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Statistical Analysis and Simulation of Orthostatic Position by Means of the Pedometer in Patients with Hyperkyphosis

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Abstract

The essential element of the "modern" man is a long time spent in the office, in front of the computer or on the phone. Such a posture leads to substantial modifications to the center of gravity, which leads to the set in of hyperkyphosis. The statistical analysis and simulation of such a symptomatology can help both the doctor and the medical recovery specialists in the early prevention of the body posture, since the primary symptomatology of the hyperkyphosis cannot be detected following a primary consultation, being usually mistaken for a kyphotic attitude. The statistical study described above offers a new, non-invasive approach in the early detection of kyphotic conditions, but also a useful tool in the evaluation of the spine's deformation degree.

Keywords: hyperkyphosis, posture test, modeling and simulation, distribution of average deviations, social impact.

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Introduction

The health – movement relationship is more and more often referred as the key elements of the modern man's life, which spends too many hours in the office or in front of the computer screen. The balance is an indispensable mechanical condition for motricity, as it ensures the stability of positions (posture) and orientation of the movements in space, being required in household, professional and sports activities. In static conditions, the preservation of balance is carried out when the projection of the center of gravity is situated inside the support base, regardless of the position of the body segments. During the evolution, the center of gravity has suffered a displacement towards the posterior side of the body, ending in localization at the level of the trunk in case of humans, next to the second lumbar vertebra. The modifications have allowed for men a type of posture and locomotion called "bipedalism", which allows the vertical position and the regular use of the lower limbs for static posture and movement.

Thoracic hyperkyphosis is a deformation in the sagittal plane of the spine, from the T1 thoracic vertebra to T12 thoracic vertebra. The spine shows three physiological curves in the sagittal plane, namely: cervical lordosis, dorsal kyphosis and lumbar lordosis. With the increase of the curve, the transfer from physiological to pathological takes place (Barrett &Lewis, 2014). The causes that can lead to kyphosis are: incorrect position (on the chair, at the table, in the office, etc.), muscular hypotonia, rickets, myopia, hearing impairments, osteoporosis, degenerative arthritis of the spine, spondylitis, the Marfan syndrome, etc.

One of the main causes for the set in of hyperkyphosis in the 21st century is the excessive and incorrect use of the cell phone. Notice that, when the head is at 0^{o}, the force exercised on the entire posterior capsule-ligament-muscular complex is 10-12 lbs., but when the head is in a flexion of 15^{o}, the force exercised on the entire posterior complex is double, reaching 27 lbs.; for a 30^{o} flexion, the force exercised on the posterior complex reaches 40 lbs., for a 45^{o} flexion the force exercised on the posterior complex increases to 49 lbs., while for a 60^{o} flexion the force exercised on the posterior complex is 60 lbs.

The transition from kyphosis to hyperkyphosis produces an elongation of the entire posterior capsule-ligament-muscular complex and a shortening of the anterior one. Beside the aspects mentioned above, with the increase of the curve in hyperkyphosis, the following risks arise: vertebral fractures, degenerations of the intervertebral disk, the decrease of physical performance and, implicitly, of the quality of life (Quek *et al.*, 2013; Tran *et al.,* 2016).

The deformation degree in case of hyperkyphosis is between 20^{o}and 40^{o}-50^{o}, an interval in which the patient can be recovered using various treatment methods, such as: physiotherapy, osteotherapy, chiropractic, corset (Barrett & Lewis, 2014). Severe hyperkyphosis, over 50^{o}are subject to a surgical treatment consisting in open surgery, through the dissection of the fascia and muscles, a minimally invasive surgical method by means of vertebrectomy (Chou, Lau, & Roy, 2014). In view of determining the hyperkyphosis degree, the following evaluations will be conducted: Cobb angle (radiography of the spine, back incidence) being the most commonly used evaluation method, Debrunnerkyphometerand kyphotic index (Giglio &Volpon, 2007; Tran *et al.*, 2016).

Material and Methods

Posture is often analyzed in relation to a special platform that provides the oscillating course made by the pressure center in time (Giglio & Volpon, 2007). Thus, the measurement of the distribution center of all the forces applied on the support surface is a simple, non-invasive technique, frequently used in medicine to determine the diagnosis.

The system used is made up of the following components: (1) A balance platform; (2) A signal acquisition system; (3) Software to process the acquisition signals.

The parameters according to which the measurements were conducted were: weight, height, the length of the foot. Depending on these parameters, values were obtained for the three pressure points inside the platform (p_a,p_b,p_c), x_{med} (deviation on Ox axis), y_{med} (deviation on Oy axis) considered as secondary parameters. The technical data of the equipment: power source: 230V~50/60Hz transformed to 5V, platform size: 500×500×100 mm, weight: 18 Kg, maximum supported weight: 300 Kg, transducers: 3 transducers able to support 100 kg each and accuracy: 0.1 Kg for each transducer. The primary processing was made using the AcqKnowledge software of the BIOPAC system. TheBiopac MP 100 system includes a hardware component of data collection, with built in amplifiers, for electrical signals coming from the podometric platform (Bohm, & Zech, 2010). The signals from the three sensors with low amplitude are amplified, filtered to remove artifacts and noise and finally converted by saving as .TXT which can be easily imported by the analysis soft. The processing of the final data was conducted by means of the graphic interface built in MATLAB (*Figure 1*). It provides an interactive, powerful and user friendly system where problems and solutions are expressed naturally.

Figure1. The main menu of MATLAB application

Results and Discussions

The increase of the frequency of spine deviations and deformations of the sternocostal plastron is caused not only by the increase of the risk factors, but also by the increase of the doctors' efforts to early identify this pathology. It is manifested by outlining the pejorative potential of the evolution of the study pathology, by an intensification of the family doctor's activity in identifying patients and by the introduction of new, non-invasive methods to assess posture disorders. Posturometry – stabilometry and impedantiometry are new methods used both for the determination of the clinical and differential diagnosis and for tracking the evolution of these disorders, being considered non-invasive methods. The result of these measurements provides us with information on the disbalance with excessive retropodalic left/right charge; unstable gate; limit normal values, allowed intervals; equal values or variations between +/- maximum 2 u.i; the technological innovation of the posturometric method offers the opportunity of conducting a detailed global analysis by means of a high-performance software, which studies the following parameters: (1) it visualizes the plantar pressures indicating the body centers of gravity, the displacement of pressure during walking, the image of the foot "in charge" obtained by scanning to study the plantar arch; (2) it conducts a complete exam of the balance, with the visualization of the displacement of the center of gravity inside the ellipsis; it provides relative data on the oscillations of the body; (3) the Romberg coefficient; (4) confrontation between two different pieces of information; (5) it manages the information received;

The study was carried out on a number of 30 subjects, male and female, aged between 20-41, with an average of 24.17 years old. The weight of the subjects included in the study lot, leads us to a mean value of 67.60 kg. Out of these, 8 have a weight between 50-55 kg namely 55-60kg, a low incidence being reported in case of patients weighing more than 100 kg and the average height was 169.33 cm.

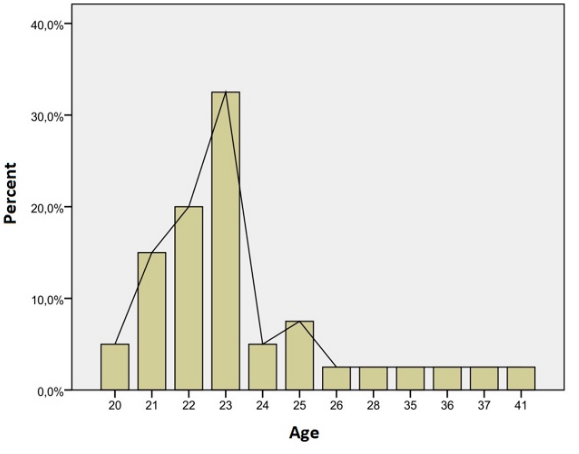

Figure 2. Distribution of the study lot on age

According to the results in the doctrine, the frequency of pathological deviations of the spine is high, the specialists' estimations being over 50% of the subjects assessed in collectivities. However, in most cases they show no pathological significance (hyper-kyphotic altitudes representing 3-5% of the total subjects). The incidence of spine deviations is difficult to determine as the patients fail to be aware of their own deformations, as they are asymptomatic first and sometimes even during the evolution of the condition.

The center of gravity should be maintained around the O point in the coordination system (xOy), but it oscillates in time, depending on certain conditions and pathologies. The blue part represents the ideal position, while the red one indicates the subject's position (figure 3). One can notice there are women who show no modifications of the center of gravity, being close to the ideal position, while other women show large deviations from the normal position. At the level of the Ox axis, one can notice a deviation between -10/+5 mm, and at the level of the Oy axis the deviation is between -20/+20 mm. According to the existing studies, these oscillations are within the normal parameters.

The occurrence of these deviations in women can be explained by the following hypotheses: (1) Due to excessive wear of high-heel shoes, certain modifications and deviations from the normal body posture are developed. The shoes modify both the length of the gate and the type of contact with the ground, which leads to certain pathologies of posture; (2) Another determining factor for these differences is the degree of openness of the lower limb from the coxofemoral articulation, which differs for men and women; (3) As a rule, women show a weaker muscular system than men.

Most of the times, these deviations cannot be noticed because the body gets used to these deviations, which are shown only in such postural analyses.

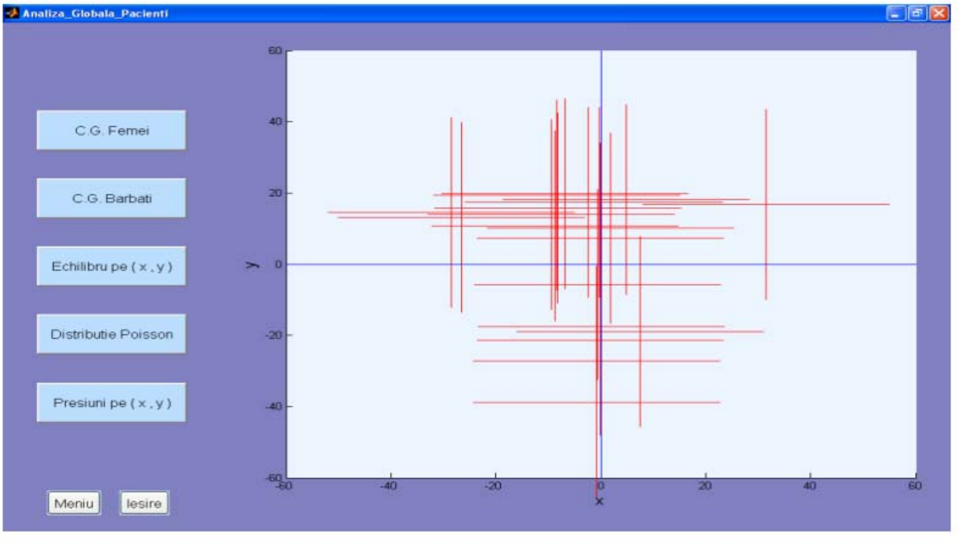

Figure3. The center of gravity in women

In the study lot, hyperkyphosis was predominant with the female sex (57.50%%), while for the other disorders of the spine and the thoracic cavity the proportion of cases depending on the patients' sex failed to show significant differences (42.50% male sex). The risk of pathologic deviations of the spine is significantly larger with the female sex, showing a risk factor of 2.02 (OR=2.02, p=0.00086, 95%CI), compared to the male sex. The analysis of the frequency of spine deformations at the patients in the study lot based on their sex was made in relation to the witness group. The results of the Chi-square test based on the contingency table showed that there is no significant association between the patients' gender and the occurrence of spine deformations (χ^2=6.58, p=0.0096, 95%CI). There is a certain prevalence of disorders in case of the female sex both in the study and the witness lot.

It is noticed that with men, the center of gravity fails to oscillate within a large range, showing a close distribution. If, in case of women, the center of gravity is found in slant position towards the four directions (anterior, posterior, left, right), with men the deviations from the ideal position are smaller, the antero-posterior oscillations being prevalent. The men in the lot selected for analysis have close ages, reason for which the deviations of the center of gravity are not significant, the existing ones being due to muscular fatigue or unfavorable conditions during measurements (*Figure 4*).

If the age categories had been more varied, we would have noticed significant deviations of the center of gravity in women, as well. Among the causes of the modifications we can list the following possibilities: (1) The fact that, with age, both the center of gravity and the center of mass suffer visible modifications; (2) A significant factor which needs to be taken into consideration in the analysis of the center of gravity is the weight of the subject: the higher the weight of the subject, the more evident the variations; (3) Furthermore, the patient's height shouldn't be overlooked, as its value visibly influences the oscillations.

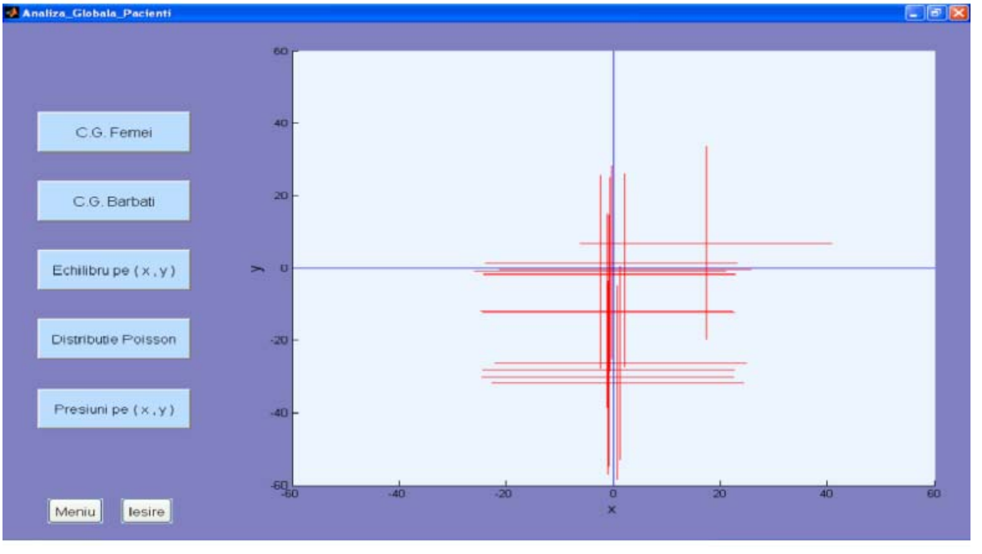

Figure 4: The center of gravity with men.

The posturometric data measurement platform is equipped with three sensors placed in the shape of an equilateral triangle, generically marked p_a, p_b, p_c. The statistical study of these parameters shows values between 10-50 u.i. The mean values for each sensor were 19.82 for p_a, 16.30 for$p_b$namely 15.82 for p_c. One can notice a significant difference between the posterior sensors (p_b, p_c) and p_a, the latter being a combination of the former. The analysis of the Pearson coefficient of the sensor pairs shows a mean relation between the pma-pmb pairs, namely pma-pmc (r=0.353, p=0.025 and 0.347, p=0.28, 95%CI) and a strong relation for the pmb-pmc pair (r=0.783, p=0.0001, 95%CI). This fact leads to a comparison of the body weight of the studied lot with the distribution of the weight at the level of the three sensors.

Table 1. The analysis of the Pearson coefficient of the sensors pairs

		N	Correlation	Sig.
Pair 1	Pma&Pmb	40	.353	.025
Pair 2	Pma&Pmc	40	.347	.028
Pair 3	Pmb&Pmc	40	.783	.000

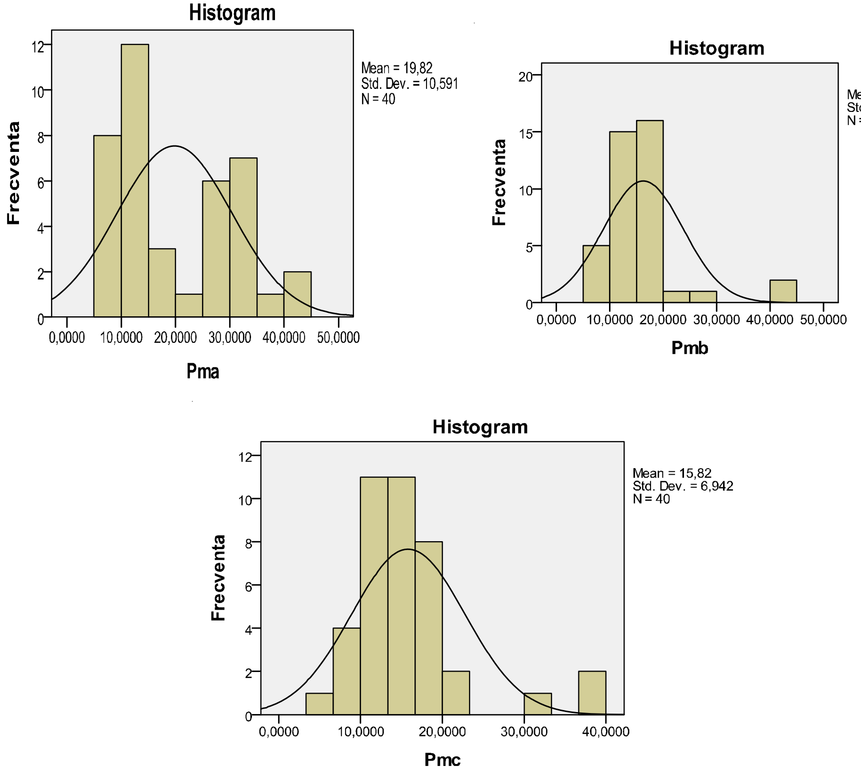

Figure 5. The distribution of the p_a, p_b,p_c sensors values

The distribution of weight at the level of the three sensors indicates a strong Pearson connection between the pair weight-pma (r=0.772, p=0.01, 95%CI), namely weight-pmc (r=0.513, p=0.001, 95%CI) and an average connection between the variables weight-pmb (r=0.34, p=0.032, 95%CI). The t test applied to these pairs of variables showed values ranging between 20.366-27.522, p<0.001 which allows an acceptance of the null hypothesis, namely the weight is one of the important variables in the study of posturometry.

*Table 2.*The distribution of weight at the level of the three sensors

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Weight - Pma	47.781755	10.9801112	1.7361080	44.2701456	51.2933654	27.522	39	.000
Pair 2	Weight - Pmb	51.304540	15.9323501	2.5191257	46.2091273	56.3999527	20.366	39	.000
Pair 3	Weight - Pmc	51.776767	14.5549120	2.3013337	47.1218808	56.4316542	22.499	39	.000

There is a significant association (r=0.62, p=0.008, 95%CI) between the types of diagnosis and the patients' gender. Thus, one can notice a prevalence of hyperkyphosis (81.09%) and hyper-lordosis (0.9%) for the female sex compared to the male sex, where one can see a higher frequency of the cases that show kypho-scoliosis and pectus excavatum. It is usually stated that the idiopathic kyphosis mainly affects the male sex, although many authors assessed an equal frequency for both genders and other find it prevalent with the female sex.

The anterior or posterior inclination of the entire body, beyond a certain threshold, triggers the reflexes meant to restore the support basis and to counteract gravitational force. Under normal conditions, static posture wouldn't be possible without myotatic reflexes. When the tension increases due to traction, the sensitive influxes trigger a reflex act whose response consists in a higher increase of the muscular tension. Thus, the reflex contraction developed is parallel with the exercised traction. When the human body tends to bend forward, the posterior muscles of the various segments are placed under tension and the chain of myotatic reflexes are activates, thus preventing the body from falling over. The reflexes shown on this graphic are balancing reflexes (balance reactions) which are very important for posture, namely the preservation of the center of gravity inside the support surface.

They are controlled by proprioceptive and labyrinthic reactions. These reactions are nothing else but automated protection defense and recovery reflexes. They are meant to preserve the balance in a certain position, at any change of the center of gravity of the body or its segments. The graphic indicates a stato-kinetogram of balance. It shows the deviations of the center of pressure on the Ox and Oy axis, during measurements. When the subject gets up on the podometric platform, the device indicates the position of the center of gravity in static balance.

In time, with the occurrence of dynamic balance, this point starts an oscillating course, trying permanently to return to the initial position. In our case, the center of gravity of the individuals oscillates with larger or smaller variations, depending on: the conditions of measurement, the time dedicated to investigations; the various pathologies of the subjects.

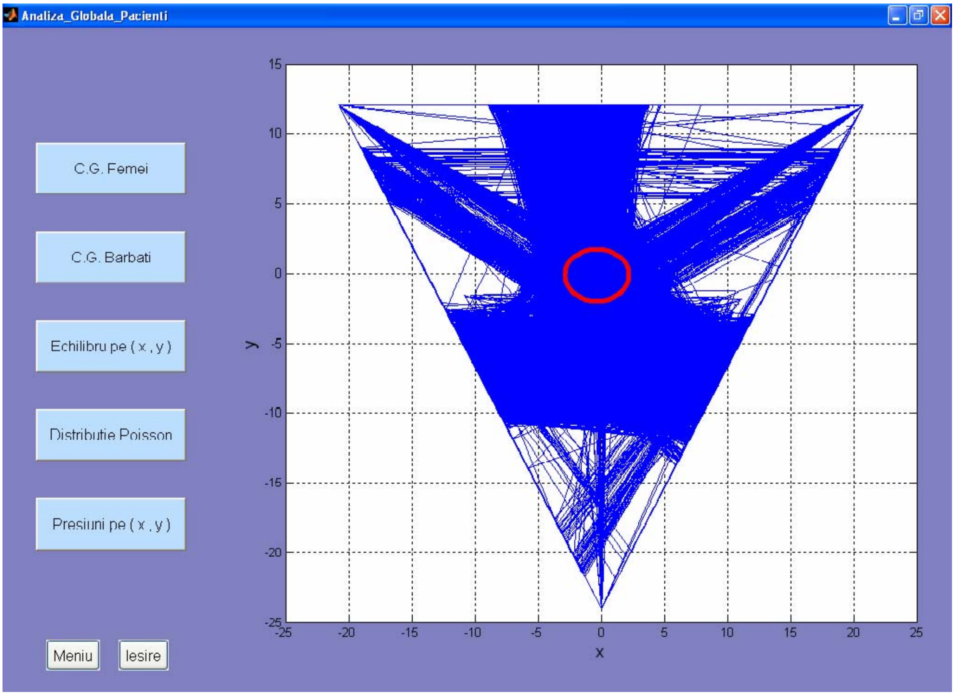

Figure 6. Balance in the (xOy) coordinates system

Posture is the spatial behavior our body assumes in relationship to the environment it lives in and in relationship to the laws that govern this environment, the first of them being gravitational force. The study of the deviations from the balance point for the study lot indicates values ranging between -0.7-5.72 horizontally, namely -11.48-4.57 vertically. Between these variables there is a weak correlation (r=-0.07) in reverse proportion. Therefore, a disbalance of one axis will lead to a tendency of balancing in the other direction. The values of the horizontal deviations for the study lot show a tendency to get closer to the regression axis, considered as a benchmark, in relation to the vertical one, which shows a much larger spread. Therefore, the study lot has a tendency to vertical inclination, specific to spine deviations.

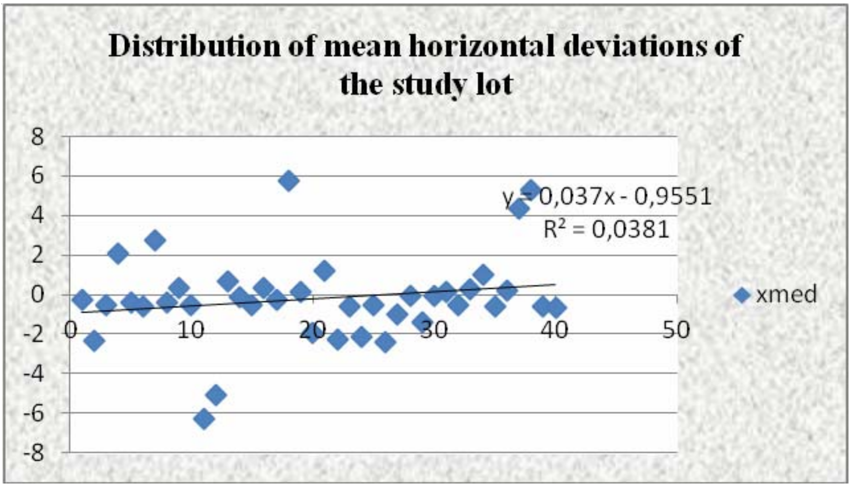

Figure 7. Distribution of mean horizontal deviations of the study lot

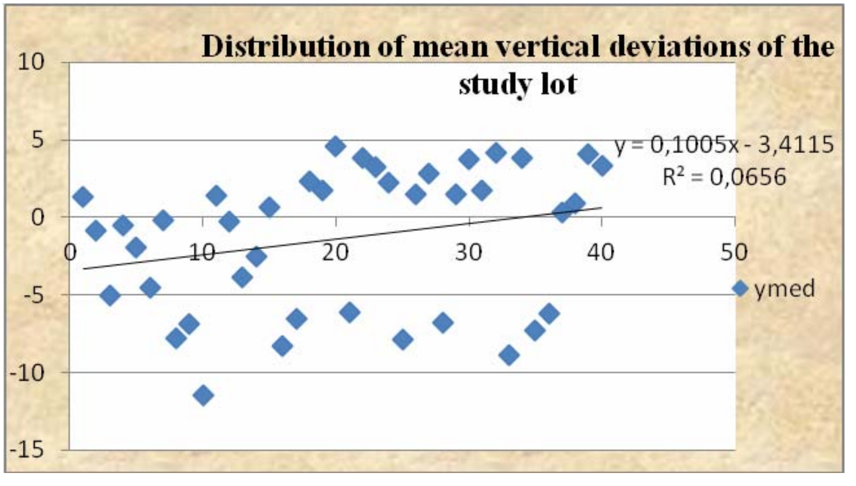

Figure 8. Distribution of mean vertical deviations of the study lot

*Table 3.*The Skewness asymmetry coefficient obtained for Xmed

N	Valid	40
	Missing	0
Mean		-.1961097
Median		-.4222300
Std. Deviation		2.21643602
Skewness		.298
Std. Error of Skewness		.374
Kurtosis		2.640
Std. Error of Kurtosis		.733

The Skewness asymmetry coefficient (Everitt, 2002) obtained for Xmed namely Ymed is 0.374. This value indicates a slight inclination to the right of the frequency distribution curve. The Kurtosis arching coefficient differs significantly for the two variables. If for Xmed we get a value of 2.64, which is indicative of a leptokurtic distribution, with a much superior height compared to the normal distribution, for Ymed we get the value of -1.082, which indicates a platykurtic, flattened distribution, close to the normal distribution.

Table 4. The Skewness asymmetry coefficient obtained for Ymed

N	Valid	40
	Missing	0
Mean		-1.3502875
Median		.1011450
Std. Deviation		4.58800999
Skewness		-.514
Std. Error of Skewness		.374
Kurtosis		-1.082
Std. Error of Kurtosis		.733

The comparative study of weight with the mean deviations after the two axes (Kirkwood & Sterne, 2003) shows a weak direct proportional correlation between weight/Xmed (r=0.216, p=0.181, 95%C.I.) namely an average inversely proportional between weight/Ymed (r=0.528, p=0.001, 95%C.I.). The t test supports the hypothesis that weight is one of the factors that lead to the set in of spine deviations.

Table 5. Comparative study of weight with the mean deviations after the two axes

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Greutate - Xmed	67,7961096	16,5070246	2,60998976	62,5169070	73,0753122	25,976	39	,000
Pair 2	Greutate - Ymed	68,9502875	19,6536373	3,10751292	62,664749	75,2358256	22,188	39	,000

Conclusion

The podometric platform has been long used as an eloquent method of functional exploration of the static and dynamic balance, but the interpretation of the results fails to show the reality every time and the social impact. Although the analysis and posture evaluation methods have improved continuously, it was impossible to completely get rid of errors during measurements or artefacts that negatively impact on the data processing. Through the complex physio-prophylaxis program and postural correction, applied in the practical study, we created the premises of a normal growth and a harmonious physical development, insisting more on the subjects' awareness on a correct body attitude, on the reeducation of attitude reflexes, on the hygiene rules and the exercise of sports activities in the free time. For an optimum corrective effect, the five successive stages of each exercise should be well conceived and analyzed: the preparation attitude for movement; the exercise in itself; the final attitude and the rest and recovery of the capacity of effort between the repetitions of the exercise. The main objectives are: the mobilization of the spine; postural recovery; selective strengthening of the muscles of the back, rebalancing the pelvis (where applicable); the general training of the body. The posturometric test shows the key points in the analysis of the features of adopted strategies in view of maintaining posture. The confrontation between the trajectories with the eyes closed and the eyes open shows how a good physical shape can positively influence the control of posture in the stabilometric trajectory.

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