ASSESSMENT OF FOOT POSTURE CHANGES

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Abstract. The structural complexity of the foot emerges from its varied and precise characteristics. This small structure can adapt to different situations, walking on uneven terrain such as mountainous areas or running on flat ground while keeping the body in balance on small surfaces. For humans, the foot is the basis of support and propulsion during walking and is also involved in providing the support and flexibility needed to achieve efficient weight transfer. Therefore, the correct distribution of loads and pressures on the surface of the foot is crucial to ensure lower limb function and proper gait and balance under static and dynamic conditions. A major limitation of studies investigating the relationship between foot posture and lower-limb muscle function is that there is currently no universally accepted method of classifying foot posture. There is a need for a dynamic way of classifying foot posture, which can be achieved by providing a reliable assessment process for foot posture changes. In clinical practice, the assessment of static foot posture is a common approach to classifying the type of foot to identify possible change-related aetiological factors and recommend therapeutic intervention. This approach involves examining the structural alignment or posture of the foot and the characteristics of its dynamic function to theoretically establish the mechanisms predisposing to pathological changes. In this context, this paper highlights the need for a reliable assessment of changes in foot posture, so our purpose is to present modern assessment and classification methods commonly used in clinical practice and research.

Keywords: foot posture, assessment, foot biomechanics.

Introduction

The foot is a unique masterpiece in terms of architecture and biomechanics, as in a small space are concentrated 26 bones, 33 joints, 114 ligaments and 20 muscles.

The feet consist of small bones connected to each other through the joints. The shape of these small bones and the biomechanical relationship between them contribute to the creation of a balanced structure for each foot, which is also ensured by the formation of plantar arches (Donatelli, 1996). Any disturbance in the foot joints will cause changes in both plantar support and posture. The slightest support abnormality requires studying the foot mobility and posture. Any joint blockage between the various bones of the foot will be likely to change the support and therefore the general posture of the body (Hunt & Smith, 2004).

Each foot has three support points consisting of three arches, of which two are longitudinal (medial and lateral arches) and one is transversal (anterior arch). Bipedal support determines the base of support through the three symmetrical arches. This base of support is the area of the foot in contact with the ground. Normally, the lower projection of the body’s centre of gravity passes through the centre of this base of support (Cordun, 1999).

The symmetry of plantar arches is an important factor in the postural balance of the body. A unilateral valgus flat foot will cause the pelvis to tilt, which in turn will affect the posture of the shoulder blade, cervical region and head.
The foot will also be subjected to pressure from the body segments above it, whether it is the shape of the bones or the general posture of the body, which does not depend on the specific support of the foot (Donatelli, 1996). In this case, there are mutual influences that need to be studied to correct the primary causes of foot support abnormalities.

The foot ensures the postural stability of the human body in the vertical position and plays an important role in propulsion and movement by adapting locomotion to different surfaces but also in the motor control of the correct posture (Nenciu, 2005).

The ideal posture is similar to the architecture of a building. The architectural rules of the various anatomical elements in the three planes in space must be respected. This gives the body perfect resistance to the action of gravitational force that disturbs its balance. Thus, the vertical position can be maintained with reduced muscle effort and therefore painful muscle contractions are avoided. Moreover, a correct vertical position ensures the proper distribution of pressure on the joints, thus protecting their cartilage. This is particularly important, as one of the most common causes of osteoarthritis is cartilage degradation (without blood supply) due to abnormal pressures. Cartilage degradation leads to the production of osteophytes, which is the expression of bone defence when cartilage protection has disappeared.

The feet are the basics of body posture, so any deviation from their normal architecture will have an impact on the entire body posture, just as the global or segmental misalignment above the foot will impact the points of body support on the ground (Donatelli, 1996).

If changes occur at any level, this system will try to activate compensation mechanisms as much as possible, and following these adjustments, some problems may appear: incorrect plantar support, shoulder asymmetry, changes in pelvic position, changes in spine alignment (Cordun, 2009). Thus, people report pain in their feet, calves, knees, cervical or lumbar spine, etc. All this is the result of muscle tension changes that eventually cause pain, and statistically significant changes in electromyographic activation have been reported, although these findings have often not been well supported when calculating confidence intervals (Murley et al., 2009).

Currently, posture issues occupy an important place in the specialists’ concerns about both the early identification of the causes contributing to their occurrence and the implementation of therapeutic and prophylactic measures that can limit their incidence and possible complications.

In clinical practice, the assessment of static foot posture is a common approach to classifying the type of foot in order to identify possible change-related aetiological factors and recommend therapeutic intervention (Razeghi et al., 2002). This approach involves examining the structural alignment or posture of the foot and the characteristics of its dynamic function to theoretically establish the mechanisms predisposing to pathological changes (Cobb et al., 2014).

**Topic Addressed**

**News on monitoring foot posture changes**

The literature provides numerous works on the relationship between foot biomechanics, lower-limb muscle activity and pain occurrence, but lack of evidence has been highlighted
among specialists in the field, who have different opinions on this issue. An important finding of the study conducted by Gijon-Nogueron et al. (2019) “is to denounce the paediatric flatfoot as deviant” (p 7), confirming that “the ‘flat’ or pronated foot is the common foot posture of childhood. […] Increased paediatric BMI was not associated with flatter feet, questioning the validity of footprint-derived measures.” (p. 7)

Rothbart (2022) has carried out numerous studies on abnormal foot structures that cause chronic pain; thus, two studies included 500 patients (adults of different ages) suffering from chronic back and knee pain, who said that they had to learn to live with pain. After one year, during which they used plantar supports, over 70% of study participants reported a significant reduction in pain.

In young children, soft-soled shoes have a minimal impact on joint kinematics and spatiotemporal assessments compared to barefoot walking. “Toddlers walked with a stiffer knee in footwear compared to barefoot, but this could have been as a result of their unfamiliarity with the footwear.” (Williams et al., 2021, p. 6)

Pronated foot posture is common in adulthood with a prevalence of about 21% (Sánchez-Rodríguez et al., 2012) and may be related to forefoot deformities such as hallux valgus (Kawakami et al., 2019). In addition, this biomechanical impairment can affect other areas such as the knee (Lee et al., 2017), and pronation also influences the time and intensity of lumbopelvic muscle activation, giving rise to low back pain or other dysfunctions at this level (Yazdani et al., 2019).

A study by Murley et al. (2008) identified 38 articles in specialised journals, which aimed to assess various situations related to the biomechanics of the foot (the result of changing foot posture or using plantar supports or different types of shoes) through electromyography (EMG) and magnetic resonance imaging (MRI) for the lower limb muscles used during walking or running. These studies highlight that pronated foot (Figure 1) is associated with greater range of motion for EMG muscles that produce inversion of the foot, namely tibialis posterior (Hunt & Smith, 2004), tibialis anterior and flexor hallucis longus (Keenan et al., 1991), when compared to the normal foot posture (Figure 1) or foot posture in supination (Figure 1). On the other hand, pronated foot posture is associated with lower range of motion for EMG muscles that produce eversion of the foot (Hunt & Smith, 2004) when compared to the normal foot posture or foot posture in supination.

Figure 1. Foot posture
A major limitation of studies investigating the relationship between foot posture and lower-limb muscle function is that there is currently no universally accepted method of classifying foot posture, which could be a way to predict the dynamics of the foot bones in motion and the association with an increased risk of musculoskeletal injury (Nenciu, 2005). Also, clinicians should not focus exclusively on foot posture and ankle flexion while ignoring the impact of overweight or obesity; in these conditions, the use of Foot Posture Index (FPI-6) and Arch Index (AI) is effective in practice and research as valid clinical measurements of foot posture (Landorf et al., 2021).

It can be assumed that a dynamic method of classifying foot posture is necessary to assess how foot posture changes are related to impaired muscle activity.

The need for a reliable assessment of changes in foot posture is highlighted, so we will present modern assessment and classification methods commonly used in clinical practice and research, namely Foot Posture Index (FPI-6) and some measurement devices represented by the Presscam V4 pressure plate and the posturograph. We believe that they are effective solutions for the accurate assessment of foot posture changes.

The Foot Posture Index (FPI-6) is a clinical diagnostic tool that quantifies the degree to which the foot is in pronation, supination or a neutral posture. It is used for foot assessment, but so far there are not many studies on the reliability of this tool for children and adolescents (Morrison & Ferrari, 2009); however, FPI-6 scores have shown higher reliability for adults, so it can sometimes be used with precaution (Aquino et al., 2018).

The Foot Posture Index (FPI-6) was developed by Redmond et al. (2008) in order to standardise a novel rating system for standing foot posture in three distinct regions: hindfoot, midfoot and forefoot. This is how foot posture can be classified. Evans and Karimi (2015) also used FPI to investigate paediatric foot posture. The FPI-6 examination shows excellent inter-rater reliability in the assessment of the paediatric foot (Morrison & Ferrari, 2009).

The characteristics of the foot are quantified in a result that gives information on the overall foot posture. In the navicular bone drop, the use of FPI-6 has relative reliability compared to traditional techniques, very high reliability in treatment monitoring and moderate inter-rater reliability. “The results can provide clinicians and researchers with a reliable way to implement foot posture assessment.” (Kirmizi et al., 2020, p. 901)

FPI-6 resulted from a study of the literature by summarising the details of clinical assessments from over 140 papers. This is a reliable multi-planar measure for the assessment of static foot posture.

For clinicians and researchers, the role of uni-planar assessment of foot posture is important, but “the lack of strong consensus between measures of foot classification underpins the need for a consensus on appropriate clinical measures on foot structure” (Langley et al., 2016, p. 6).

In the FPI-6 assessment, the user attaches a score to a number of observations that are currently used by experienced clinicians. Combined scores or cumulative values provide an overall estimate of foot posture. High positive values indicate a pronated foot posture, significantly negative cumulative values indicate a supinated foot posture, while for the neutral foot posture, the cumulative FPI final score should be somewhere around zero.
The FPI-6 assessment process uses six clinical criteria (Morrison & Ferrari, 2009):

- talar head palpation (Figure 2);
- curvature at the lateral malleoli (Figure 3);
- position of the calcaneus in the frontal plane (Figure 4);
- talonavicular bulging (Figure 5);
- congruence of the medial longitudinal arch (Figure 6);
- abduction/adduction of the forefoot on the hindfoot (Figure 7).

Each test component is assigned to a predetermined category as follows:
- 0 for neutral posture;
- a minimum score of -2 for clear signs of supination;
- a maximum score of +2 for positive signs of pronation.

If the criteria set for each of the features are clearly fulfilled, then the consecutive score should be granted. The FPI-6 final score will be an integer between -12 and +12. In most cases, there will be a consistent pattern of scores, and the clinical picture will be established immediately and clearly.

“Foot Posture Index is a quick, easy, and reliable clinical assessment for measuring foot posture variation in different environments” (Martinez et al., 2021, p. 218), which is why it can be used in both clinical practice and scientific research.
Presscam “is a hybrid pressure-posturology platform that complies with Directive 93/42/EEC and is certified by DEKRA” (Podiatech, 2021, p. 6). New features and presentation modes are provided by its state-of-the-art software.

Figure 8. Presscam V4

This device (Figure 8) allows viewing and analysing seven parameters such as clinical examination, plantar pressure in static and dynamic modes or movement of pressure centres.

The analysis of the centre of pressure (CoP) is a method used to assess the function of the foot, but its reliability and repeatability have not been demonstrated. CoP can be altered by certain conditions, for example, excessive foot pronation. (Madura-Armada et al., 2021)

These systems allow accurate quantification of magnitude and timing of force, pressure and contact area in some regions of the foot. The main benefits of plantar pressure technology for older people compared to other gait analysis methods are the feasibility, portability and relatively efficient data processing. (Menz, 2015)

An analysis of the CoP trajectory during stance and gait can elucidate possible foot pathology, provide information on the comparative effectiveness of foot orthoses and allow assessing balance control and joint kinetics during walking.

The trajectory of CoP displacement has been identified as a way to assess neuromuscular control during stance and gait. Defined as the centre of external forces acting on the plantar surface of the foot, CoP displacement is used to assess balance, foot function and treatment effectiveness (Chesnin et al., 2000).

CoP velocity is a reliable measure of gait efficiency in patients with hallux limitus or rigidus, metatarsalgia, hallux abducto valgus or lower limb amputation (Cornwall & McPoil, 2000). CoP velocity during gait has been shown to be higher over time in patients with hallux valgus and metatarsalgia compared to people with normal feet.

Posturograph (Darnell, 2014) is the latest and most complex postural assessment unit (Figure 9), which involves a system for advanced non-invasive global analysis of functional diagnosis and monitoring of the effects of medical recovery programmes. It is used to detect the body’s centre of gravity movement by modifications of gravitational force and recording length, velocity and area of the driving path (Shimizu et al., 2021). Previous studies have reported characteristic models of posturography in the pathology of central nervous system (Tokita et al., 1981).

Computed dynamic posturography can be used to assess people with balance disorders that have not been diagnosed by conventional tests. From a clinical point of view, the
importance of these findings is given by the possibility to diagnose balance disorders and subsequently identify whether these disorders are a consequence of afferent or sensory integration, motor response inefficiency or both.

Figure 9. Posturograph

The posturograph consists of three diagnostic units and software:

- **Podoscope** - is used to analyse static foot disorders; the special software processes the captured images to determine the exact length of each foot, the existence of plantar static disorders (flat foot, hollow foot, etc.) and possible deviations at the ankle.

- **Stabilometric platform** - is used to reveal and analyse balance disorders and to determine the position of the body's centre of gravity. With this platform, the projection of the centre of gravity within the base of support can be determined, and this information has a high therapeutic value in the postural attitude analysis.

- **Postural analysis unit** - is used to determine spinal deformities through a video camera system that allows the collection of high-resolution images that are then processed by the software to analyse any segmentation or global misalignment of the body, but also to measure different segments. Postural analysis is performed from the front, back and profile and can diagnose spinal defects in a sagittal or frontal plane.

The software allows the storage of data resulting from posturographic tests or related to the medical history or medical treatments that the patient follows. With all this information, the patient’s status can be easily monitored, comparative analyses can be made and the effectiveness of recommended therapies can be assessed.

Hammerberg and Kramer (2021) claim that the dynamic system consisting of the bipedal body in motion is relevant to engineers, clinicians and biological anthropologists alike. The use of digital technology allows a practical approach to the two-dimensional topography of the foot, which quantifies “the clustering of the centre of pressure (CoP) on the foot and the consistency of the location of peak forces on the foot during walking” (Hammerberg & Kramer, 2021, p. 1).
Conclusion

Early identification of the causes that contribute to the occurrence of posture problems occupies an important place in the concerns of specialists in the field of medical recovery.

At present, there is no universally accepted method of classifying foot posture, which could be a way to predict the dynamics of the foot bones in motion and the association with an increased risk of musculoskeletal injury.

The proper assessment of foot posture changes is a first step towards an effective therapeutic approach aimed at improving and correcting these changes.

Authors’ Contribution

Both authors have equally contributed to this paper and should be considered as main authors.

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