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***Original article***

# POSTURAL ANALYSIS FROM FOOT TO THE CENTRE OF MASS WITH LEDPODOLASER

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**Abstract**

*Aim.* The article deals with the postural analysis and the recruitment procedures of the information about it with the use of a new investigative tool called LedPodoLaser.

The postural and motor control of man, indeed, is an organized system of mechanisms that use motor activities reflected (automatic) in response to afferents provided by various eso-sensory and endo-sensory system (visual proprioceptive, foot system, odontostomatological, cutaneous, muscular and vestibular systems). Each body subsystem responds to the frequency and the stimulus, which it receives from the receptors, with specific reflexes; each input/output is adjusted by the tonic postural system with the purpose that man might keep his centre of gravity inside the support base, all in muscle economy.

*Conclusions.* A good and objective postural assessment is the starting point for setting up a correct individual, programmed and adapted intervention according to imbalances and postural asymmetry that the patient has.

*Keywords*: foot, centre of mass, posture

## Introduction

Man is never motionless in upright position, but rather in continuous oscillation (Peterka, 2002; Peterka & Loughlin, 2004; Mergner et al., 2003; Horak, 2006); his condition can be likened to that of an inverted pendulum where the tibial-tarsal joint track makes pivot and the rest of the body coincides with the oscillating mass (Gagey & Webwer, 2000; Dichgaus & Brandt, 1978). Foot, with ankle, represents the terminal buffer of the posture, adapting to all situation, even complex, which the body can take; it is on it that all vectors, generated by the body with its movements, act on and its anatomical structure is thought out in such a manner as to re-establish balance and stability.

As foot action is closely linked to the whole lower limb functionality, with this analysis it is also possible to understand the behaviour of ankles, knees and pelvis. In order to understand the postural control in neurophysiological and biomechanical terms, the article will introduce the examination by podoscope, describing the physical properties of instrument used and the entire evaluation protocol of the LedPodoLaser.

The study of posture arouses great interest but at the same time also divergent opinions. The approach, indeed, is multidisciplinary and includes different disciplines, integrating them, such as ophthalmology, dentistry, speech therapy, neurophysiology, endocrinology, orthopaedics and, not least, motor science. Therefore, the posture is a complex phenomenon that synthesizes the interweaving of a plurality of factors. In it, furthermore, there is a continuous dialogue between various structures and systems, aimed at maintaining the posture itself. This dialogue performs the task of:

- Fighting against the force of gravity
- Placing the body in space-time surrounding it
- Ensuring static and dynamic balance.

In this context, it is obvious that foot fulfils a particularly important function. First of all, the biomechanical action, which consists to absorb the energy resulting from the impact with the ground, storing a part of it to use it as elastic energy in the push phase and a receptor action necessary to inform the upper structures about the fluctuations of the centre of mass by fulfilling the functions of a real stabilometric platform.

In other words, the main role of the foot is the maintenance of balance and its particular architecture guarantees the position and intensity of the supporting force exerted on the ground. The foot plant does not rest completely on the ground, because it has a rise scientifically called *plantar arch*. It is a concave surface delimited by three ideal arches, called *plantar arches*; transversal arch, longitudinal medial arch and longitudinal lateral arch (fig.1)

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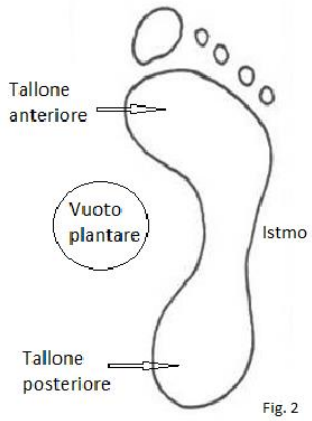
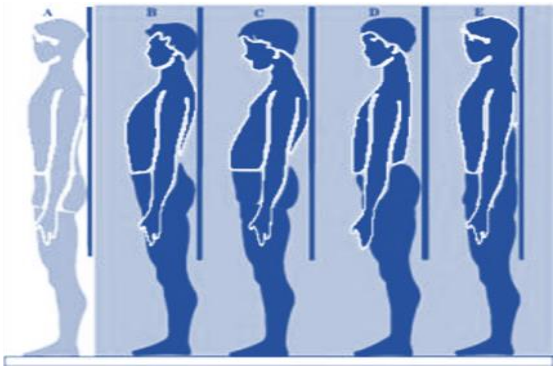



Fig. 2

As part of postural alterations/imbalances, the foot can be viewed as:

- Causative: when it is responsible for the postural imbalance, for the pathology;
- Adaptive: when it blocks a postural imbalance which comes from the upper parts of the body (for example teeth, eyes, muscle insufficiencies or contractures);
- Mixed: when it manifests both causative and adaptive components. This type of foot is the most widespread.

Among the most common alterations of foot we find: 1. Valgus flat feet 2. Asymmetric flat feet 3. Varus cavoid feet 4. Asymmetric cavoid feet 5. Disharmonic feet 6. Compensating feet 7. Double component feet



The plantar imprintmorphology is important for a correct postural assessment (fig.2). In order to differentiate a normal imprint from pathological one is essential observe the isthmus width.

Isthmus = 1/3 of the forefoot width and 1/2 heel = normal foot

Isthmus > 1/3 of the forefoot width and 1/2 heel = flat foot

Isthmus < 1/3 of the forefoot width and 1/2 heel = cavoid foot

A) Good posture. Normal foot.
B) Increase of the physiological curves: compensation of valgus flat feet.
C) Posteriority scapular plane: reflex flat foot.
D) Flat back, front scapular plane: double component foot.
E) Decrease of physiological curves: compensation varuscavoid feet.

Postural organization

The posture has to be understood as a reactive position to the gravitational environment, ergonomic and with cybernetic control, suitable for the performance of functional activities finalized by means of an integrated psycho-body action (Massara & Pacini, 1996). The concept of posture is not related to a purely static condition but more generally, it identifies itself with the concept of balance understood as optimization of the relationship between the subject and the surrounding environment in that certain moment and for the planned motor programs.

The "ideal" posture

The good posture is outlined by a good muscular and skeletal balance, which protects the fundamental structure of the body from a lesion or a deformity. In these situations, the muscles work in an efficient way and the abdominal and thoracic muscles are in an optimal position, whereas in a wrong posture, the balance between the parts of the body is compromised. This last situation will lead to the onset of muscular tensions that will be reversible at

first but later the system fixes itself in its compensations.

An ideal posture does not bring with it any tensions but instead the presence of proportionate relationships between the various body segments. The subject can be postural assessed on three planes: frontal plane (front and rear), sagittal plane and transverse plane. For each plane you will to consider the vertical lines of Barrè and Kapoula indicating both the verticality and the symmetry of the anatomical landmarks. The patient's body is observed and assessed globally, considering the symmetry of the various parts that make up the locomotor system with respect to the body axes. The postural assessment:

- On the front frontal plane are observed: the position of feet and fingers, varus and valgus knees, the rotation of the femur (which is indicated by the position of the kneecap), the symmetry between the triangles of the size (space between arms and body trunk), the wavy aspect of the ribs, the alignment of the head. Also it is considered the horizontality of some lines passing through specific anatomical landmarks (line passing through the iliac crests and line passing through the malleolus)(Nart, 2008)
- On the rear frontal plane are observed: the alignment of the longitudinal line of the leg with the heel, the popliteal folds and the varus or valgus knees, the gluteal folds, the horizontality of the line passing through the rear iliac spines, the lateral pelvic tilt, the lateral deviations of the spine (scoliosis), the relationship between the shoulder blades themselves and between them and the human spine, the triangles of the size, the horizontality of the line crossing the shoulders, the tilt of the head(Nart, pp 64-68 2007).
- On the transverse plane there should be no retreat or advancement of a buttock respect to the other or of a shoulder respect to the other (Bricot, 1996).
- On the sagittal plane are observed: lateral malleolus, the axis of knee joint and the axis of hip joint. It will be taken into consideration the alignment of the knees, the lower limbs (if they are hypertensive or bended), any accentuations of the physiological curves of the human spine (lordosis or kyphosis) and finally if the head has any rotations (Nart&Scarpa, 2008).

Generally, it is good to follow the guidelines mentioned so far to perform a postural assessment, not forgetting however that the patient must be assessed as its whole taking into account the balance ties, which unite the individual body parts rather than assessing individual body segments excluded from each other (Johnson, 2012).

The tonic postural system

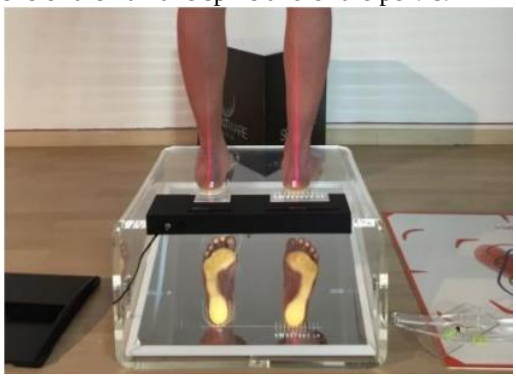
Substantially, the tonic postural system takes care of the control of muscle tone. Its task is to allow a certain stability to the body, in both static or dynamic position, interacting with the urges of the external environment. STP integrates all information resulting from the proprioceptive sensitivity of the visual-podalic axis, which crosses the occlusal apparatus and the whole body musculature, with its cognitive part to allow the conscious mental representation of verticality (Rossato, 2015). "These informations originate from: the retina, the macule the orticoli e daisacculi, the baroreceptor plantars, the oculomotority, from all the proprioceptive receptors – muscle spindle, Golgi tendon organs, from the mouth, from ATM – divided into muscles, tendons, ligaments of the body axis set, of the atlanto-occipital joint, up to the last foot joints" (Gagey et al, 1995 – p 204).

STO system is a complex system where foot has a relevant importance. This organ is always in contact with the ground and its imbalance but anyway, at any moment, it can divide pressure on the two leg in a relatively equal and symmetrical manner (Bricot, 1998).

**Methods**

The podoscope is a tool that uses a visual method that allows making an assessment with a selection of icons representing the plantar morphological status. It is made up by a transparent holder where the subject that needs to be assessed is placed; once he is settled, it is observed the support surface tangentially enlightened by a fluorescent light and conveyed to the observer's eye by a tilted mirror that allows to get a plantar image of the person under static loading.

As observable from the image, this toot helps us to identify the different degrees of plantar arches, to determinate the different foot pressure distributions, to assess the position of heel and to highlight possible tensions of the humane spine and of the pelvis.



In other words,it will be possible to assess the general condition of the lower limbs starting from the objective measurement of the feet up to the pelvis. The innovative contribute of this tool is the possible

to assess with Led. As any other podoscopes, indeed, it is formed by a methacrylate surface, but it is backlit by particular led (9 volts, 9.72 W/m) which emphasize the areas of major and minor loading or

eventually not in contact. The below reflective part with mirror is inclined with an angle such as to allow a total analysis of foot, of ankle, of leg, knees, thighs, pelvis and therefore globally of the lower part of the body which forms the adaptive and compensatory part. But the main innovation of this tool is the use of Lasers. Indeed, they point to us, with greater precision and objectivity, how the alterations of the podalic support system are connected in a kinematic and adaptive chain to the ankle, to the leg, to the knees, to the coxo-femoral joints and at least to the pelvis which fits itself in the three space dimensions (Rossato et. Al. 2010/14). Lasers produce two vertical lines exactly orthogonal to the floor plane, which ease the assessment of the dysmetries and of the angles outlining subject's posture. The podoscope is connected to a computer with a special software (Sprint Ware), which in a rapid and precise way guides who use it, in the clinical assessment methodology (SprintIT2015). Unlike other podoscopes, which are limited to the assessment of the plantar support only, this tool allows the operator to assess the plantar footprint and to puts it in relation with eventually postural alterations which the person has until the centre of mass.

Postural assessment protocol with LedPodoLaser

Six postural assessments were made using the LedPodoLaserpodoscope of new generation, a PC with the Sprintware software, a webcam and an optical focus with a self-centring laser generating a very bright vertical line (>200 lumen of environmental delta). Some students attending the Master of Functional Rehabilitation and Applied Posturologyparticipated in the assessment at IRAM (Research Institute on Motor Activity) in Urbino. The podoscope was positioned in such a way that the examined person could see the laser beam projected into a wall for the vertical line of Barrè. The vertical line of Barrè reproduces the visual-podalic axis. Laser is projected at a distance of 240 cm approximately from the subject's eyepiece plane, fixed in the centre among the feet on the centre of the quadrilateral of the support. The optical focus was placed at this distance because: "the weight of the visual entrance decreases to become of no importance at a distance greater than 2 metres" (Ouaknine et al, 2006).

Assessment with "LedPodoLaser" podoscope

Podoscope analysis

With the use of a gauge, the median has been calculated exactly in order to find the anatomical landmarks in the right and left laterality to place the markers: on the talus bone, on the popliteal cavity, on the gluteal fold of each leg and on the tibial and peroneal malleolus.

As per protocol the subject's left foot has been placed up the special form reproduced on the podoscope, taking care that the median of the talus (where the marker applied previously) would match with the point of the shape drawn on the surface; instead the right foot has been placed parallel to the left one with the width of the pelvis; both feet have to be oriented in accordance with the sagittal plane of the subject. Once the feet are placed, it is proceeded with the lighting of the lasers, whose positions is adjustable according with the subject's feet opening capacity. The lasers have to be adjusted so that each of them overlap perfectly with the vertical median of Achilles tendon.

It is important to ensure reproducibility of the feet position.

Also for this reason, the webcam have been used: so it was possible to take a photo to place the subject in the same position for the following observations.

Right after placing feet and switching the lasers on, the subject was invited to stare the vertical laser line projected at 240 cm from the frontal plane of the subject, without clenching teeth and/or opening his mouth.

Then the subject was invited to stand, without flexing knees, with erect body, without moving himself or speaking.

**Results**

*LedPodoLaser Protocol*

Here are the list of the various steps:

1. *Placement*: place the left foot on the drawn figure on the podoscope. Then suggest to the subject where putting the right foot (pelvis' width). Inspect the corresponding letter to the feet opening (from A to M) directly on the podoscope's surface and select the corresponding icon. Take a photo. The corresponding icons have been selected.
2. *Bipodalic footing*: looking at the surface which reflects the footing, choose and assess the width of the space between feet and select the corresponding icons of both feet. The corresponding icons have been selected.

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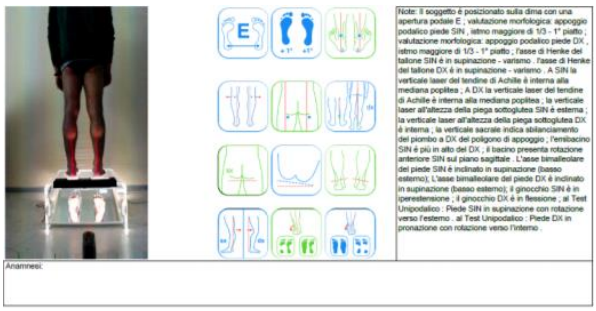
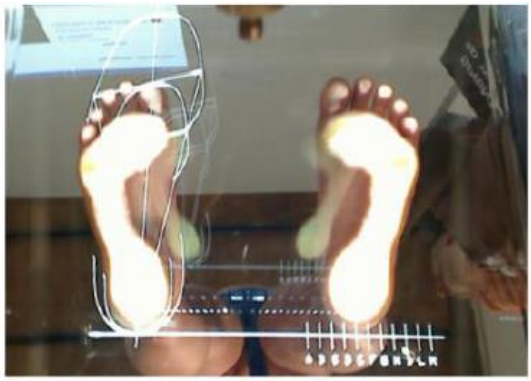
3. *Heel vertical axis test*: the line of Helbing has been assessed, previously marked with a marker compared to the laser light; that is, if the median of the talus bone would fall inside or outside the laser. This allow us to understand if the foot is valgus or varus. The corresponding icons have been selected.
4. *Vertical popliteal axis test*: assess where the popliteal axis is compared to the laser light (in, out or in line with it). The corresponding icons have been selected.
5. *Vertical axis of the gluteal fold test*: assess if the gluteal median falls into line with the laser light or lies externally or internally to it. The corresponding icons have been selected.
6. *Vertical axis of intergluteal line test*: placing the lead wire at the level of the intergluteal line, check if it falls to the left or to the right of it or in a central position.
7. *Horizontal axis of gluteal line test*: with the use of an air bubble level, check the gap of height of the gluteal folds, then check if there is a tilting of the pelvis.
8. *Vertical axis of the gluteal line test from above*: check if the left gluteus is putted before or, on the contrary, is retracted to the other, so assess if there is a front or rear rotation of the pelvis. The corresponding icons have been selected.
9. *Bi-malleolar axis test*: assess the directing (upward or downward) of the line inclination which connected the internal and external malleolus with the use of a inclinometer. The corresponding icons have been selected.
10. *Vertical axis of the lateral view of the popliteus test*: assess the normality, the hyperflexion and the hyperextension of the knees viewed sideways. The corresponding icons have been selected.
11. *Monopodalic footing test*: it was required to the subject to raise one foot, without looking at his feet or at the ground, but looking the vertical line of Barrè to assess the rotation of the remaining foot. The action was be repeated with the other foot and the corresponding icons have been selected.

The mentioned above tests and any free notes are reported in a single final report.





**Discussion**

The LedPodoLaser is a new and effective tool, objective and ease to use. However, its greater importance, which is its innovation among the podoscopes used until now, is to put the correlation between feet, which are adapters and compensators, and the whole lower part of the body until the centre of mass, as essential standard. This particular podoscope is easy to read and can be used by Doctors of Motor Science too, to assess a patient, as well as possible, and propose an individual postural rehabilitation program.

**Conclusions**

A good and objective postural assessment is the starting point for setting up a correct individual, programmed and adapted intervention according to imbalances and postural asymmetry that the patient has.

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