MEDIAL LONGITUDINAL ARCH CHANGE IN DIABETIC PERIPHERAL NEUROPATHY

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ABSTRACT

Objective: To describe and compare foot anthropometry in healthy and diabetic subjects using Medial Longitudinal Arch (MLA) classificatory indexes: Arch Index (AI), Chippaux-Smirak Index (CSI) and Â Angle (Â), as well as to compare the classification of these methods in each group. Materials and Methods: Control Group (CG) composed by 21 healthy subjects and Diabetic Group (DG), with 46 diabetic neuropathy subjects. The indexes were calculated from footprints. Results: A larger proportion of flat feet was seen in DG for the three indexes (AI: 32,2%, CSI: 59,7%, A: 17,5%), while highly arched feet acted oppositely. The groups were statistically different for the proportion of flat feet in AI (p=0,0080) and CSI (p=0,0000) and high feet in Â (p=0,0036). There were significant differences when compared GC and GD in the three indexes: IA (p=0,0027), CSI (p=0,0064), Â (p=0,0296). Conclusion: Data showed motor and orthopedic changes originated by peripheral neuropathy, which is responsible for foot changes, causing longitudinal arch crumbling. It was seen that A Angle strongly disagreed when compared with the arch classification made by the other two indexes and therefore, its application needs care.

Keywords: *Anthropometry. Evaluation. Foot. Diabetes Mellitus. Polyneuropathies.*

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INTRODUCTION

Diabetes is being considered as a disease of endemic proportions all over the world, with an increasing number of new cases diagnosed each year. Currently, according to WHO, there are 150 million diabetic patients throughout the world. It is estimated that by 2025 this number will reach to 300 million. Still according to WHO, Brazil, with about 6 million diabetic individuals, is the 6th country in the world with the highest number of diabetic people.[1] It is usually associated to complications accountable for significant health expenditures, as well as a substantial reduction on labor capacity, on quality and life expectation.

Among chronical complications, we can mention the diabetic polyneuropathy which is characterized by a progressive somatosensorial sensitivity loss, proprioception, muscular function and anatomical functions. Diabetic neuropathy may be classified according to its severity and progression into sensitive, motor and autonomic neuropathy.

Feet are the target of almost all chronic complications to which a diabetic patient is subjected, a fact that must be discussed separately due to its high potential to produce disability. A large number of amputations of lower limbs occur each year in diabetic individuals, and over half of these are estimated to be avoidable with appropriate feet care.[2] Estimates show that foot ulceration occurs in approximately 15% of the diabetic patients. In addition, more than 60,000 lower limb amputations are performed in diabetic patients each year.[3] It is also estimated that 20% of the hospitalizations attributed to diabetes result from feet ulcers and infections. Another study indicates that ulcers involving the diabetic feet are associated to mortality rate increase.[4]

Motor neuropathy produces a disarrangement of the intrinsic foot musculature, its atrophy and resultant joint mobility loss, particularly of the subtalar and metatarsal-phalangeal muscles.[5] This motor and motion loss increases foot-ankle complex stiffness thus increasing the susceptibility of plantar tissue to produce hyperkeratinization in a response to a mechanical stimulus leading to calosities and joint deformities that may become lesions in the future.[6,7] These changes on the normal architecture of a diabetic foot are frequently associated to the disarrangement of its supporting arches, promoting a collapse of the transverse and medial longitudinal arch (MLA) that can be the cause of a stronger pressure on the region of metatarsian head, leading to foot function loss.

Some direct and indirect methods for evaluating MLA have been mentioned in literature. Among the methods described, X-ray imaging is relatively expensive, and radiation causes some risks to the patient, factors that make its use in large scale studies difficult, but footprint method is fast, non-invasive and simple, providing an indirect measurement of the MLA, being also a cheap, risk-free and easy method.[8]

Forriol and Pascual[8] describe a way to classify MLA based on the calculation of one index: the Chippaux-Smirak Index (CSI).[9,10] For calculating it, a straight segment is drawn (A-A') between the medial edge of the footprint at the most medial ends of the metatarsal (Point A) and of the heel (Point A'), from the point A, the

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wider point of the metatarsals is drawn (point b) and a segment of parallel line is represented as the minimum width of the foot on the arch area (Line C). Both straight lines are measured dividing the shorter by the longer (c/b). The higher the index, the wider the arch and the flatter the MLA. (Figure 1) Clarke[11] describes another way to provide an indirect classification of MLA, called Footprint Angle or Alpha Angle (Angle A). For measuring this angle, another straight line is drawn between point A and the point corresponding to the acme of arch concavity. The angle between line A-A' and this second line segment is the Clarke footprint angle. (Figure 1) A small angle indicates a lower arch.

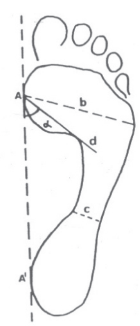

***Figure 1** - Footprint parameters for calculating longitudinal arch indexes: α: angle Â; c and b%: Chippaux-Smirak Index (CSI)*

Another form of arch classification is described by Cavanagh and Rodgers.[12] The authors classified the MLA using the proportion of one third of the footprint area by total foot area. The first mark was made at the center of the heel up to the second toe. This line was named "foot axis". A tangential line to the axis was made based on the most protuberant point of the metatarsals and an additional line at the same point on the heel. The line formed between intersection points between these lines and the axis is named *jk*. Then, this line was divided into three equal portions: forefoot, midfoot, and hindfoot. (Figure 2) These three areas are then measured with a planimeter and the area of the midfoot is divided by the total foot area except for the toes, thus providing the arch index. The higher the ratio value, the lower the MLA.
Upon this context, this study has the following purposes: to describe and compare the anthropometric characteristics of feet of adult healthy and diabetic subjects with neuropathies receiving care at the Diabetic Foot Outpatient facility at São Paulo University Hospital using three classification indexes for medial longitudinal arch, and; to compare the classification of three evaluation methods for plantar longitudinal arch in these groups: Arch Index based on Cavanagh and Rodgers[12], Chippaux-Smirak Index (CSI)[9,10] and Angle Â.[11]

MATERIALS AND METHODS

All subjects were informed about the experimental procedures submitted to and approved by the Committee of Education and Research of the local Institution, by signing a free and informed consent term.

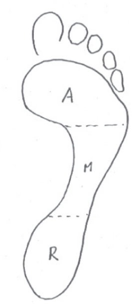

***Figure 2** - Parameters for calculating Arch Index. A= forefoot; M= midfoot; R= hindfoot (Iarch = M/A+M+R).*

The experimental sample was constituted of two adult volunteer groups composed by subjects of both sexes, up to the age of 65: control group (CG) and diabetic neuropathy group (DG). Control group (CG) was composed by 21 healthy individuals (7 males and 14 females). The Diabetic Neuropathy group (DG) was built with 46 diabetic patients (29 males and 17 females) with diabetic neuropathy, clinically diagnosed. Among the subjects of CG and DG, 44 Caucasians (65%), 13 African-Americans (20%) and 10 Asians (15%) were assessed. The inclusion criteria for the diabetic group were the following: type-1 or type-2 diabetic subjects with diabetic neuropathy first identified by their scores (above 2 points) on the baseline screening of patients receiving care at the Diabetic Foot Outpatient facility of the local Institution, up to 65 years old, without macroangiopathy, osteoarthrosis on lower limbs, no history of neurological, muscular or rheumatic diseases out of the diabetes etiology, no history of alcohol abuse or amputations up to metatarsian-phalangeal region. Also, X-ray studies were performed for ruling out Charcot arthropathy, a potential influencer of the longitudinal arch.
The experimental protocol was constituted of two phases: (1) in-person interview based on a questionnaire intended to investigate personal and diabetes data, as well as the characteristics of the neuropathy[13]; (2) bipodal footprint with bilateral distribution of load using a pedigraph.
From the footprint using a planimeter, the Plantar Arch Index was calculated according to Cavanagh and Rodgers.[12] Plantar arches were classified as follows: Iarch ≤ 0.21: high arch, 0.22 < Iarch < 0.26: normal arch, Iarch≥ 0.26: low arch. The Chippaux- Smirak Index (CSI)[9,10] was calculated, and five categories are employed for classifying arches: 0%: high arch foot; 0.1% - 29.9%: morphologically normal arched foot; 30% - 39.9%: intermediate foot; 40% - 44.9%: low arch foot; ≥ 45%: flat foot. Angle A' was indirectly measured, with feet showing angles between 0 and 29.9° are regarded as flat; 30° - 34.9°, as low; 35° - 41.9°, as intermediate, and, above 42°, feet are classified as cavus.
The core objective of the statistic study was to describe the populations in study, comparing control and diabetic groups. For describing the variables of the study, we employed: arithmetic average, median and standard deviation. After checking for data normality by the Shapiro Wilks test, we used the Mann Whitney's non-para-

metric test for comparing control and diabetic groups in terms of Arch Index, CSI, and Angle A, and the chi-squared non-parametric test for comparing both groups for each ordinal MLA classification (flat, normal, and cavus). A significance level of < 5% was adopted.

RESULTS

Table 1 describes the anthropometric and clinical data of diabetic patients with neuropathies and control subjects included in the study.

***Table 1** – Descriptive and clinical anthropometric characteristics of CG and DG, with mean and Standard Deviation values.*

Variables	CG (n=21)	DG (n=46)
Age (years)	53.3 ± 4.3	59.7 ± 8.2
Mass (kg)	70.8 ± 11.2	75.4 ± 14.8
Height (m)	1.6 ± 0.1	1.7 ± 0.1
BMI (kg/m^2)	25.4 ± 6.7	26.3 ± 4.1
Males (%)	33	63
Time elapsed since diagnosed with diabetes (years)	---	12.9 ± 8.3
Last glucose test (mg/dl)	---	176.5 ± 81.7

The diabetic neuropathy group showed a score median on the questionnaire proposed by Feldman et al.[13] in order to characterize and classify diabetic neuropathy severity as 7, and control group, as expected, as zero. Therefore, we can characterize the diabetic group as having an advanced form of neuropathy, with very important symptoms.

On Table 2, the percentages of subjects according to the classifications of Arch Index, CSI, Angle A for Control Group and Diabetic Group are presented.

Concerning Arch Index, control group presented a higher percentage (61.9%) of normal feet, with cavus feet accounting for 26.1% and flat feet for 11.9%. Concerning the same index, the diabetic group presented 44.9% of normal feet, a significantly higher number of flat feet (32.2%, p=0.0080) and a lower percentage of cavus feet (22.9%).

Concerning CSI, control group showed a higher percentage of normal feet (47.6%), a significantly lower number of flat feet compared to CG (45.2%, p=0.0000) and 7.2% of cavus feet. Concerning the diabetic group, a significantly higher number of flat feet was found (59.7%), followed by 40.3% of normal feet, and no cavus foot.

Concerning Angle A, we found that both CG and DG showed a higher percentage of cavus feet (90.4% and 68.7%, respectively), presenting with a statistically significant difference (p=0.0036). Normal feet accounted for 9.6% in control group and 13.8% in diabetic group, while flat feet accounted for 17.5% in the diabetic group.

DISCUSSION

Diabetic group subjects provided a large number of positive answers for primary symptoms of diabetic neuropathy on the questionnaire proposed by Feldman et al.[13], and, as described by Cavanagh et al.[14], a diabetic neuropathy patient presents with parestesia (tingling sensation) and pain more frequently evidenced at nighttime.

By the results achieved, for the three assessed indexes, a higher incidence of flat feet was found for the diabetic group when compared to the control group, while normal and cavus feet showed a reduced incidence in the diabetic group. At statistical comparison, we found that these differences were significant for Arch Index (p=0.0080) and for CSI (p=0.0000) on flat feet, and for Angle Â (p=0.0036) on cavus feet.

The foot is a highly-specialized structure, with enough resilience and smoothness to perform quite different functions, such as supporting major loads, absorbing strong impacts, promoting impulsion and deceleration, stabilizing, balancing, accommodating and sensitizing[15], being a target for almost all chronic complications to which a diabetic person is subjected, showing a strong potential to produce disability.

Both the increased number of flat feet by the Arch Index and by CSI and the reduced number of normal feet by Angle Â show the several bone and muscle changes resulting from diabetic neuropathy, which lead to diabetic foot disarrangement. Among the most common structural changes, we can highlight: claw toes associated to dorsiflexion of metatarsal-phalangeal joints due to the simultaneous contraction of flexor and extensor long muscles to offset atrophy.[16] Changes on the normal architecture of a diabetic foot is frequently associated to a disarrangement of its supporting arches as a result of the disarrangement on the intrinsic musculature of the foot especially due to the diabetic neuropathy motor component, promoting a collapse of the medial and cross-sectional longitudinal arch, which may cause a stronger pressure on metatarsian head region, leading to a reduced foot function.[6]

A foot's ability to change from a flexible to a stiff structure within a single step is dependant of the bone structure of the three foot arches, the static ligament-fascia support and of the dynamic muscle contraction, structures that, on a diabetic neuropathy subject are found to be largely changed.[17] Motor neuropathy produces a disarrangement on the intrinsic foot musculature, producing hyper pressure points on the plantar region (callosities) and deformities (claw toes, Charcot's foot, metatarsian head protuberances), which can potentially turn into lesions.[6]

Orthopaedic changes on diabetic feet involve both neuropathy and the loss of a protection feeling, concerning heavy load release

***Table 2** - Percentage of flat, normal and cavus feet for indexes studied in CG and DG, as well as p values.*

	Arch Index (%)			CSI (%)			Angle A (%)		
	GC	GD	p	GC	GD	p	GC	GD	p
(1) flat	11.9*	32.2*	0.0080*	45.2*	59.7*	0.0000*	0	17,5	-------
(2) normal	61.9	44.9	0.2578	47.6	40.3	0.1563	9,6	13,8	0,2841
(3) cavus	26.1	22.9	0.1172	7.2	0	------	90,4*	68,7*	0,0036*
	0.0027**			0.0064**			0.0296**		

*, ** represent statistically significant differences, chi-squared test for proportions and Mann Whitney test between CG and DG.

leading to the deformities seen in those patients.[18] Thus, motor neuropathies result in muscle unbalance, causing an abnormal stress on the affected end leading to mechanical and orthopaedic changes. Authors also stress that the lost motor neurons innervation on intrinsic feet muscles can change this load release dynamics, promoting joint instability, enabling these deformities to occur.[19] Typically, on a neuropathy patient, sudden or repeated overloads may induce fractures and dislocations that will ultimately lead to severe deformities.

As a result of the broad picture that has been described here, a diabetic neuropathy patient's foot is expected to present a different format compared to control subjects without such musculoskeletal and sensorial changes. These differences were found on the studied sample, with a statistically significant difference between diabetic and control groups for all reviewed indexes: Arch Index ($p=0.0027$), CSI ($p=0.0064$), Angle A ($p=0.0296$). Nevertheless, it is worthy to highlight that the studied samples showed an uneven n, and this fact could have compromised comparisons between the groups.

Still by the comparison performed here, we can suggest that only the AI and CSI could be quite reliable for anthropometric evaluations also in diabetic neuropathy patients, since the evaluation of Angle A strongly disagreed with the classification provided by the other two indexes. CSI and AI indexes are mentioned and validated by literature, but none of these had been used in patients with such characteristics so far.

CONCLUSION

Particularly, the arch indexes of Cavanagh and Rodgers and Chip-Paux-Smirak are strongly recommended methods in literature and used by professionals, showing to be valid for characterizing feet in the studied control and diabetic groups. Data analysis showed an increased number of flat feet in the diabetic group sample, while cavus feet behaved oppositely, with a larger number in control group. This fact shows the orthopaedic and functional changes resulting from diabetic neuropathy, responsible for musculoskeletal disarrangement of diabetic feet, mostly leading to medial longitudinal arch collapse, target of our study.

Studies with larger samples and similar both for healthy and diabetic neuropathy subjects should be conducted with the purpose of confirming the results achieved here. The X-ray study of foot bone structure could also be adopted as a previous data to the comparison of indexes for classifying the arch like other studies in literature.

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