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**Artigo de Revisão**

# Protocols of Balance Assessment Using Baropodometry in Healthy Individuals - Systematic Review

Protocolos de Avaliação do Equilíbrio por Baropodometria em Indivíduos Saudáveis - Revisão Sistemática

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## ABSTRACT

**Objective:** To assess the protocols of balance assessment in baropodometer in healthy individuals through a systematic review of the literature. **Material and Methods:** The review included publications made up to June 2020, in English, Portuguese or Spanish, studies with human beings, age from 18 years, with no previous diseases, relevant studies on baropodometry in the assessment of postural balance. **Results:** In all articles, information regarding the assessment protocol in baropodometry were screened, extracting positioning data of feet, arms and mouth, eye fixation, data acquisition time, rest time and number of collections. In the initial search a total of 130 articles were found, in the final sample 18 articles were included. **Conclusion:** Through this review, it is suggested for a more effective use of the baropodometer, protocols that use guidelines for positioning the foot, considering a comfortable position and hip width; keep the mouth half open or closed so that there is no grip; keep your eyes fixed on a point marked at eye level; collection time between 30 seconds to 60 seconds, with two to three repetitions and 30 to 60 seconds of rest between them.

**Keywords:** Baropodometry; Postural Balance; Foot; Reference Standards.

## RESUMO

**Objetivo:** Avaliar os protocolos de avaliação do equilíbrio em baropodômetro em indivíduos saudáveis por meio de uma revisão sistemática da literatura. **Materiais e Métodos:** A revisão incluiu publicações realizadas até junho de 2020, nos idiomas inglês, português ou espanhol, estudos com seres humanos, com idade a partir de 18 anos, sem doenças prévias, estudos relevantes sobre baropodometria na avaliação do equilíbrio postural. **Resultados:** Em todos os artigos foram triadas as informações referentes ao protocolo de avaliação em baropodometria, extraindo-se dados de posicionamento de pés, braços e boca, fixação ocular, tempo de aquisição de dados, tempo de descanso e número de coletas. Na busca inicial foi encontrado um total de 130 artigos, na amostra final 18 artigos foram incluídos. **Conclusão:** Por meio desta revisão, sugere-se para uma utilização mais efetiva do baropodômetro, protocolos que utilizam orientações para o posicionamento do pé, considerando uma posição confortável e a

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largura do quadril; manter a boca entreaberta ou fechada para que não haja pegada; mantenha os olhos fixos em um ponto marcado ao nível dos olhos; tempo de coleta entre 30 segundos a 60 segundos, com duas a três repetições e 30 a 60 segundos de descanso entre elas.

**Palavras-chave:** Baropodometria; Equilíbrio Postural; Pé; Padrões de Referência.

## INTRODUCTION

Maintaining the human equilibrium depends on the integration and processing of the visual, somatosensory and vestibular systems[1], and can be classified as static, which is related to the ability to keep the body upright or dynamic, related to the ability to maintain balance during a task, considering the body in motion[2]. One reaches a balance state when the body can keep itself together and control postures and positions; however, there may be constant oscillations even maintaining the most stable feet possible[2].

Balance is often assessed in various populations and, currently, there are several tools to evaluate it[3], with the force platform considered the gold standard, since it performs stabilometric analysis, which corresponds to the analysis of the balance through the oscillations of the pressure centers. Nonetheless, it is a relatively expensive equipment[3,4].

Yet, there is another instrument capable of performing the stabilometric analysis, which is the baropodometer. It also has sensors distributed on the platform surface, which capture the pressure exerted by the feet, with the advantage of being relatively cheaper when compared to the force platforms[5].

According to Rosário[6], there is still no methodological standardization in the assessment parameters of baropodometry due to various dysfunctions of the population, tasks proposed and the lack of information in the studies, making it difficult to compare studies and their scientific implications.

Thus, before the potential of baropodometer to evaluate the balance and the various evaluation protocols used, it is necessary to check them in the literature, in order to subsidize a more effective use of the instrument. Then, the aim of the study was to assess the protocols of balance assessment in baropodometer in healthy individuals through a systematic review of the literature.

## MATERIAL AND METHODS

### Study Design

A systematic review was conducted, following the guidelines of the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA), with the registration in the International prospective register of systematic reviews (PROSPERO) - CRD42019116605.

### Search strategy

The searches were conducted in databases National Library of Medicine (PubMed/Medline), Scientific Electronic Library Online (SciELO) and Physiotherapy Evidence Database (PEDro), with the following keywords: “baropodometria”, “baropodômetro”, “equilíbrio postural” and their equivalents in English, “baropodometry”, “baropodometer” and “postural balance.” Initially, it was applied the search for “baropodometry” OR “baropodometer” and later it was associated to “baropodometry” AND “postural balance”.

### Eligibility criteria

The review included publications made up to June 2020, in English, Portuguese or Spanish, studies with human beings, age from 18 years, with no previous diseases, relevant studies on baropodometry in the assessment of postural balance. Cross-sectional studies, clinical trials, experimental and methodological studies were included in the review

Studies with children and individuals with associated disorders were not included.

### Selection process

Two researchers conducted the searches at the same time, independently. Later, it was held the conference of the articles selected and the disagreements during the process were decided by consensus.

The selection was divided into three stages: in the first, it was held the initial search for the articles in the databases with their respective keywords; in the second, articles repeated were excluded and studies were selected according to the reading of the titles and abstracts. In the third stage, the full reading of the articles previously selected were performed and, after reading, those that were not related to the review issue were excluded.

**Methodological procedures searched**

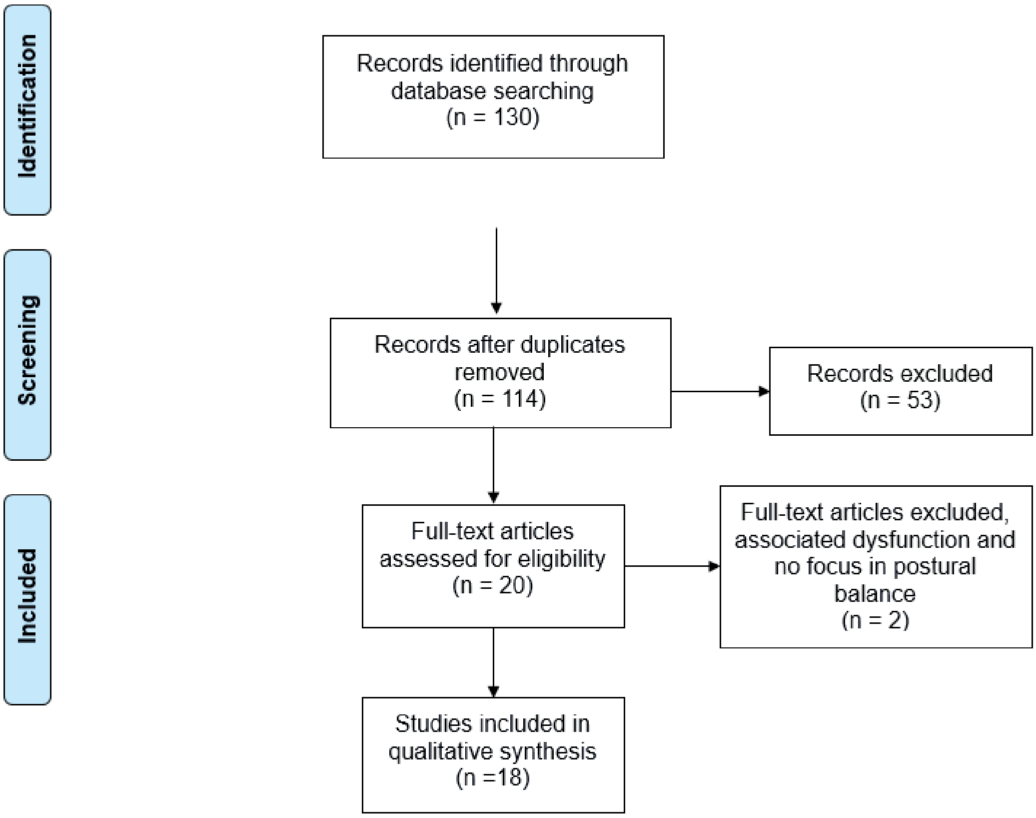
In all articles, information regarding the assessment protocol in baropodometry were screened, extracting positioning data of feet, arms and mouth, eye fixation, data acquisition time, rest time and number of collections. Data extraction was performed independently by two evaluators, with the final table being subsequently performed.

## RESULTS

In PubMed a total of 88 articles were found, 34 in SciELO and 8 articles in PEDro, resulting in 130 articles in the initial search. From the reading of the titles and abstracts, the duplicate articles and those that addressed some dysfunctions were excluded. Repeated articles were considered in the first database. Thus, 20 articles were selected for reading in full. After full reading, 18 articles were included in the final sample. Data from the three stages are shown in Figure 1.

Among the articles selected, eight are in English, four in Portuguese and no one in Spanish. Regarding the type of study, six were clinical trials, four were cross-sectional studies, a methodological study and an experimental one.

**Figure 1.** Flow diagram




The general characterization of the studies included in this review was described in Table 1, with the following information: authors and year, type of study.

**Table 1.** General characterization of the studies

| Title | Author / Year | Aim | Type of study |
|---|---|---|---|
| Plantar Pressure Distribution in Female Olympic-StyleWeightlifters | A Hawrylak and H Gronowska, 2020 | To determine if female Olympic-style weightlifters show diferences in foot shape and selected plantar variables in both static and dynamic conditions. | Cross-sectional study |
| Investigating prismatic adaptation effects in handgrip strength and in plantar pressure in healthy subjects | RE Bonaventura et al, 2020 | To explore interhemispheric asymmetries in the prismatic adaptation effects on hand strength and plantar pressure distribution. | Experimental study |
| Effects of core strengthening on balance in university judo athletes | HS Martins et al, 2019 | To verify the effect of core strengthening on orthostatic balance in university judo athletes. | Clinical trial |
| Test-retest reliability of baropodometry in young asyntomatic individuals during semi static and dynamic analysis | R Alves et al, 2018 | To evaluate the reliability of baropodometry in young individuals during semi-static and dynamic analysis. | Methodological study |
| Lower limb auriculotherapy points improves balance in young healthy subjects-assessed by computerized baropodometry | AM Antônio et al, 2018 | To analyze the effects of lower limb auricular stimulation points on the static equilibrium of healthy subjects, assessed by computerized baropodometry. | Clinical trial |
| Reliability of Baropodometry on the Evaluation of Plantar Load Distribution: A Transversal Study | D Baumfeld, 2017 | To evaluate changes in distribution of plantar pressure due to a work period and elongation of the posterior muscle group. | Cross-sectional study |
| Proprioceptive evaluation in healthy women undergoing Infrared Low Level Laser Therapy | G Silva et al, 2017 | To assess whether the application of low level infrared laser therapy changes proprioception in young women. | Clinical trial |
| Effect of a Proprioceptive Neuromuscular Facilitation (PNF) protocol on postural balance in elderly women | IA Silva et al, 2017 | Analyze the plantar support and the functional balance in older adult women subjected to a PNF exercise protocol to better adapt to future rehabilitation programs. | Cinical trial |
| Effects of Plantar Foot Sensitivity Manipulation on Postural Control of Young Adult and Elderly | AS Machado et al, 2016 | To investigate the effects of foot sensitivity manipulation on postural control. | Experimental study |
| Immediate effects of whole-body vibration on neuromuscular performance of quadriceps and oscillation of the center of pressure: A randomized controlled trial | DT Borges et al, 2016 | To analyze the immediate effects of the body vibration with two different frequencies on the neuromuscular performance of the quadriceps femoris and postural control in healthy individuals. | Experimental study |
| Effects of noise on postural stability when in the standing position | R Azevedo et al, 2016 | Provide a new insight on the effects of the noise on postural stability. | Cross-sectional study |

| | | | |
|---|---|---|---|
| Relationship of plantar pressure and range of motion of lower limbs with the risk of falls in elderly women | MLV Lopes et al, 2016 | To check the list of plantar pressure variables, relating the hip, knee and ankle ROM with the risk of falls in older adult women. | Cross-sectional study |
| Physical performance and balance analysis under influence of cryotherapy in indoor soccer athletes | TR Freire et al, 2015 | To evaluate physical performance, heart rate and static balance with eyes open, in indoor soccer players before and after cold-water immersion of lower limbs. | Experimental study |
| Immediate effect of tibiotarsal osteopathic manipulation on the static balance of young women | AR Carvalho et al, 2013 | To check the immediate effect of osteopathic manipulation to anterior talocrural on static balance in young women. | Clinical trial |
| Kinesio Taping® does not alter neuromuscular performance of femoral quadriceps or lower limb function in healthy subjects: Randomized, blind, controlled, clinical trial | CA Lins et al, 2013 | To analyze the immediate effects of the application of Kinesio Taping (®) in the neuromuscular performance of the quadriceps femoris, in postural balance and in its function of the lower limbs. | Clinical trial |
| Immediate Effects of Bilateral Grade III Mobilization of the Talocrural Joint on the Balance of Elderly Women | A Pertille et al, 2012 | To evaluate the immediate effects of a single treatment session of bilateral grade III mobilization of the ankle talocrural joint in the balance of older adult women. | Clinical trial |
| Correlation Between Static Balance and Functional Autonomy in Elderly Women | FNR Daniel et al, 2011 | To verify the correlation between static balance and functional autonomy in elderly women. | Cross-sectional study |
| Relationship between quadriceps angle and distribution of plantar pressure in soccer players | RG Braz, GA Carvalho, 2010 | To check for the relationship between Q-angle and plantar pressure distribution in football players and in non-practicing individuals of this modality. | Cross-sectional study |

Table 2 shows the samples of the studies, as well as all of the baropodometry protocols used.

**Table 2.** Baropodometry protocol used in each study

| Author / Year | Sample | Variables analyzed | Baropodometry protocol |
|---|---|---|---|
| A Hawrylak and H Gronowska, 2020 | 48 womans, averaging 18-19 years | Static and dynamic evaluation: limb peak and average plantar pressure, forefoot and rearfoot plantar pressure distribution. Dynamic evaluation: medial and lateral plantar pressure distribution. | Static and dynamic evaluation: Feet: barefoot and positioned in parallel; Arms: beside the body; Eyes open. No rest interval. Static collection: duration of five seconds, without repetition. Dynamic collection: normal walking, repeating four times. |
| RE Bonaventura et al, 2020 | 46 male, averaging 25 years | Rear, forefoot and total plantar pressure; surface area | Static evaluation in orthostatic position. Feet: bare, positioned parallel with heels aligned; Arms: beside the body; Head: neutral position; Eyes: open looking ahead; |

| | | | |
|---|---|---|---|
| HS Martins et al, 2019 | 18 athletes, mean age 23-25 years | Pressure center area and width | Static evaluation in orthostatic position. Calibration of the platform: individuals 'weight. Feet: positioned in a natural and comfortable way. Arms: beside the body; Eyes: open with fixed eyes on a point on the wall and then with eyes closed. Collection: three repetitions, lasting 30 seconds each, with no reported resting time. |
| R Alves et al, 2018 | 33 healthy individuals aged18-35 years | Contact surface (cm2), maximum pressure (KPa), mean pressure (KPa), arc index (%), pressure center (mm) and the areas of the feet: % A (forefoot), % B (midfoot) and % C (hindfoot) | Semi-static and dynamic evaluation. Semi static - in standing position, barefoot, walk and stop for 15 seconds, with two repetitions. Dynamic - walk the walking way until the software to capture at least one full foot of each member. |
| AM Antônio et al, 2018 | Experimental group: 20 Control group: 20, aged 18-30 years | Contact area and peak pressure | Static evaluation in bipedal support. Feet: positioning in parallel; Arms: beside the body. Eyes: eyes open with fixed eyes on a point on the wall. Mouth: closed without contacting the masseter muscle. Collection: three repetitions with an acquisition time of six seconds. |
| D Baumfeld, 2017 | 27 healthy professionals, with an average age of 35 years | Mean pressure medium and pressure difference | Static evaluation in bipedal support. Arms: at the side of the body; Eyes eyes open with fixed eyes on a point on the wall. Collection: duration of 60 seconds. |
| G Silva et al, 2017 | 26 healthy college women, aged 18-25 years | Static evaluation: Distance from the center of the foot, maximum pressure and average pressure Dynamic evaluation: maximum pressure, average and area. | Static and dynamic evaluation - Feet: barefoot; Arms: supported on the hips. Eyes eyes open with fixed eyes on a point on the wall. |
| IA Silva et al, 2017 | 20 older adult women, aged 65-85 years | Total plantar support area, forefoot and forefoot support area hindfoot | Static evaluation in bipedal support. Feet: barefoot, separated according to hip width. Arms: beside the body; Eyes: eyes open with fixed eyes on a point on the wall, at eye level. Collection: duration of 30 seconds. Dynamic assessment: same positioning, but performing limb flexion greater than 90º. Collection: duration of 30 seconds. |
| AS Machado et al, 2016 | 38 young adult and elderly, aged 35-79 years | Average speed of center of pressure, anteroposterior and mediolateral amplitude, considering the contact area of each foot with the surface | Static evaluation in bipodal support. Feet: barefoot, positioned in an abduction of 30º with the heels kept five cm apart. Arms: beside the body. Eyes: first eyes open with fixed eyes on a point on the wall, at eye level, then with eyes closed. Collection: three repetitions, with duration of 30 seconds and with a 30 seconds rest interval between them. |
| DT Borges et al, 2016 | 60 active and healthy women, aged 18-28 years | Pressure center oscillation amplitude and speed | Evaluation in unipodal support with support of the non-dominant limb at 40º of knee flexion and the dominant at 90º of knee flexion. Bare feet; Arms: supported at the waist; Collection: three repetitions lasting 10 seconds each, with a one-minute rest interval between them. |

| | | | |
|---|---|---|---|
| R Azevedo et al, 2016 | 20 healthy volunteers averaging 21 years | Displacement of the pressure center, anteroposterior and laterolateral oscillation | Evaluation in bipedal support. Arms: beside the body; Eyes open; Head: neutral position; under different noise conditions. Collection: duration of 20 seconds. |
| MLV Lopes et al, 2016 | 39 healthy older women, averaging 71 years | Maximum pressure and average pressure | Static evaluation in bipedal support. Feet: barefoot and comfortable positioning; Arms: beside the body. Eyes: open with a look at a fixed point on the wall 2 meters away, at the height of the eyes. Collection: 30 seconds of duration. |
| TR Freire et al, 2015 | 32 male subjects | Area of the center of pressure and average pressure | Static evaluation in bipedal support. Feet: barefoot and comfortable positioning; Arms: beside the body. Eyes: open. Collection: three repetitions |
| AR Carvalho et al, 2013 | 20 women, with 10 in the control group, considered in the study | Area of the center of pressure and mean amplitude of the center of pressure | Evaluation in bipedal support. Feet: Barefoot, positioned parallel, freely and in a comfortable position. Arms: beside the body; Mouth: semi open; Eyes: open with a fixed point of view and then with closed eyes. Collection: two repetitions, the first with eyes open and the second with eyes closed, with 10 seconds of accommodation, 20 seconds of evaluation and 30 seconds of rest between them. |
| CA Lins et al, 2013 | 60 healthy women, aged 18-28 years | Displacement amplitude and displacement velocity of the pressure | Evaluation in unipodal support, with support of the dominant leg with the knee flexed at 20º, non-dominant limb at 90º of knee flexion. Arms: supported on the hips. Head: neutral position. Eyes: look at a fixed point. Collection: two repetitions, lasting 10 seconds each and a one-minute rest time between them. |
| A Pertille et al, 2012 | 32 older adult women, aged 65-80 years. | Center in the antero-posterior and latero-lateral directions | Static evaluation in bipedal support. Platform calibration: individual weight. Feet: barefoot in a comfortable position. Eyes: open with the gaze towards the horizon and later with the eyes closed. Collection: six evaluations, three with eyes open and three with eyes closed, evaluation time of 6 seconds each. |
| FNR Daniel et al, 2011 | 32 elderly women, aged 60-86 years | The average amplitude of postural oscillations of the center of pressure (COP) in the frontal plane, right and left lateral displacements, the average amplitude of postural oscillations of the COP in the sagittal plane, anterior and posterior displacements, and the elliptical area | Static evaluation in bipodal support. Feet: barefoot, angled 30º with the heels kept two cm apart.Arms: beside the body. Eye: looking at a fixed visual target situated 90 cm from the platform. Collection: 20 seconds of duration. |
| RG Braz, GA Carvalho, 2010 | 121 males aged 18-30 years | Total peak pressure (kg / cm2); peak pressure, right and left (kg / cm2); distribution of forces in the medial and lateral forefoot, midfoot and hindfoot regions | Static evaluation in bipedal support. Feet: barefoot, positioned by the evaluator in order to correct the hip rotation, the second finger was positioned in the same direction as the ipsilateral calcaneal. |

## DISCUSSION

Several studies on balance assessment using baropodometer were found during the electronic search; however, with the use in populations in varied conditions. The articles selected in this review address reviews of static and dynamic balance in healthy subjects, with different assessment protocols.

This protocol variation occurred due to the following categories: 1- feet positioning, 2- mouth positioning; 3- eye fixation, 4- acquisition time, 5- rest time and 5- number of collections, besides the absence of data in some studies.

### Feet Positioning

All articles included in the study guided participants to be barefoot for baropodometric assessments.

In the study by Alves et al.[7] it was performed the evaluation of the relative and absolute reliability of the baropodometer in healthy individuals, through the test-retest method, with semi-static and dynamic analysis. They found that five variables analyzed in the semi-static evaluated presented high reliability (≥ 0.70), but in the dynamic analysis was low to moderate (≤0.69). Regarding methodological aspects, instructions on where to look, distance between the feet, step length and speed were not carried out.

It is important that some guidance on the positioning of the feet be given so that evaluations take place under the same conditions. But in some studies no guidelines were given or they were not described[7-10]. This no standardization could make it difficult the repeatability of the test in a second time.

Some authors instructed participants to keep their feet in a comfortable position[11-15], others to keep the feet positioned just in parallel[13,16-18] and distanced according to hip width[19].

A method of standardization of the feet has been shown by Braz and Carvalho[20], where the responsible evaluator positioned the second finger, which is considered the middle line of the foot and axis of the tibiotarsal joint, towards the ipsilateral calcaneus, without losing contact with the platform, in order not to change the pressure exerted by the volunteer. This methodology was applied for possible changes in position during collection could generate limitations in the study.

Another method of standardization of the feet has been shown by Daniel et al[21], positioning the heels 2 cm apart and feet angled 30°.

### Mouth positioning

Regarding the positioning of the mouth, some evaluators instructed to close the mouth without gripping[17] or have the mouth half open[13]. Some studies have shown a relationship between occlusion with bucal grip in balance, showing better performance in the balance when performed the occlusion with bucal grasp; but there is not enough scientific evidence to support this relationship[22]. In view of these possibilities, it is important to orient the mouth positioning, so that it does not influence the test.

### Eye fixation

About eye fixation on static analysis, guidelines were found to look at a fixed point[8,10-13,17,19,23] or to the horizon[14] at an eye level[19]. Some articles report the demarcation with a distance of two meters of the assessment tool[12], four meters[24] or 90 centimeters. In semi static and dynamic analysis, guidelines have not been performed[7,25].

### Acquisition time

Another possible limitation of the studies is the non-standardization of the acquisition time. In the studies of this review, time ranged from 6 to 60 seconds. Pertille et al.[14] conducted sampling of 6 seconds to assess the immediate effects of a single treatment session of bilateral mobilization grade III of the talocrural joint in the balance of older women, but found no significant change in static and dynamic balance between the mobilization and the control group. Antônio et al.[17] also used acquisition times of 6 seconds to analyze the effects of atrial stimulation points of the lower limb in static balance of healthy individuals aged 18-30 years and demonstrated that the points of auriculotherapy were helpful to change the ipsilateral balance of the lower limb. Age differences and distinct conducts make it difficult to infer whether the acquisition time was or not sufficient to observe changings in balance.

Braz and Carvalho[20] and Lins et al.[23] used acquisition times of 10 seconds and did not find significant differences in stabilometric variables between the initial and final evaluations. Lopes et al.[12] and Machado et al[24] used acquisition time of 30 seconds. Carvalho et al.[13] and Daniel et al[21], an acquisition time of 20 seconds, and 10 seconds to accommodation. Baumfeld et al.[8] made collections with acquisition time of 60 seconds for calibration and measurement, and the results suggested that any heavy work activity, posterior chain stretching session can cause detectable changes in the plantar pressure distributions in normal individuals.

According to the literature, collection times between 25 and 45 seconds are considered reliable for data acquisition, being recommended recordings of 30 seconds, preceded of five seconds of adaptation on the plate before the start of recording[26].

It is noteworthy that this time variation may occur according to the population to be evaluated and the task proposed. Duarte and Freitas[3], reported in the study on the force platform, that static analyses with time less than 60 seconds can lead to erroneous conclusions. However, time of 30 seconds is sufficient for analysis of adults, older adults and special clinical settings, where the volunteer cannot keep up any longer. According to the task, prolonged periods can lead to fatigue of the voluntary, generating erroneous answers.

Gimenez, Stadnik & Maldaner[27] found that most studies, with baropodometry in diferente diseases, used a 30-second *acquisition* time and report being adequate as it allows a complete analysis of the oscillatory behavior of postural balance[28].

### Rest time

Few studies have reported the rest time. Borges et al.[25] have advocated a range of 1 minute between the collection, Carvalho et al.[13] and Machado et al.[24] determined times of 30 seconds; other studies from this review do not describe the rest time applied. This information is essential to exclude the influence of fatigue in the evaluations and possible bias in the results.

### Number of collections

According to the number of collections, some studies conducted three for each position[14,15,17,24,25] and just two[7,20,23], with some studies having the absence of such information. According to literature data, to obtain a good data reliability it is required from three to five collections in each position[1].

## CONCLUSION

Through this review, it is suggested for a more effective use of the baropodometer, protocols that use guidelines for positioning the foot, considering a comfortable position and hip width; keep the mouth half open or closed so that there is no grip; keep your eyes fixed on a point marked at eye level; collection time between 30 seconds to 60 seconds, with two to three repetitions and 30 to 60 seconds of rest between them.

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