LITERATURE REVIEW

A review of the utilization of baropodometry in postural assessment

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Summary Postural deviations have been linked to a series of different kinds of pain and dysfunction. Since the human foot is the basis of support and propulsion for gait, and baropodometric analysis assesses dysfunctions of the feet, it may be valuable in terms of postural assessment. Therefore, the aim of this literature review was to investigate which studies have used this baropodometric equipment and how the equipment was used, as well as to discuss the scientific problems and solutions associated with the study and clinical practice of baropodometry. Twenty-eight of the 48 articles found in the Pubmed and Lilacs databases were used. The baropodometer has the potential to provide excellent research in the postural field and related areas. However, baropodometry requires standardization and an improved calibration system. Further significant scientific papers, using properly calibrated equipment, are important in order to improve the quality of the technique and display evidence of its clinical and scientific value.

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Introduction

Postural deviations have been linked to a series of different kinds of pain and dysfunction. Posture is not an easy subject to study, mainly because postural assessments are still scientifically inaccurate (photography), or expensive (Magnetic Resonance Imaging), while others (X-ray) involve radiation problems (Rosário et al., 2012; Suzuki et al., 2010; Berthonnaud et al., 2009; Steffen et al., 2010).

There is scientific evidence that associates posture and equilibrium problems with orthopedic and rheumatologic diseases such as knee osteoarthritis, ankle instability, neck tension and back pain (Missaoui et al., 2008). According to Bellizzi et al. (2011), a problem in the postural system generates a state of imbalance, leading to functional overload, dysfunction, degeneration, and the onset of pathological
clinical problems, sometimes associated with intense, disabling pain.

It seems that neurological control of posture and locomotion are interdependent at different levels of the central nervous system (Mazzocchi et al., 2012). The structures involved provide the appropriate spatial frameworks required for postural adjustments. For example, specific areas of the hypothalamus or brain stem trigger changes in posture when stimulated (Mazzocchi et al., 2012). The same authors stated that there are numerous factors modulating these afferent inputs, including mood state and anxiety. Bellizzi et al. (2011) postulated that the postural system maintains balance while standing (static) and during motor activities (dynamic), such as the gait. This information is sent from the peripheral afferent structures (ears, eyes, muscles, tendons, viscera) to the cerebral cortex for processing, the outcome of which causes the body to adapt, assuming the relative postures and movements (Bellizzi et al., 2011).

The human foot is the basis of support and propulsion for gait. It provides support and flexibility for effective weight transfer (Vianna and Greve, 2006; Orlin and McPoil, 2000). A proper biomechanics of the foot is responsible for the maintenance of body posture and symmetrical distribution of plantar pressure (Vianna and Greve, 2006). Furthermore, it exerts an important effect on postural control in terms of the orthostatic position and gait (Lafond et al., 2004).

High plantar pressures may be a causal factor for several diseases and deformities that affect the feet such as pain, stress fractures, callus and neuropathic ulcerations. Thus, the analysis of these pressures is important in terms of a proposal to prevent diseases, pain and postural disorders, especially in the feet (Menz and Morris, 2006; Zammit et al., 2010). Furthermore, according to Bricot (2008), non-antalgic postural problems can begin in the foot (ascendant) or the head (descendent: eyes; temporo-mandibular joint or vestibular system). However, even when the problem comes from the head, the feet are affected and also require treatment (Bricot, 2008).

Baropodometric analysis assesses dysfunctions of the feet. The principle is to map the pressure of the plantar surface, which, indirectly, indicates important postural abnormalities (Bellizzi et al., 2011; Kaercher et al., 2011). Computerized baropodometric analysis records plantar imprints and ground reaction forces during upright quiet standing. This is divided into the right and left feet and subdivided into the forefoot, midfoot and hindfoot. This allows the determination of the percentage of weight supported by each foot and the symmetry ratio between them. Moreover, it can also calculate an arch index informing the type of foot: normal; cavus or flat (Menezes et al., 2012). It also provides the stabilometric parameters derived from the spatial and temporal behavior of the center of pressure, similar to a force plate (Menezes et al., 2012). Therefore, this method is very important to understand the adoption of a modified orthostatic position which could result in/from an erratic postural adaptation, secondary to certain diseases that affect, or can be affected by posture (Kaercher et al., 2011; Bricot, 2008).

Based on a correct assessment of the feet, a number of authors suggest treating postural problems through strengthening and stretching postural muscles (Bricot, 2008; Rosário, 2011) and/or the use of insoles (Bricot, 2008; Mafinski and Cordeiro, 2005).

The aim of this literature review was to investigate which studies have used this baropodometric equipment and how the equipment was used, as well as to discuss the scientific problems and solutions associated with the study and clinical practice of baropodometry.

Materials and methods

Search methods

The Medline and Lilacs databases were consulted for relevant articles from 2003 to 2013 using the keywords “baropodometer” and “baropodometry”. Articles needed to be in English, Portuguese, French, Italian or Spanish.

Inclusion and exclusion criteria

All articles that assessed posture with a baropodometer were considered. Reviews of postural assessment and articles that discussed the equipment in some manner that could help the discussion were also included.

Empirical research, letters to the editor and conference proceedings were excluded.

Study selection

The titles, keywords and abstracts of all research articles identified during the search were read to confirm if they satisfied the inclusion criteria. Full text copies of all articles that met the inclusion criteria were obtained for analysis and data extraction. Preference was given to recent reviews on postural assessment and studies with new or unusual forms of assessment. Older articles that contained the same information as the newer ones were excluded.

Results

Forty-eight articles were found that had used the baropodometer to assess human posture in some way. There was no review study among them. Twenty-eight articles were selected to be part of this review.

Discussion

Plantar pressure measurement is a tool that is not commonly used in clinics. Even in research environments, this device is seldom utilized, although its potential is highly recognized in the specific scientific literature (Putti et al., 2008). One reason for this may be a certain lack of accuracy in baropodometers. Among the causes that may lead to significant differences in the overall accuracy are the following: sensor technology; matrix spatial resolution; pressure range; sampling rate; calibration procedures; raw data post-processing and ageing (Giacomozzi, 2010a).

There are very few papers that used this equipment. Furthermore, a considerable number of the papers do not report the acquired absolute pressure values. Among those which report absolute values, there are significant...
discrepancies when dealing with similar pathologies, comparable population samples and comparable experimental setups (Giacomozzi, 2010a).

1. Overview of the equipment

The equipments currently available in the market for an assessment of plantar pressure can be divided into three different types: platforms, which measure the pressure between the foot and soil (Menz and Morris, 2006; Zammit et al., 2010); insoles, which measure the pressure between the foot and the footwear (Robain et al., 2006); a gait track, which works like a longer version of the platform and is more suitable for studying the gait.

The basic platform consists of support where the sensors are placed, connected through a USB cable to the computer and the appropriate software. There are two fundamental types of plantar pressure sensors used in baropodometry devices: resistive and capacitive.

There are many different types of resistive sensors, all of which involve the modulation of an electrical current flow when pressure is exerted on the sensor surface. The most common physical mechanism is that of contact resistance. Thus, the small-scale deformations due to an increase of pressure on the surface of the sensor cause an increase of electrical conductivity. Another type of resistive sensor is not based on a surface effect, but on a volume effect. The conductive particles are dispersed in a polymeric matrix and the elastic deformation results in an increase of volume conductibility. The typically low impedance of the sensor also makes it easy to obtain a satisfactory noise immunity of the measurements (Fadda, 2010).

The usual capacitive sensors are based on the variation of thickness of an elastic material. Since capacitance depends on the inverse of thickness, an increase of pressure generates a proportional and linear increase of capacitance. Fast measurement of capacitance is not as easy as resistance. Also, as a result of the high impedance of small capacitors, it is easier to produce noise and interference problems with this kind of sensor (Fadda, 2010).

However, the performance of a baropodometer is not only determined by the type of sensor. It is the result of many factors, such as mechanical assembling, matrix scanning electronics and data transfer protocol (Fadda, 2010).

The image that the computer produces is similar to the image that appears in a podoscope. The only difference is the range of thermographic colors shown by the software, which varies depending on the difference of pressure. The baropodometer shows the center of gravity, like a force plate. When analyzing static pressure, the areas that usually receive the greatest pressure (colored in red) are the heel and the metatarsal head. High pressure with a decreased support surface mainly in the midfoot means a cavus foot. Low pressure with an increased surface means a flat foot (Oliveira et al., 1998).

The following data are supplied in a qualitative manner: image of the gait morphology; plantar pressure distribution in the hindfoot, midfoot and forefoot; the charge distribution on the plantar surface and the displacement of the center of force (Oliveira et al., 1998). The following data are provided in a quantitative manner: time of the different phases of gait; the step duration; the time of support in different parts of the foot; values of vertical forces in conventional force units and pressure along the step (Oliveira et al., 1998).

2. Calibration

Calibration is an “Achilles’ heel” of baropodometry (Cavanagh and Ulbrecht, 1994). According to these authors, one of the major issues that must be addressed before baropodometry can be used routinely in a clinical context is the adoption of industry-wide standardization and traceable calibration. However, it seems that a solution is on the way. Putti et al. (2008) have developed an interesting and simple way to verify the calibration of plantar sensor devices. A subject is measured while standing on one leg. After that, the overall force derived from the pressure measurements is compared with the body weight of the subject. Hallemans et al. (2006) reported a calibration method which involves coupling the baropodometer to a force platform. Giacomozzi (2010b) technically tested and compared five baropodometers, revealing different levels of accuracy and different overall performances.

Giacomozzi (2010a,b) developed two devices aiming to calibrate baropodometers: a custom pneumatic bladder-pressure tester meant for in-factory calibration and a dedicated pneumatic-force testing device meant for in-the-field assessment. This author tested the device with a number of baropodometers and received some encouraging feedback from the companies involved. A number of them started to improve their own technical assessment methodology whereas others disagreed with the results but not with the methodology.

Researchers and the industry should work together for improved standardization, thereby improving the quality and reliability of papers and providing the basis for effective clinical use. The differences rely on sensor technology, matrix spatial resolution, pressure range, sampling rate, calibration procedures and raw data processing (Giacomozzi, 2010a,b). Although baropodometry is very promising in terms of aiding postural treatment, it suffers from a lack of scientific data. Furthermore, these data are often not interchangeable because of the lack of standardization between equipment from different companies. This also affects clinicians, who cannot compare their results with papers that used different equipment.

3. Interesting postural studies using baropodometry

There are very few scientific works using the baropodometer. However, there are some bright ideas among them about how to use the equipment to understand gait, posture and dysfunctions of the feet. Most of these ideas are clinically applicable to the neurology and orthopedic fields, although they could be correlated to other areas. For example, Menezes et al. (2012) analyzed types of weight-bearing in the hemiparetic upright position. Kaercher et al. (2011) conducted a cross-sectional study of the association between plantar pressure and chronic pelvic pain. Valentin et al. (2011) studied the repeatability and variability of baropodometric gait parameters in healthy subjects and in stroke patients. Rubira et al. (2010) compared the efficiency of stabilometry and baropodometry in the assessment of
balance in patients with vestibular disorders, finding similar positive results for both sets of equipment. There are also applications for injury prevention in athletes, mainly in sports that involve running (Mantini et al., 2012).

Examples of studies related to foot posture itself include the work of Gravante et al. (2005) and Martinez-Novell et al. (2010). Gravante and collaborators found associations between claw-feet, with reduction of the plantar support surface, and an increase in forefoot and hindfoot areas in young, normal-weight, sedentary subjects of both sexes. Martinez-Novell et al. (2010) found that women with mild hallux valgus exhibited pathologically increased pressure under the hallux with related pain, probably caused by pressure under the head of the first metatarsus.

A number of studies should be highlighted, not because of their conclusions, but because of the idea and conception of the study and their demonstration of the possibilities of plantar pressure assessment. Cuccia (2011) used the baropodometer to better understand the association between dental occlusion and the plantar arch. Two studies by Tecco and collaborators supported this idea. The first study (Tecco et al., 2008) concluded that subjects with temporomandibular joint disorders exhibited a smaller loading surface and an increase of load pressure in the foot, compared with control subjects during walking. The second study (Tecco et al., 2010) showed that healthy subjects, without temporomandibular joint disorder symptoms, exhibit detectable interrelationships between occlusion and locomotion. A study by Cuccia has also shown that there are differences in the plantar arch of the temporomandibular joint disorder group when compared to the control group. Besides these results, it seems that the condition of voluntary teeth clenching can promote a load reduction and an increase in surface contact on both feet, while the inverse situation occurs with cotton rolls. Furthermore, the author argues that a change in the load distribution between forefoot and hindfoot, when cotton rolls were placed between the dental arches, can indicate a pathological condition of the stomatognathic system, thus affecting posture. If these findings are correct, baropodometry helped to demonstrate the interconnection between occlusion and posture, thereby providing an indication for the clinical use of this equipment.

Some authors (Bellizzi et al., 2011; Bricot, 2008) theorized that all of the systems involved in posture (musculoskeletal-somatic, occluomotor, otovestibular, and occuloso-craniomandibular) are essential to maintain balance. In addition, they stated that certain eye conditions, such as strabismus, may lead to an anomalous position of the head and thereafter, the whole body. In order to understand this part of the postural system, they used baropodometry to assess patients affected by ocular torticollis. The feet alterations were more significant when vertical and torsional muscular defects were present (Bellizzi et al., 2011).

Grassi et al. (2011) believed that sacroiliac joint manipulation could influence asymmetric tension throughout the pelvic complex and result in a more equal force distribution to the lower extremities. In order to test this theory, they used the baropodometer to assess the immediate and lasting weight distribution following a high-velocity, low-amplitude sacroiliac joint thrust. They obtained a positive influence on weight distribution among the feet of an asymptomatic population immediately after the manipulative intervention, as well as in the one week follow-up assessment.

Beyond the scientific applications, a number of studies have tried to find unusual ways to use this equipment in the clinic. For example, Descatoire et al. (2009) tried to help patients with a loss of protective pain sensation. These patients were unable to modify their gait when abnormal and excessive plantar pressure occurred, which may eventually result in ulcer formation. The authors developed a baropodometric biofeedback system to prevent these injuries by informing the patient when local pressure exceeds a determined threshold. Femery et al. (2008) did the same, although only for the first metatarsal head.

Conclusion

It is difficult to construct a review of this equipment due to the lack of scientific articles. However, the baropodometer has the potential to provide excellent research in the postural field and related areas.

Baropodometry requires standardization and an improved calibration system. Further significant scientific papers, using properly calibrated equipment, are important in order to improve the quality of the technique and display evidence of its clinical and scientific value.

References


