COMPARASION OF FLAT FOOT EVOLUTION BETWEEN AGE GROUPS

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Abstract. *The vicious static of the flat foot (FF) has a significant impact on the general body posture. This study aimed to perform a comparative analysis of the biomechanical parameters of the FF, for a 37 FF subjects group, aged between 18 and 77 years. The 37 subjects, are divided in to 4 experimental groups (18-30yrs; 42-49yrs; 50-63yrs; 70-77yrs). The evaluation using the RSScan platform and the parameters are: contact area (CA) and the maximum force (Fmax) for plantar areas. The results show high values in all age groups, significantly increased for the CA: midfoot, heel, metatarsus 1, 2, 3, 5. Statistical analysis proves similar results for group 30-40 vs 18- 30 years and group 70-77 vs 18-30 years, thus for the right foot significant average increase of 9% for the area metatars1, 2 and 5, midfoot, heel and for the left foot an average growth of 12% for all CA. Group 70-77 vs 42-49 years shows us for the right foot as a significant average increase of 8% for midfoot and for the left foot an increase of 4% for the metatarsal areas 1-5. Group 70-77 vs 50-63 years shows for the right foot significant increase of 8% for the metatars1-5, midfoot areas and for the left foot 9% for metatars1 and 2 and midfoot areas. The results demonstrate importance of a complex assessment for FF and indicate a progressive static deformity of the foot, particularly in the metatars1-3, midfoot, heel area (CA increases progressively from younger to older people).*

Keywords: *Pes planus, Age, Gender, Plantar pressure, Pedobarography*

Introduction

The human foot has to endure the tasks of walking and locomotion through the whole life (Bosch et al., 2009). While walking, plantar pressure is generated while weight bearing is transferred to the supporting leg (Guet al., 2011; Chen et al., 2019; Fang, 2018). Plantar pressures represent a permanent concern due to the risk of foot deformity and as a source of pain (Mei et al. 2019). The plantar pressure patterns had been shown to be distorted in patients with peripheral neuropathy or foot deformity (Tong et al. 2011; Bus et al. 2005). Elderly patients with diabetes have demonstrated full time-pressure integral with higher values (Zhang and Qianyu, 2020). Multiple studies show that foot pain is reported on average in one by four elderly people (Thomas et al., 2011), this leads to a decrease in the ability to perform daily activities (Benvenuti et al., 1995) demonstrated by exacerbation of problems in balance and gait (Menz et al., 2005), and overall leads to a poor quality of life (Mickle et al., 2011). Static foot disorders with painful charges are the main limiting factor for movement in general in the elderly (Thomas et al., 2011) one by five elderly people consider that this is the main cause of their inability to move outdoors (White et al. al., 1989). The elderly who complains on foot pain are the main consumers of medical services: family doctor, orthopedics (Menz et al., 2010) and podiatry (Menz, 2008), the vast majority being treated in the end, surgically (Menz et al., 2008). Several risk factors for foot pain are identified, including age, female gender, obesity, chronic conditions such as diabetes and osteoarthritis, and inadequate footwear. (Thoolen et al., 2000). The biomechanical factors for the development of foot pain in the elderly have also been researched, with the help of technology that allows accurate assessment of gait pressures. This evaluation highlights the role of measuring plantar pressure both in monitoring but especially in the design of orthotic intervention as a device in the management of foot pain in this age group.

The plantar epidermis has several unique features that are related to the biomechanical requirements of gait but especially in weight bearing, it is considerably thicker (approx. 1.5 m, compared to 0.1 mm in other regions of the body) and demonstrates a ridge pattern that helps generate the friction needed while walking. Aging leads to changes in the plantar epidermis leading to increased hardness, loss of elasticity, leading to a predisposition to the development of hyperkeratosis, this being one of the main foot problems for the elderly. This hyperkeratosis leads to increased pressure on the nerves in the dermis. There are studies showing that plantar lesions form with predisposition in the elderly with hallux valgus, due to high plantar pressure and abnormally distributed. Considerable pressure under the metatarsal ends when walking has been shown to be 9-12% higher in the elderly with calluses in these places (Caselli et al., 1997).

These findings suggest that the management of hyperkeratosis in the elderly is necessary. Clinical studies show that only dermatological management of this condition is not sufficient to relieve pain (Landorf et al., 2013) and it has been shown that the use of foot orthoses in combination with dermatological management has a greater effect than single dermatological (Caselli et al., 1997). Deep plantar soft tissues anchor the dermis to the underlying bone architecture of the foot, protect the underlying blood vessels and nerves, and alleviate gait pressure. These tissues contain fat cells as a buffer and in the metatarsal bones, they vary in thickness from 9 to 14 mm and support a compression of up to 46% when walking (Cavanagh, 1993). As they age, they retain their thickness but lose their elasticity, disperse more energy when compressed, and recover more slowly after pressure is removed (Hsu et al., 2005) (Kwan et al., 2010). Similarly, the heel retains a thickness of 18–20 mm with age, but becomes stiffer and disperses more energy when compressed (Hsu et al., 1998). The ultrasound shows an increased rigidity of the heel, accompanied by an increase in thickness and a decrease in the echogenicity of the plantar fascia; this may be indicative of a physiological process of aging the plantar fascia itself or a side effect of the loss of elasticity of the heel (Cheng et al., 2014). It has been shown that in the elderly with pain in the forefoot and heel, the peak pressure under the lateral metatarsal ends is 10% higher than in the elderly without pain in the forefoot (Menz et al., 2012), (Mickle et al., 2010). It is likely that these differences are due not only to age-related changes in plantar soft tissues, but also to associated changes in the degree of altered movement in the subtalar joint, altered posture, and leg dynamics.

Regarding the flexibility of the ankle-foot joint and especially the flexibility of the subtalar joint in the elderly, several studies show a decrease of 12-30% (James et al., 1989) (Nitz et al., 2004). There are studies in the elderly that show, for the dorsiflexion movement of the metatarsal-phalangeal joint of the hallux, a decrease of 32% in the range of motion compared to younger people (Scott et al., 2007). Given the importance and role of the foot ankle joint, especially its adaptability regardless of the type of terrain on which it operates, whether flat or uneven, the reduced mobility of this joint is strongly associated with impaired balance and functional capacity in the elderly (Menz et. al, 2005); (Spink et al., 2011). Menz and the team demonstrate the correlation between low flexibility in the ankle and foot joint and an increased risk of imbalance and falls (Menz et al., 2006).

Fall injuries (imbalances) are a major cause of "unintended" injuries worldwide (Caldevilla et al., 2013), (Awale et al., 2017; Dellinger et al., 2006). People over the age of 65 are most prone to these types of accidents that can lead to death, hospitalization, disability, loss of independence. In addition, the fear of falling can lead to restricted activity and reduce daily functions (Baixinho et al., 2014). The economic costs of falls are substantial: medical care, social care (Herdman and Kamitsuru, 2014). Postural balance, body orientation reflexes, muscle strength and tone, pitch height, all decrease with age and make the elderly more susceptible to falls (Ahn et al., 2019). Research into fall prevention has increased over the last 10-15 years. A number of programs (eg, risk factor reduction, exercise, environmental change, and education) were tested, and a meta-analysis identified the effectiveness of several approaches (Bhasin et al., 2020).

Exercise recovery programs improve muscle strength, endurance and body mechanics and reduce falls (Sherrington et al., 2019). There is a need to create intervention programs to improve balance and muscle strength that can reduce the number of falls, restoring the quality of life in seniors (Weber et al., 2018). Several studies have investigated the effects of exercise using visual biofeedback as an intervention tool that can be used in balance rehabilitation (Alhasan et al., 2017). Combined balance and strength training, in which visual feedback is provided, is the ideal type of kinetic, treatment program that fully involves the patient during rehabilitation.

Exercise programs using the strength and pressure plate allow patients to check their positions and location of the center of gravity during postural changes (in real time), allowing patients to perceive the postural information used to control and maintain their posture (Lee et al., 2018). A summary of evidence from systematic reviews reports that combined balance and strength training is an effective method of improving postural balance following stroke (Arienti et al., 2019). Randomized controlled trials compare combined balance and strength training programs with conventional physical therapy and have reported benefits (Ghomashchi, 2014).

A study from 2014 correlates the reduction of the radius of movement at the level of the hindfoot and middle leg and the imbalance of the foot when walking, implicitly affecting the degree of taking the plantar shock (Giacomozzi et al., 2014).

The main feature with advancing age is the reduction of muscle mass, given both reductions in size and number of muscle fibers, developing large motor units with slow contraction (Doherty, 2003). There is also a progressive decrease in power with percentages between 20–40% in individuals aged between 30 and 80 years (Vandervoort, 2005). Changes in muscle tone due to age are evident in the lower limb compared to the upper limb and tend to degenerate from distal to proximal. The muscles of the foot are prone to age-related atrophy, a process that can also be exacerbated by long-term wear of inappropriate footwear.

Loss of leg muscle strength has several implications for the elderly. Decreased strength of the plantar flexors has been associated with difficulty getting up on the toes (mobility test - lifting on tiptoes) (Chimenti et al., 2014), this decrease affecting the statics of the foot when walking leading to damage balance, functional capacity (Menz et al., 2005) considerably increasing the risk of falling and injury (Menz et al., 2006), (Mickle et al., 2009). Atrophy associated with a reduction in the tone of the toe muscles plays a major role in deforming the forefoot (Stewart et al. 2013), (Mickle et al., 2011). Physical therapy should be considered as a basic treatment in the general approach to rehabilitation of elderly people with foot pain and has been shown to increase the strength and range of motion for the ankle complex (Schwenk et al., 2013).

The differences in kinematics between young and old show us for the elderly's foot a reduced mobility at the level of the middle and forefoot as well as a reduction of plantar flexion (Arnold et al., 2014). Evidence of age-related gait dynamics can be found in numerous studies of groups of patients of different ages (26–36 years) and (67–73 years), respectively, the researchers showing that the elderly group showed a tibial rotation (internal / external) significantly shorter, and a significantly shorter contact time with the ground for the forefoot compared to the younger group of patients (Fukuchi et al., 2008). These changes suggest that the elderly have a pronounced dynamic function of the foot, and this pattern is accompanied by reduced mobility of the ankle-foot joint.

Vicious foot posture (especially pronation of the foot) is associated with generalized foot pain, most common in the heel and middle foot for older men (Menz et al. 2013). The correlation between pronated foot function and foot pain is not fully understood, as flat foot simulation studies result in plantar fascia tension, amplification of movement in the talo-navicular joint, and increase in dorsal compressive strength at the level of the middle leg. leads to tissue damage and subsequent foot symptoms (Menz et al. 2013).

All of these studies argue for the usefulness of custom-made foot correctors, specially designed to support the longitudinal medial arch with an essential role in the management of foot pain in the elderly (Mulford et al., 2008), with the recommendation to use materials to ensure flexibility. , the elderly person's foot is already affected by the flexibility limitation.

With the development of technology, the ability to assess gait and implicitly plantar pressure provides information on the basic mechanisms that may be responsible for the development of static foot disorders but also for the design of orthotic therapeutic interventions such as custom orthopedic footwear or static correction orthoses. of the foot. A wide range of sensor technologies have been developed for this purpose (Orlin, et al., 2000).

We found studies evaluating the effectiveness of orthoses in reducing plantar pathological pressure, we evaluated the properties of calcaneus silicone cups, calcaneal insoles in the foot, calcaneal lifts (used in apophysites for pain reduction, in the management of the flat foot and in people with segmental length differences).) and prefabricated foot orthoses in the elderly with heel pain and prefabricated orthoses were found to have better efficiency, reducing heel pressure by 29% (Bonanno et al., 2011).

This reduction was accompanied by increases in force in the contact area for the middle leg, suggesting that redistribution of the load to the medial arch is a much more effective method of reducing calcaneal pressure than by simply calcaneal damping.

In a study of elderly people with pain in the forefoot, four types of corrective orthoses used to correct the forefoot were analyzed, and it was concluded that the most effective is the plantar orthosis for the transverse arch in the form of a "tear" with a 6 mm thick, its position being approximately 5 mm distal to the metatarsal ends, the pressure under the forefoot was significantly reduced by up to 19% (Lee et al., 2014).

All of these biomechanical findings suggest that custom orthoses are essential in the management of static foot problems and can be designed to reduce plantar pressures under specific regions of the foot.

The effectiveness of orthoses for the transverse plantar arch, in reducing the symptomatology of the foot was also evaluated by Kang et al. ani (Kang et al., 2006). The evaluation was performed over a period of 2 weeks, and a correlation was found in the gradual reduction of pressure and reduction of foot pain.

Another study found that using a foot orthosis to correct transverse and longitudinal arch for 4 weeks leads to a 47% reduction in plantar pressure in the forefoot and a reduction in forefoot pain by 86% for people. aged between 65-84 years. (Chang et al., 2014) [59]

We must also keep in mind that the relationship between the change in plantar pressure and symptoms is complex and is influenced by a number of factors and anthropometric parameters such as body mass and foot posture. (Najafi et al., 2014).

The purpose of this study is to perform a comparative analysis of the biomechanical parameters of the flat foot, on subjects aged between 18 and 77 years.

Material and Method:

Our study has 37 subjects, criteria for inclusion: age between 18 and 77 years, to have foot static problems, respectively diagnosis of flat foot, and criteria for exclusion: associated pathology (metatars adductus, neurological disorders or post-traumatic orthopedic sequelae).

All patients signed informed consent and the research is made under the rules of Declaration of Helsinki version 2013.

All subjects were divided into 4 experimental groups: Group 1: 18-30 years, Group 2: 42-49 years, Group 3: 50-63 years, Group 4: 70-77 years. Average age: 46 years, average weight: 74 kg, average height: 167cm, body mass index (BMI) average: 26.75. The evaluation of the biomechanical parameters of the flat foot was performed with the RS Scan pressure platform (Figure 1) and consisted of the evaluation in static stance (Figure 2) and dynamic gait (Figure 3), the platform providing complex data for the active contact area (CA) and of the maximum force (Fmax) for 10 areas of the foot (Figure 3) found in the following regions: medial heel, lateral heel, midfoot, toes, hallux, metatarsals.

Figure 1. RSSCAN platform

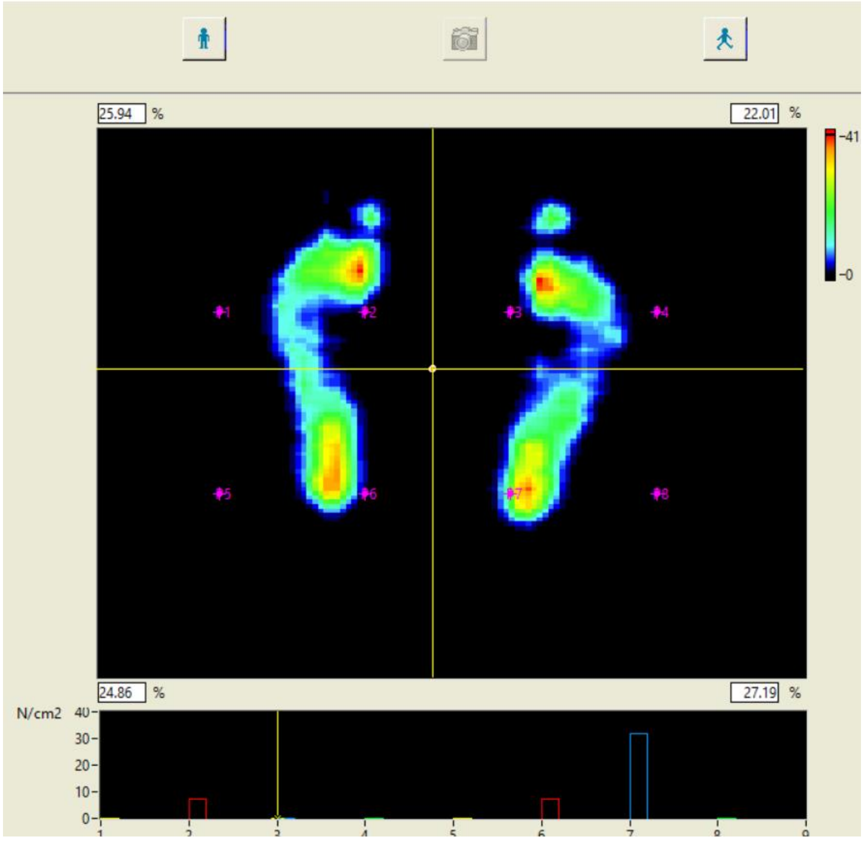

Figure 2. RSSCAN platform, static data

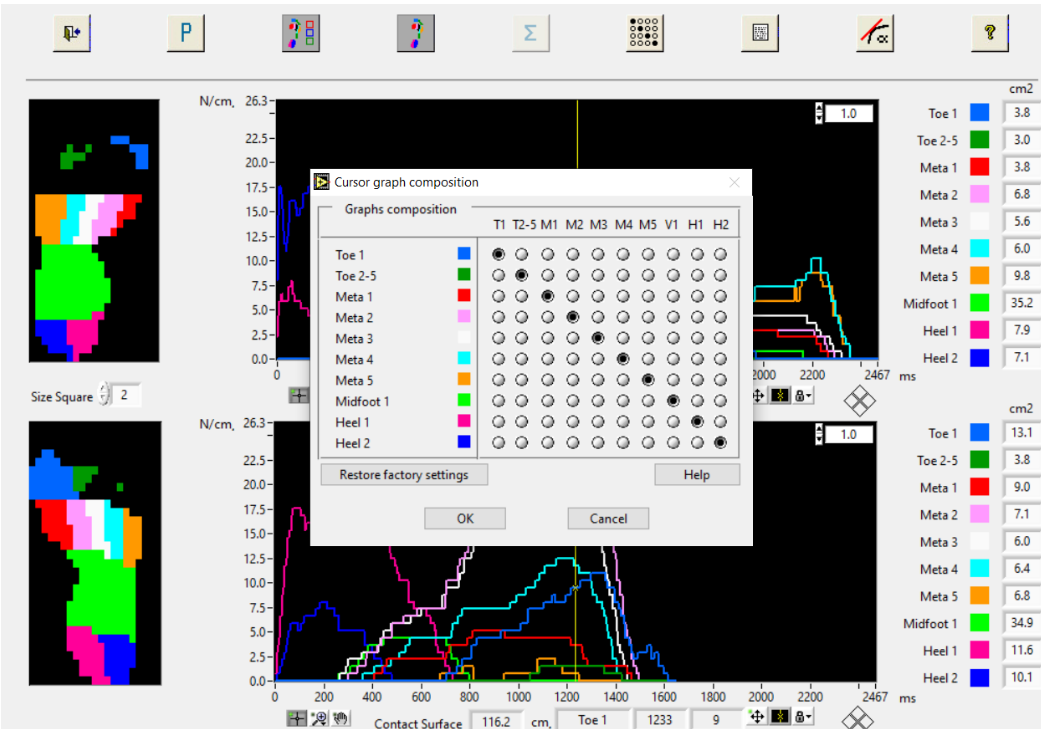

Figure 3. RSSCAN platform, dynamic data

Results

In the results of our study we observe in all age groups, higher average values in the following areas of contact: midfoot, heel, metatarsus 1, 2, 3, 5 (Figure 4 and Figure 5). The comparative analysis of the *contact areas in cm2* between the age groups 30-40 years vs 18-30 years shows us for the right leg (Figure 6) a significant average increase of 9% for the areas: metatarsus 1, 2 and 5, midfoot, medial heel, lateral heel and for the left foot (Figure 7) shows an average increase of 12% for all contact areas. The comparative analysis of the *contact areas in cm2* between the age groups 70-77 years vs 18-30 years shows us a significant average increase for left foot: (Figure 7) of 12% for the areas: midfoot, metatarsus 1, 2 and 5 and for right foot (Figure 6) average increase of 9% for the areas: metatarsus 1, 2, 3, 5, midfoot, medial heel, lateral heel. The comparative analysis of *the contact areas in cm2* between the age groups 70-77 years vs 42-49 years shows us for the right foot (Figure 6) a significant average increase of 8% for the midfoot area and for the left foot (Figure 7) a 4% increase for metatarsal areas 1, 2, 3, 4 and 5. Comparative analysis of *contact areas in cm2* between age groups 70-77 years vs 50-63 years shows us for the right foot (Figure 6) a significant increase 8% for metatarsal areas 1-5 and midfoot and for left leg (Figure 7) 9% for metatarsal areas 1 and 2 and midfoot.

The contact areas: midfoot, medial heel, toe1, metatarsus1-3, are the most requested contact areas in all age categories. It is also observed, a progressive load distribution from the youngest to the oldest groups, from the medial-forefoot area to the medial-hindfoot area, especially the areas - medial heel, metatarsus1 and midfoot (Figure 6 and figure 7). Midfoot area, is the most exposed area, being the area with the largest contact surface in all age categories. (Figure 6 and Figure 7). The comparative analysis (right and left foot) for metatarsal area 2 and 3 shows us similar values for all age groups.

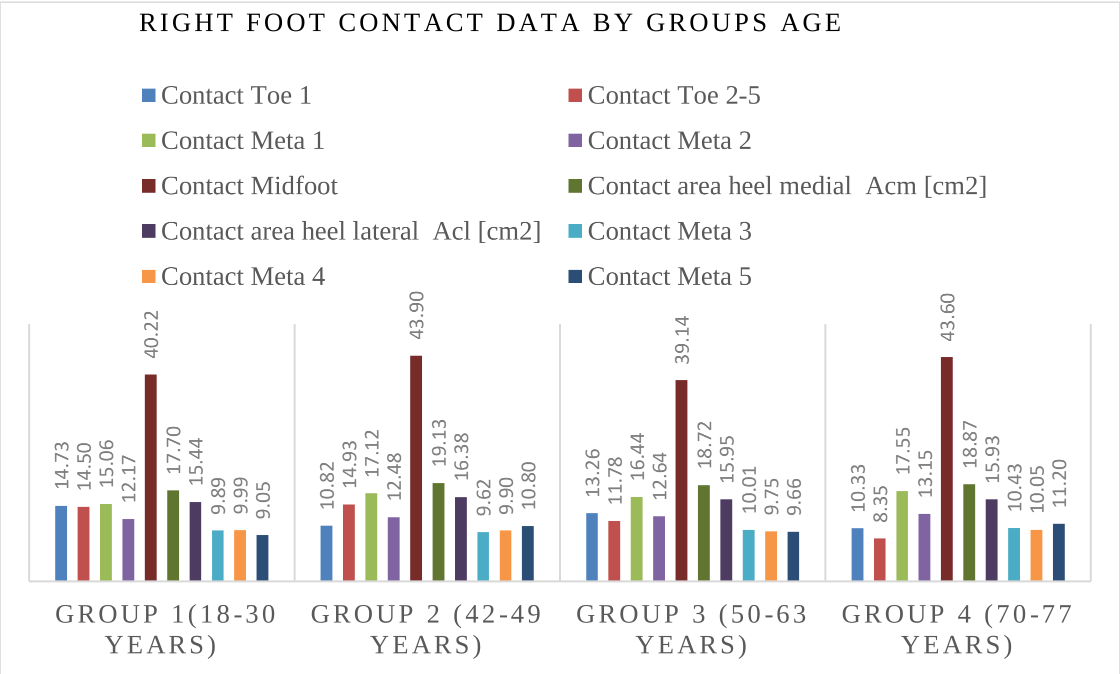

Figure.4 Right foot contact data by groups age

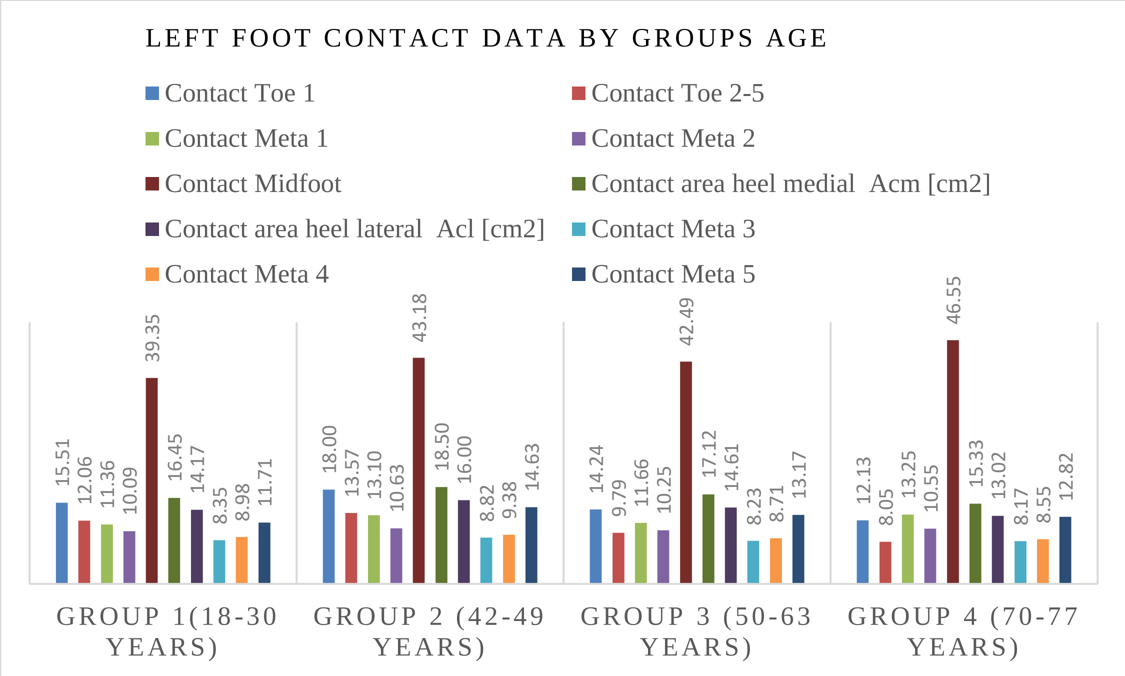

Figure.5 Left foot contact data by groups age

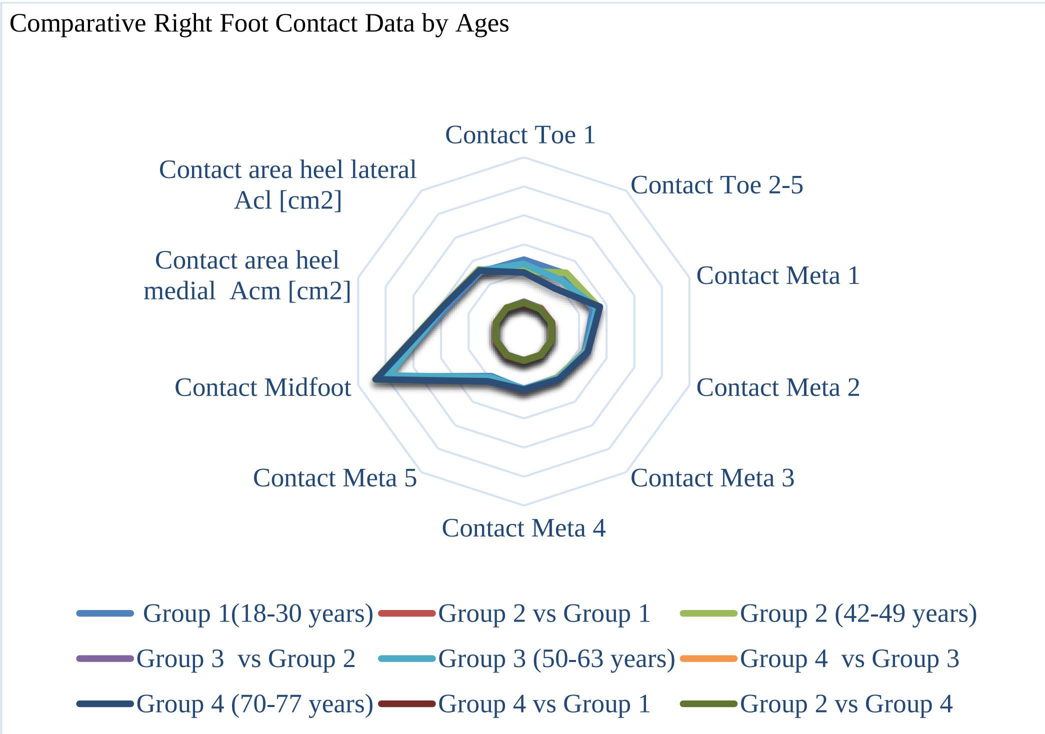

Figure 6. Comparative Right Foot Contact Data by Ages

Figure 7. Comparative Left Foot Contact Data by Ages

Discussions:

The results of our study are in according with the results of different authors that spoke about the correlation between age and the descent of the longitudinal plantar arch that this decrease may be normal in a physiological aging process. The lowering of the medial longitudinal arch associated with aging has implications for how the foot works during walking. Regarding the pathomechanics of the flat foot, we observe "exposed" metatarsal 2-3 contact areas in all age categories and without major changes from one age group to another.

Studies measuring the dynamic function of the foot by assessing plantar pressure during walking have shown a large medial displacement of the center of pressure for the elderly (Chiu et al. 2013), (Hagedorn et al., 2013). Scorza et. al. in their study demonstrates that the devices such as power plates are used to assess balance and gait and therefore provide information from a biomechanical point of view and highlight changes that directly affect the balance of posture and dynamics of an individual (Scorza et al., 2018).

This aspects are also in according with our results about the importance of make a complete evaluation and monitoring the evolution of flat foot for development the prevention program and limits the effects under the foot balance and limits the possibility of injuries.

The longitudinal medial arch of the foot demonstrates an important role in attenuating shocks and in generating propulsion during walking. There is a gradual decrease in the longitudinal medial arch starting at age 40, evidenced by an increase in the contact surface of the medial foot when walking (Staheli et al., 1987) and higher scores of the foot posture index (Redmond et al., 2008). This aspects are also in according with the results of our study. The cause of this longitudinal decrease in the longitudinal medial arch is insufficiently known. It is correlated with posterior tibialis muscle dysfunction, and the existence of a degenerative process of gradual weakening, elongation and rupture of the posterior tibialis muscle tendon, all of which are common causes in the acquisition of flat foot in the elderly (Kohls et al., 2004).

Conclusions:

The results of this comparative study demonstrate the importance of evaluating and monitoring this pathology. In the case of flat foot, the evaluation and monitoring of its evolution associated with early, complex, personalized therapeutic intervention can prevent the development of associated pathologies and segmental deformations caused by the vicious statics of flat feet. A permanent management of this pathology is recommended, with physical therapy as essential elements in the treatment scheme. The analysis of the results indicates a progressive static deformation of the foot, particularly in the metatarsian area 1, 2 and 3, midfoot area and medial and lateral heel area (in the case of the heel, the total contact surface increases progressively from the young age group to the elderly).

The originality of the study consists in the analysis of flat foot by age categories: 18 to 77 years, we find few studies that include such an analysis.

Our analysis is limited by the number of evaluation sessions, we have to follow further in 2-3 evaluations the differences in the contact areas between the 4 age groups. In the evaluation, the level of physical activity was not taken into account and different groups can be made depending on this indicator. Future research should focus on the role of therapeutic interventions in the management of the flat foot (kinesitherapy, orthotics, lifestyle changes).

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