable surface(mm^2). C4: eyes closed condition, unstable surface(mm^2). C5: optokinetic stimulation condition to the right, unstable surface (mm^2). C6: optokinetic stimulation condition to the left, unstable surface(mm^2). C7: unstable surface, tunnel stimulation condition(mm^2). RFB1: eyes open, stable surface(%). RFB2: eyes closed, stable surface(%). RFB3: eyes open, unstable surface(%). RFB4: eyes closed, unstable surface(%)(%). RFB5: optokinetic stimulation to the right, unstable surface. RFB6: optokinetic stimulation to the left, unstable surface(%). RFB7: tunnel stimulation, unstable surface(%). SOM: somatosensory(%). VIS: visual(%). VEST: vestibular(%). RVDP: visual optokinetic dependence to the right(%). LVDP: visual optokinetic dependence to the left(%). VTDP: visual tunnel dependence(%). CBI: composite balance index(%).

Table 5. Percentile values regarding posturography parameters for males in different age groups

AGE	VARIABLE	N	P1	P5	P10	P25	P50	P75	P90	P95	P99
20-59	SL	65	17171.00	19221.00	20286.00	22606.00	26057.00	30583.00	35195.00	36529.00	42629.00
	C1	65	14.20	25.10	30.00	49.90	87.90	124.30	186.30	237.80	291.70
	RFB1	65	98.70	99.12	99.17	99.49	99.70	99.83	99.88	99.92	99.96
	C2	65	19.00	50.00	55.40	75.90	124.70	191.10	296.50	352.00	447.70
	RFB2	65	98.30	98.39	98.60	99.32	99.56	99.71	99.79	99.81	99.95
	C3	65	150.00	188.90	218.00	320.30	440.90	637.00	1050.20	1105.40	1473.50
	RFB3	65	92.34	95.54	95.97	97.61	98.47	98.85	99.09	99.35	99.46
	C4	65	410.70	502.20	601.30	827.60	1169.50	1805.60	2386.30	2787.80	3557.00
	RFB4	65	84.68	88.16	90.52	93.23	95.50	96.65	97.83	98.04	98.77
	C5	65	253.20	389.10	482.70	594.10	833.50	1060.20	1451.00	1787.20	2211.70
	RFB5	65	90.70	93.59	94.28	95.77	96.99	97.75	98.42	98.81	99.12
	C6	65	207.90	367.80	477.90	590.00	773.60	1212.10	1663.60	2113.00	2244.10
	RFB6	65	88.32	92.39	92.94	95.94	97.05	97.80	98.50	98.81	99.07
	C7	65	259.60	291.20	390.30	536.80	806.50	1252.00	1423.90	1647.30	1972.40
	RFB7	65	89.74	93.36	94.02	95.49	97.13	98.00	98.77	98.90	99.03
	SOM	65	98.86	99.05	99.47	99.71	99.88	99.96	100.06	100.16	100.52
	VIS	65	93.05	96.04	96.38	98.16	98.77	99.10	99.44	99.58	100.17
	VEST	65	85.14	88.35	91.09	94.00	95.77	96.98	97.93	98.13	98.91
	RVDP	65	98.48	99.05	99.88	100.35	101.73	103.05	104.65	107.11	112.57
	LVDP	65	97.70	98.97	99.29	100.46	101.44	102.47	104.39	105.60	114.01
	VTDP	65	98.15	99.08	99.99	100.76	101.43	103.25	105.42	107.32	113.28
	CBI	65	90.29	93.79	94.92	95.89	97.29	97.86	98.37	98.53	99.06

Caption: N: volunteers. SL: stability limit (mm^2). C1: eyes open condition, stable surface (mm^2). C2: eyes closed condition, stable surface(mm^2). C3: Confidence Ellipse (CE) area of the eyes open condition, unstable surface(mm^2). C4: eyes closed condition, unstable surface(mm^2). C5: optokinetic stimulation condition to the right, unstable surface (mm^2). C6: optokinetic stimulation condition to the left, unstable surface(mm^2). C7: unstable surface, tunnel stimulation condition(mm^2). RFB1: eyes open, stable surface(%). RFB2: eyes closed, stable surface(%). RFB3: eyes open, unstable surface(%). RFB4: eyes closed, unstable surface(%)(%). RFB5: optokinetic stimulation to the right, unstable surface. RFB6: optokinetic stimulation to the left, unstable surface(%). RFB7: tunnel stimulation, unstable surface(%). SOM: somatosensory(%). VIS: visual(%). VEST: vestibular(%). RVDP: visual optokinetic dependence to the right(%). LVDP: visual optokinetic dependence to the left(%). VTDP: visual tunnel dependence(%). CBI: composite balance index(%).

Table 5. Continued...

AGE	VARIABLE	N	P1	P5	P10	P25	P50	P75	P90	P95	P99
60- 69	SL	37	11744.00	12161.00	14455.00	19662.00	21392.00	27393.00	30469.00	31627.00	37601.00
	C1	37	40.90	44.00	53.40	69.20	100.50	154.00	192.00	301.20	345.70
	RFB 1	37	98.07	98.99	99.06	99.31	99.50	99.69	99.79	99.85	99.86
	C2	37	66.10	89.20	102.40	150.40	226.70	307.40	495.00	522.70	625.40
	RFB2	37	94.86	97.05	98.24	98.58	98.96	99.28	99.59	99.63	99.67
	C3	37	173.60	236.00	286.20	384.60	683.00	778.60	985.80	1204.90	1948.20
	RFB3	37	89.12	92.06	94.13	96.42	97.42	98.10	98.97	99.01	99.37
	C4	37	581.70	744.00	864.40	1188.90	1624.40	2061.00	3621.80	3941.60	4810.30
	RFB4	37	66.72	84.70	85.25	89.85	92.55	93.90	96.47	96.57	98.45
	C5	37	467.60	468.40	603.80	844.90	1171.70	1509.90	1867.50	2735.10	3159.20
	RFB5	37	84.73	88.21	89.94	92.80	94.64	96.47	97.62	97.90	97.96
	C6	37	460.50	498.80	584.40	834.80	1123.30	1451.70	2084.60	2622.10	2692.50
	RFB6	37	82.24	84.97	89.17	93.13	94.45	96.31	97.67	98.54	98.59
	C7	37	419.10	434.40	523.90	738.30	1139.10	1728.10	2338.20	2466.40	2544.70
	RFB7	37	82.40	85.19	88.59	92.44	94.97	96.53	97.46	98.10	98.29
	SOM	37	95.75	97.57	98.88	99.27	99.52	99.76	99.90	100.33	100.41
	VIS	37	90.88	93.01	95.07	97.10	97.95	98.40	99.16	99.51	99.78
	VEST	37	67.39	85.16	85.77	90.25	93.08	94.74	96.72	97.29	99.25
	RVDP	37	93.78	97.86	99.41	100.80	102.28	104.98	109.08	110.79	132.21
	LVDP	37	94.04	97.17	98.89	100.91	101.81	104.54	110.11	111.21	123.26
	VTDP	37	94.26	95.23	98.05	100.19	102.48	105.33	109.29	110.58	123.49
	CBI	37	84.62	88.81	91.57	93.58	95.08	96.75	97.56	97.89	98.22
70-89	SL	23	7020.60	8794.40	9681.60	11516.00	16921.00	22094.00	25446.00	25738.00	26310.00
	C1	23	24.50	49.10	69.60	79.40	141.40	200.30	254.00	290.20	342.30
	RFB1	23	98.03	98.29	98.36	98.67	99.12	99.50	99.66	99.71	99.89
	C2	23	58.30	93.60	134.70	156.90	270.40	405.40	475.60	596.10	615.00
	RFB2	23	95.22	96.36	97.20	97.21	98.06	99.01	99.17	99.35	99.57
	C3	23	284.70	294.30	330.30	718.00	988.30	1205.80	1507.90	1654.30	1940.70
	RFB3	23	78.52	88.53	88.62	92.09	94.13	96.37	98.04	98.09	98.47
	C4	23	755.40	1581.50	1646.70	1846.70	2411.10	3023.20	3298.10	3573.60	5845.60
	RFB4	23	65.66	67.62	74.14	77.23	85.70	90.42	92.31	92.69	94.79
	C5	23	540.90	796.10	894.70	1173.10	1638.60	2114.40	2617.60	2690.90	3006.10
	RFB5	23	77.36	78.03	81.93	86.09	90.33	93.76	94.79	96.27	96.33
	C6	23	730.40	787.60	881.60	1159.30	1840.50	2120.10	2519.30	3377.00	3953.80
	RFB6	23	71.35	73.78	76.69	85.39	90.92	92.48	95.22	95.87	96.36
	C7	23	524.10	614.40	795.80	1033.30	1474.80	1950.60	2162.90	2259.80	2433.30
	RFB7	23	80.08	80.13	83.16	88.37	90.49	94.67	96.00	96.33	96.39
	SOM	23	97.14	97.48	97.69	98.17	99.29	99.69	99.85	99.92	99.95
	VIS	23	79.71	88.79	89.54	93.62	95.67	96.70	98.58	98.82	98.91
	VEST	23	66.65	68.31	75.43	78.32	86.97	91.45	93.02	93.14	95.31
	RVDP	23	97.49	98.59	100.14	101.11	106.43	112.63	116.12	117.82	118.07
	LVDP	23	94.80	96.25	99.12	100.15	103.96	110.73	112.79	115.51	119.92
	VTDP	23	98.28	100.01	101.68	103.25	104.95	112.58	121.94	121.97	131.32
	CBI	23	77.77	82.33	83.67	88.58	90.73	93.58	95.56	96.06	96.45

Caption: N: volunteers. SL: stability limit (mm^2). C1: eyes open condition, stable surface (mm^2). C2: eyes closed condition, stable surface(mm^2). C3: Confidence Ellipse (CE) area of the eyes open condition, unstable surface(mm^2). C4: eyes closed condition, unstable surface(mm^2). C5: optokinetic stimulation condition to the right, unstable surface (mm^2). C6: optokinetic stimulation condition to the left, unstable surface(mm^2). C7: unstable surface, tunnel stimulation condition(mm^2). RFB1: eyes open, stable surface(%). RFB2: eyes closed, stable surface(%). RFB3: eyes open, unstable surface(%). RFB4: eyes closed, unstable surface(%)(%). RFB5: optokinetic stimulation to the right, unstable surface. RFB6: optokinetic stimulation to the left, unstable surface(%). RFB7: tunnel stimulation, unstable surface(%). SOM: somatosensory(%). VIS: visual(%). VEST: vestibular(%). RVDP: visual optokinetic dependence to the right(%). LVDP: visual optokinetic dependence to the left(%). VTDP: visual tunnel dependence(%). CBI: composite balance index(%).

DISCUSSION

The Brazilian posturography Horus is innovative and comprises low-cost equipment compared to those existing in the international market and was created according to the demand of professionals in the area of diagnosis and treatment of balance since it was necessary to have an evaluation protocol with reference values of the Brazilian population.

The static posturography records the body oscillation when the individual remains in an upright posture, without movement. However, the dynamic posturography records the body oscillations after a disturbance had been applied to the individual[7]. In our study, we included procedures that involve static and dynamic postural control through the stability limit test and also through an unstable surface created by the use of a pillow, assessing the contribution of the proprioceptive system to balance. Therefore, we adopted the nomenclature "Static posturography with dynamic tests". Research carried out with 89 individuals[15] in which 59 were healthy and 30 of them had peripheral vestibular alterations, and used static posturography with dynamic tests. The authors observed that healthy individuals had lower oscillations and, consequently, higher stability limit values and better results in rhythmic and directional control tests than sick individuals. We concluded that static posturography with dynamic tests is a viable method of evaluation, capable of assisting the diagnosis of vestibular alterations.

According to the statistical tests applied, this study demonstrated that different age groups and genders showed statistically significant differences. Comparing each age group, we noted that the quantitative data changed, suggesting changes in postural control with advancing age even in healthy individuals. They used the same age groups to define normative data for Neurocom's Equitest dynamic computerized posturography and Bertec Dynamic CPD platform[11]. Other authors[1,4,7] also noticed that the age group directly influenced the results of the stabilometry. When studying the elderly population, they confirmed that age deteriorates the balance, increasing the risk of falls. They observed significant changes in the elderly while performing tests that suppressed vision and proprioception, justifying the high rate of falls and reinforcing a vestibular disorder as a base change.

Regarding the stability limit test, with increasing age, there was a tendency to reduce its area, which could explain, in part, the increased incidence of falls in the elderly people in symptomatic individuals. In addition, when comparing the area of the stability limit between genders, we found higher values for male individuals. This difference can be explained by the height of male patients, which, in general, was higher than the female group since the higher the individual is, the greater his support base will be. Indeed, we came to similar conclusions in previous research[1,4,7].

The percentile values were studied considering the AP and ML speeds and the frequency band that covers 80% of the signal power in each axis. Authors[14] revealed the importance of studying postural control related to body oscillation speed and the area of CE using static posturography with the Balance Rehabilitation Unit (BRU™) equipment, analyzing 30 patients with defined Ménière's disease and 40 healthy individuals. They found abnormalities in the area of the CE and the speed of body oscillation in patients with Ménière's disease. Thus, the lower the frequency of the body's oscillation is, the lower the dynamic characteristics in maintaining balance will be. For frequencies up to 0.2 Hz, about 10% of the PC oscillation does not represent the CG oscillation, but accelerations of body segments. The frequency band that covers 80% of the spectral power is the one that best characterizes the changes in the postural control system[10].

Analyzing the data from the sensory integration test, regardless of the age group, we noted an increase in the CE area, the average speed and the values of the FB1 frequency band, and a reduction in the RFB, as the inputs visual and somatosensory sensorial were removed/distorted. This can provide information on how individuals with body balance disorders perform the process of sensory integration, allowing for a more accurate diagnosis of changes in postural control. Authors of other studies[3-5,12-14,16-18] observed the same effect.

The study[19] with Brazilian technology and also of low-cost called "foam-laser posturography", for the performance of tests of sensory organization with the use of a medium-density pillow, concluded to be a simple method, which produced organization analyzes that are comparable to those obtained with dynamic posturography equipment. The technique used in our work had the same objective, but with a force platform and a computerized system that facilitated the obtaining of the answers, the measurement of quantities that could not be obtained with simple observation, the repeatability of the measures, and the organization of the information collected in a previously calibrated system.

Horus posturography has similarities with most posturography[1,3-5,9-16-18]. The software records the PC signals during each test, extracts numerical parameters in the domains of time and frequency, and incorporates a structure to enable the comparison of these parameters against reference values, presenting graphs that facilitate the understanding of the responses of the sensory analysis. From this study, the values obtained can be used by users of the Horus system to assist in identifying patients who have compromised one or more of the systems that make up the balance, as long as the protocol proposed here is executed.

Posturography is an important tool to complement balance assessment but the equipment available so far was difficult to access for the reasons already explained and according to several other studies[3,4,6,8,9,11,14,18] This is a fact that prevented its dissemination in clinical practice. Based on the protocol proposed in this work and the established reference values, we can carry out further research addressing different types of disease and changes, even as vestibular, visual, and somatosensory conditions, contributing to a better assessment and understanding of the evolution of diseases of balance.

CONCLUSION

We could establish a protocol to investigate body balance with reference values according to different age groups and genders.

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Author contributions

LKN participated in the idealization of the study, collection, analysis, and interpretation of data and writing of the article; GDR participated in the collection, analysis, and interpretation of data and writing of the article; TSAS participated in data collection and correction of the article; FAQR participated in the condition of the orientation of the article, analysis, and interpretation of data and writing of the article; PLS participated in the condition of guidance of the article, collection, analysis, and interpretation of data and writing of the article