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Clinical significance of measurement reliability of diagnostic tools used for evaluation of body posture

ABSTRACT:

Development of electronics has led to the increase in the number of available diagnostic tools with different measurement reliability and, consequently, different clinical utility.

Title: The clinical significance, the reliability of measurements, diagnostic tools used to body postural

Summary: Application in the diagnosis of body posture, units affected by large measurement error. this results in an incorrect diagnosis, and thus disqualifies its clinical utility.

Keywords: Diagnostics, baropodometry, posturography, biomechanics.

Similar to somatoscopic observation, all electronic devices are affected by measurement errors. Each clinician and therapist that conducts examinations should be guided by two basic criteria: reliability and objectivism (1). Therefore, the following questions were asked:

- What is the clinical significance of using a device with high measurement errors in diagnostics?
- What is the measurement error of non-invasive diagnostic tools used for evaluation of human body posture available in the Polish market?
- What are the differences in the level of measurement errors (poor diagnostic accuracy and reliability) in tools used to analyse/evaluate the same parameters in the same patient?

Non invasive methods used for the diagnosis of body posture can be divided into:

a) Visual inspection based on knowledge and experience of the therapist
b) Manual and functional diagnostics
c) Methods based on the use of simple measurement instruments
d) Photometric methods
e) Baropodometric methods

Visual inspection based on knowledge and experience of the therapist include:

- Examination according to the simplified design of the orthopaedic examination
- Descriptive methods
- Postural methods

Manual and functional diagnostics include:

- Manual examination
- Selected clinical trials, e.g.: evaluation of muscle strength, examination of myofascial and ligament contractures or posturographic tests.

Among the methods that utilize simple measurement instruments are:

- Clinometry
- Scoliometry
- Plantography and plantocontourography

Contemporary photometric methods include:

- Videography
- Photogrammetry and its "derivatives"
- 2D scanners
- 3D scanners

The baropodometric systems include:

- platforms for measurement of ground reaction forces
- posturographs
- baropodometric pathways
- baropodometric treadmills

The authors of this paper, based on the Scientific Project „Analysis of reproducibility of the photogrammetric method used for evaluation of human body posture and its optimization using stabilography" (Project No. 2011/01/N/NZ7/03578, funded by the National Centre for Science in Kraków, Poland), attempted to evaluate the measurement reliability of tools used

for body posture diagnosis..

Since many authors (2, 3) have already evaluated measurement reliability of older measurement instruments e.g. podoscopes or plantocontourographs, the authors of this study decided to limit the explorations to the analysis of measurement reliability of four selected methods of body posture diagnosis, such as photogrammetry, videography, posturography and baropodometry.

Methods of diagnosing the attitude of the body

Photogrammetry has been used in medicine mainly to measure the alignment (shape) of human body or its parts. Graphical representation of body measurement of the whole body (in the form of contour lines and profiles) allows for the "derivative" analysis of abnormal spinal curvature and its measurements in rehabilitation. The moiré projection technique is very popular. It consists in optical projection of two similar linear rasters on a spatial object with limited depth, leading to the formation of a moiré topography on the object surface (contour map).

The analysis of photogrammetric systems available in the market showed that none of them feature options of automated adjustment of the camera height are not equipped in distance sensors (rangefinders) that allow for a precision measurement of the distance of selected body part of a patient (e.g. points C7 and S1) from the camera lenses. Another finding is that the systems do not evaluate the asymmetry of body fat in the patient.

Part of these problems that lead to measurement errors were solved by using 3D scanners (mostly laser scanners) featuring a texture analysis option (3D measurements with color recognition). However, such instruments are very expensive and available only in a few locations in Poland.

One of the most popular instruments used for feet examination is podoscopes. However, it should be noted that each podoscope with a camera (or a mirror) mounted at the bottom is affected by an error or distortion. Diagnosticians, doctors and scientists seem to be unaware of this problem while most opticians and people involved in photography are well familiar of this fact.

Two photographs are enough to demonstrate this problem: one by holding the camera at the height of the person's face and the other at the knee height. This method reveals substantial differences between the photographs. The second photograph will show the person with shorter body trunk and longer legs.

The camera used in the podoscope leads to the same distortion of the image. This occurs when the patient stands again on the podoscope but slightly wider or higher than the "camera eye". The results are substantially different. A similar effect is observed when one person is standing in a different way than the other with respect to the lens.

This problem can be solved by the use of podoscanners (Phot. 1) which scan the plantar side of the feet with the 1:1 scale. Most (but not all) podoscanners used in the market (Podoscan2D) allow for the analysis and archiving of both a part of feet adjacent to the instrument (similar to the plantocontourographic print) and other parts of the foot (4). Similar to conventional cameras available in the market, podoscanners differ from each other in resolution that affects

$$BAQS = \frac{R\ (\text{right side parameter}) - L\ (\text{left side parameter})}{\text{dimension of the smaller side parameter}} * 100\%$$

the quality of the photograph (scan). The most modern models of 2D podoscanners offer resolution of 1,600DPi while in older versions, this value was 600DPi, affecting the quality and accuracy of the examination. Tests have demonstrated that in older podoscanners, the feet should be additionally obscured before the examination. This inconvenience was solved in podoscopes with greater (1,600DPi) resolution, with the intensity of the "scanning cathode" being adequate for balancing the external light.

The most popular tool used in the diagnosis of balance and visual-motor coordination is posturographs. Numerous authors (5, 6) have emphasized that posturographs are used to measure "the projection of the centre of gravity of human body on the support surface". The authors of this paper, during the works on the research project „Examination of the relationships between balancing of body weight, asymmetric unloading lower extremities, asymmetry of lower limb stability and maintaining balance by people with disturbed balance, healthy people and athletes" (project No. N404 316240 funded by the National Centre for Science), demonstrated that the **COP** (Center of Pressure) measured by means of posturographs, previously described in the literature (7, 8) as **„a change in the location of the point to which ground reactions forces are applied"**, actually represents the **„net force of 3 net forces"**, since it is the net force of:

- changes in the location of the point where **net ground reaction force of the left foot** is applied (COP-FL),

- **changes in the location** of the point where **net ground reaction force of the right foot** is applied (COP-FR),

- **„balancing"** i.e. the process of transfer of body weight from one leg to another, which actually is **the net force of changes in the values of net ground reaction forces for** the right and left feet.

Nowadays, posturographs come in two versions: single-platform and two-platform. With the single-platform posturograph, the patient places both feet on a single platform, thus measuring/recording a net force of 3 net forces. If a two-platform posturograph is used, one foot of the person is placed on one platform and the other foot on the other platform. This allows for two independent measurements for all 3 net forces, which substantially extends diagnostic options.

Balance Asymmetry Quotient (BAQS) was developed during the work on the above mentioned research project (8). Development of a new quotient helped unify the evaluation of asymmetry of the parameters that describe balance on the two-platform posturograph. During comparison of the results obtained by athletes and untrained people and patients with impaired balance, the most significant differences were observed in the values of 4 parameters:

- balancing range,
- asymmetry quotient,
- safety margins,
- stability ranges (in the sway test).

These parameters have not been described in the literature so far.

Balancing range (the difference between minimal and maximal value of the load to the lower limbs) was over 20% of body mass in people with balance disorders, whereas this value never exceeded 3% in athletes, which substantially differentiates between these study groups.

Very high **values of the BASQ quotient** (over 1000% in several cases) were recorded in patients following strokes.

The abnormal "regularity" was observed in people with balance disorders as they loaded the less stable limb even more, i.e. asymmetry of loading lower limbs was greater for the side of the platform (leg) where higher sway area (surface area covered by the moving COP-FR or COP-FL) was documented.

The authors of this study emphasize one limitation of posturographs (both single-platform and two-platform): these devices record only **the change in the location of the point (or two points) of application of the net force (or two points) of application of the net force (or two net forces) of ground reaction forces and the net force (or two net forces) of the change in the value** of the net force **of ground reaction forces of the right and left feet.**

The substantial extension of the diagnostic opportunities for evaluation of balance is offered by baropodometric devices, often erroneously termed podobarographs or baropodographs.

The tools used in the feet diagnostics can be divided into:

a) static, such as:
- plantocontourographs,
- podoscopes,
- 2D podoscanners,
- 3D podoscanners,
- 3D scanners of polyurethane foam foot impressions,

b) dynamic:
- podoscopes with cameras,
- platforms/ pathways of ground reaction forces,
- baropodometric treadmills.

Baropodometric platform measures distribution of the load to the ground by feet, both in standing and during walk. These platforms were popularized in the environment of podologists due to the wide diagnostic range and opportunities for both static and dynamic evaluation.

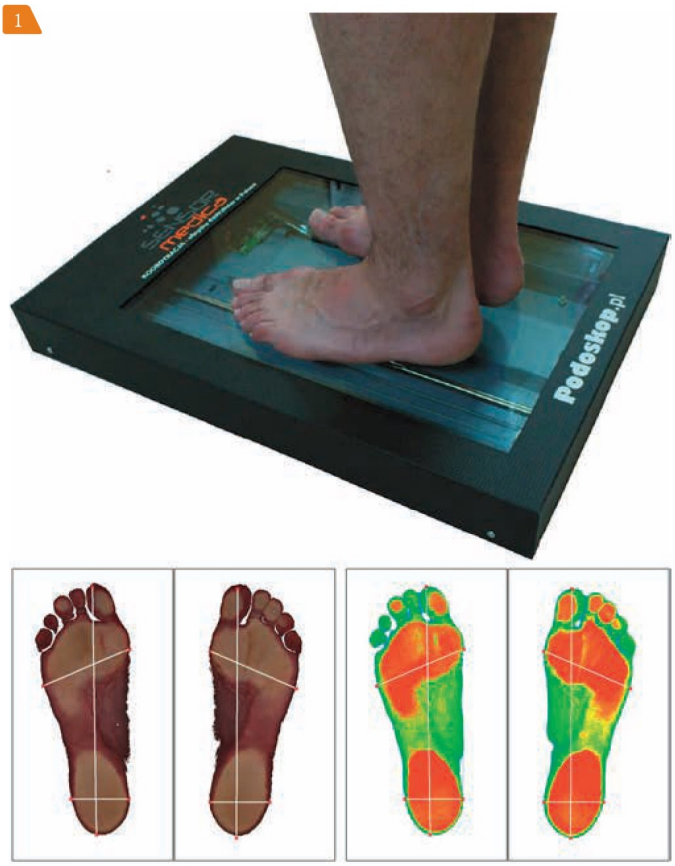
The authors are concerned with substantial differences between the results obtained for the same patients examined using various force platforms (baropodometers) manufactured by several various manufacturers (Phot. 2).

In order to find the explanation of substantial differences in the results documented for the same patients on several devices of different manufacturers, we decided to analyse the interior ("hardware") of force platforms.

After taking several systems (of different manufacturers) to pieces, it was found that they featured sensors with different shape.

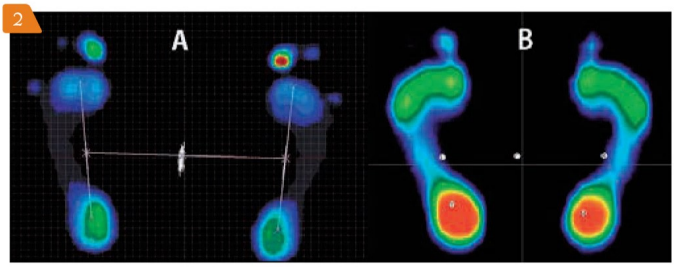
The photograph 3 presents sensors / measurement field (yellow / gold) of three different devices. The magnitude of surface area not measured by the mat / platform A is over 60%, whereas

1



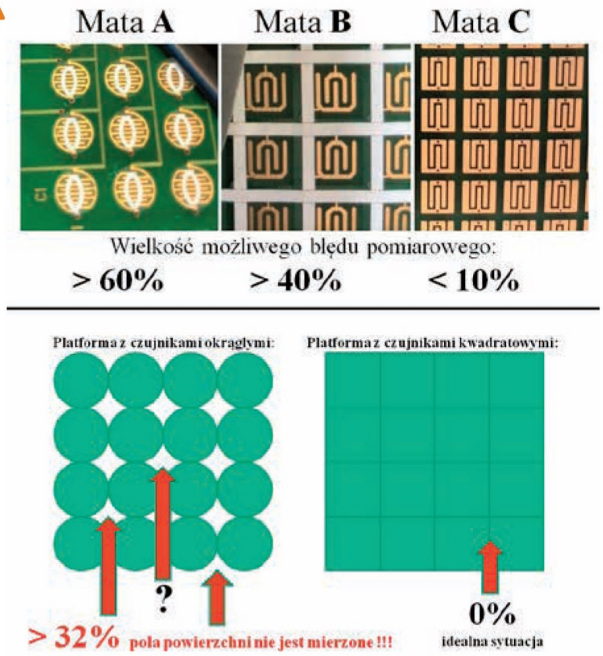
2D podoscanner (Podoscan) with printed examination results

2



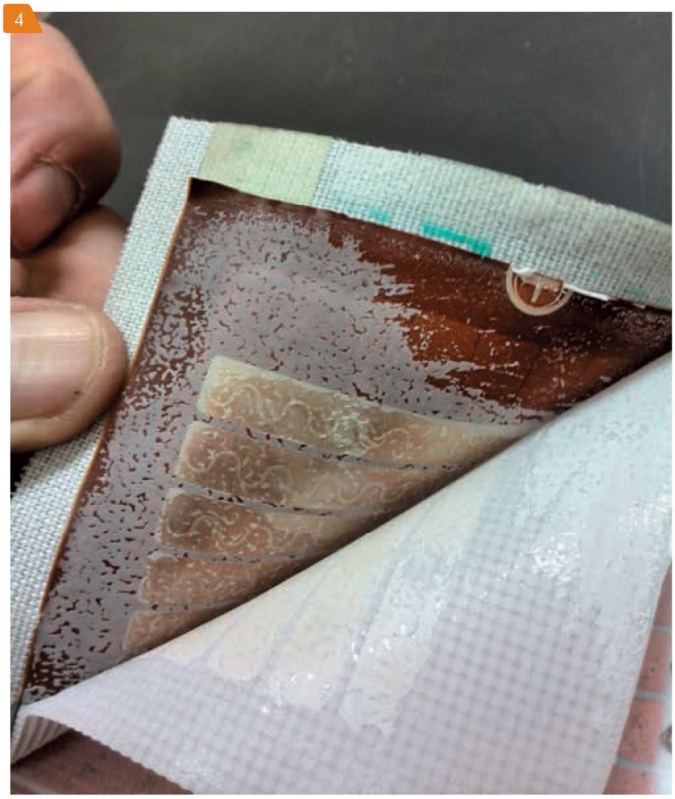
Results of the study of the same patient using two force platforms from two different manufacturers

3



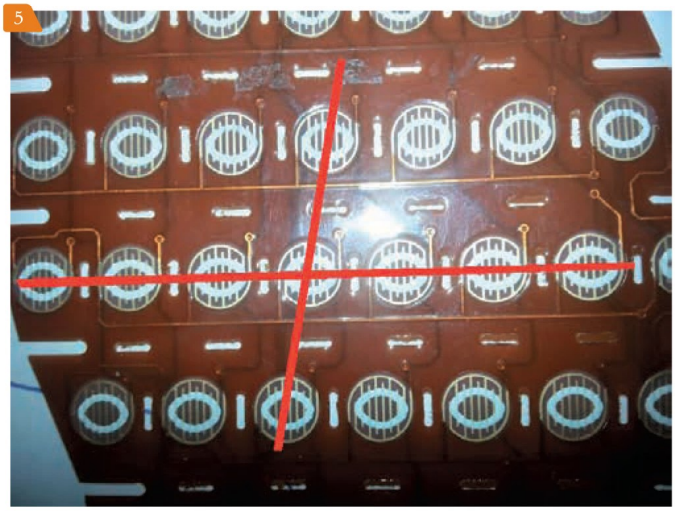
Photographs of various shapes of the sensors used in platforms, with computations

4



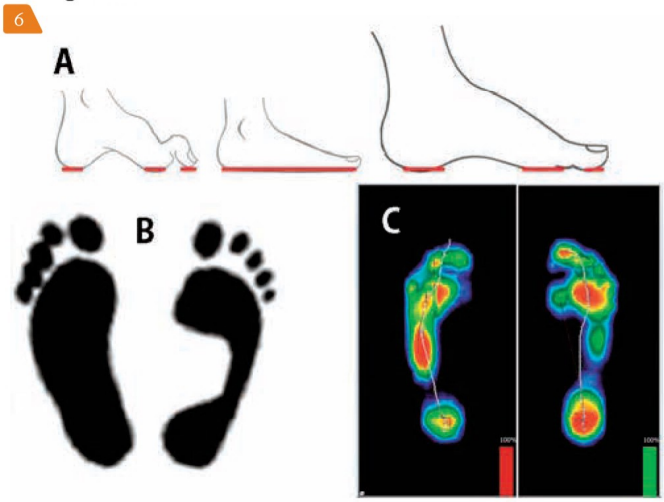
Photograph of the device without sensors

5



Photograph of the measurement system with oblique sensor arrangement

6



A) feet with different types of foot arch, B) plantocontourgraphic impression, C) distribution of load to the feet during a dynamic

this value for the mat B is over 40%. With round sensors, minimal unmeasured surface area will be always over 30%, which is presented in Fig. 3. The sensors are additionally located at a distance from each other. This leads to the presence of large surface where nothing is measured although feet are in contact with these locations.

The shape of sensors and magnitude of the surface area which is not measured under the foot is critical to the comparison of the load in the forefoot with the load in the rear foot and to the analysis of the asymmetrical load of lower limbs, which represents the major focus of the podological study.

This "mathematics", according to the authors of the present study, points to the uselessness of 9 in 20 force platforms (also termed baropodometers or podobarographs) available in the Polish market and commonly used in the body posture diagnostics.

Another example of an "interesting" design of the platform/mat is the device presented in the Photograph 4. Although it is expected to feature several thousand sensors (as can be read in the manual/advertising leaflet), its interior contains only a few hundred of intersecting strips. In this design, the reading/measurement is conducted at the intersection.

Extremely surprising is the design presented in the Photograph 5. The oblique arrangement of sensors can be found, although it is difficult to imagine round television sets or round tables in Excel used in mathematics and information technologies. Furthermore, the distance between individual sensors differs between X and Y axes.

Analysis of the above information should lead to the following question:

What is clinical significance of such differences in the design of diagnostic instruments?

The answer to the question is Photograph/Figure 6 as no one is symmetrical.

The study showed that even two (simple and purchased for several to several hundred zlotys) scales placed next to each other (and levelled) will offer a diagnostic tool that is more reliable for the diagnostics of e.g. asymmetry of loading of both lower limbs than the tool with improperly mounted sensors, purchased for several thousand or even several hundred thousand zlotys that lead to erroneous results and, consequently to erroneous diagnosis, recommendation of improper therapy/treatment and making improper orthotic insole.

And what about **Primum non nocere** (Latin: "first, do not harm"), which is one of the major ethical principles in medicine?

Summary

At the end of the explorations, the authors asked the following question:

Which force platforms were the most popular, i.e. the most frequently bought by Poles until recently?

Analysis of available publications concerning the trademarks/models/manufacturers of the diagnostic tools and numerous consultations during conferences and collaboration with other research centres in Poland demonstrated that the most popular instruments in Poland (and all over the world) were baropodometric devices affected by the substantial (often over 50%) measurement error.

Why does this happen?

Two conclusions can be drawn:

a) the major factor in buying such devices in Poland is price

b) and poor awareness of buyers (physicians, therapists, scientists) of what they actually purchase.

The intention of the authors of this paper is to raise awareness among therapists/diagnosticians/physicians/scientists and to emphasize the problem of measurement reliability of the tools used to evaluate/analyse body posture and human locomotion.

Analysis of measurement reliability of the tools for evaluation of body posture and its locomotion is the responsibility of diagnosticians/therapists/scientists so that treatments that result from the diagnosis are not affected by errors and, consequently, do not have a harmful effect on patients. ❑

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