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Abstract: Background: Menopause is associated with a decrease in fat free mass and an increase in fat mass. Sarcopenic obesity is more strongly associated with physical limitations than either obesity or sarcopenia and their effect in plantar pressure is not known. Consequently, the scope of the present study is to examine the effect of obesity and sarcopenic obesity in plantar pressure of postmenopausal women, during walking.
Methods: Body composition and biomechanics parameters of plantar pressure were assessed in 239 women.
Findings: Compared to non obese and non sarcopenic women, obese postmenopausal women have higher: peak pressure in the metatarsal areas 1, 4, 5, midfoot and HL; absolute impulses in all metatarsal and heel areas; metatarsals 4 and 5 relative first contact. On the other hand, sarcopenic obese postmenopausal women presented higher peak pressure and absolute impulses under all metatarsal areas, midfoot and heels.
Interpretation: The pressure increase found in different foot areas of obese and particularly in sarcopenic obese can cause discomfort and pain in the foot deriving an irregular movement, which may cause injuries in the soft tissues. Sarcopenic obese postmenopausal women also present a higher loading during the stance phase comparing with non sarcopenic non obese denoting frailty susceptibility related to both obesity and sarcopenia fact that might limit their basic daily activity tasks, such as walking.

CONFLICT OF INTEREST STATEMENT

Dear Editor of the journal *Clinical Biomechanics*

In the name of the authors of the manuscript **"Influence of obesity and sarcopenic obesity in plantar pressure of postmenopausal women"** I declare that we do not have any financial or personal relationship with other people or organizations that could have inappropriately influenced this study.

Sincerely yours,

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*** Cover Letter**

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Dear Editor of the journal Clinical Biomechanics

In the name of the authors of the manuscript **"Influence of obesity and sarcopenic obesity in plantar pressure of postmenopausal women"** I declare that the material within has not been and will not be submitted for publication elsewhere except as an abstract, authors do not have any commercial relationship that might lead to a conflict of interests, and finally, all authors were fully involved in the study and preparation of the manuscript, each of the authors has read and concurs with the content in the final manuscript.

Sincerely yours,

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Influence of obesity and sarcopenic obesity in plantar pressure of postmenopausal women

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Influence of obesity and sarcopenic obesity in plantar pressure of postmenopausal women

ABSTRACT

Background: Menopause is associated with a decrease in fat free mass and an increase in fat mass. Sarcopenic obesity is more strongly associated with physical limitations than either obesity or sarcopenia and their effect in plantar pressure is not known. Consequently, the scope of the present study is to examine the effect of obesity and sarcopenic obesity in plantar pressure of postmenopausal women, during walking.

Methods: Body composition and biomechanics parameters of plantar pressure were assessed in 239 women.

Findings: Compared to non obese and non sarcopenic women, obese postmenopausal women have higher: peak pressure in the metatarsal areas 1, 4, 5, midfoot and HL; absolute impulses in all metatarsal and heel areas; metatarsals 4 and 5 relative first contact. On the other hand, sarcopenic obese postmenopausal women presented higher peak pressure and absolute impulses under all metatarsal areas, midfoot and heels.

Interpretation: The pressure increase found in different foot areas of obese and particularly in sarcopenic obese can cause discomfort and pain in the foot deriving an irregular movement, which may cause injuries in the soft tissues. Sarcopenic obese postmenopausal women also present a higher loading during the stance phase comparing with non sarcopenic non obese denoting frailty susceptibility related to both obesity and sarcopenia fact that might limit their basic daily activity tasks, such as walking.

Key words: locomotion, foot biomechanics, body composition, menopause.

1. Introduction

Menopause is associated with modifications in body composition components like a decrease in fat free mass and an increase in fat mass (Aubertin-Leheudre et al., 2005). Obesity is the major health problem with an increasing incidence in many parts of the world and among numerous other medical conditions, a high incidence of osteoarthritis, painful feet, and symptomatic complaints in the joints of the lower extremities are frequently reported for overweight people (Teh et al., 2006). Beginning in mid life, ageing is associated with a time dependent loss of muscle mass (sarcopenia) that is a major cause of disability, frailty and loss of independence (Dorrens and Rennie, 2003). Nevertheless, the sarcopenic obesity is more strongly associated with physical limitations as walking disorder and disability, than either obesity or sarcopenia (Baumgartner, 2005).

In a general way an active lifestyle is associated with the maintenance and improvement of the body composition in postmenopausal women (PW) (Aubertin-Leheudre et al., 2005). Walking has proved an increasing interest in the promotion of well-being and health, being the most common activity among adults, suitable to decrease the risk of hip fracture in PW (Feskanich et al., 2002).

In the biped locomotion, the foot becomes an essential study object in the control of this way of locomotion as a result of its location and associated locomotory functions (Eils et al., 2004) and also to understand the adaptations performed during the walking and consequently the difficulty to make it, namely those related to discomfort and pain in the lower extremity. An unsuitable force distribution caused by obesity, sarcopenia or both of them may lead to an irregular movement, particularly during the stance phase, which will cause an excessive stress and injuries in the soft tissues (Abboud, 2002).

Plantar pressure analyses may provide additional insights into the etiology of pain and lower extremities complaints (De Cock et al., 2005) detecting deviant foot biomechanics, that can be associated with obesity and/or sarcopenia or be potential determinants of the gait disability in PW, particularly concerning temporal aspects of foot unroll and local (over)loading of the plantar surface. Few studies have addressed the gait characteristics of obese adults (Hills et al., 2001, Gravante et al., 2003, Birtane and Tuna, 2004, Teh et al., 2006) and as far as we know no study was made about gait characteristics of sarcopenic and sarcopenic obese PW. Therefore the present study is the first to provide an objective summary of the foot biomechanics plantar pressure data in PW with obesity and sarcopenic obesity and which have completed the walking protocol.

2. Methods

2.1 Subjects

The sample was composed by 239 PW (age, 57.4 ± 6.6 years; height, 155.1 ± 5.1 cm and weight, 69.2 ± 11.2 kg). Before testing, all subjects visited a physician for a comprehensive injury history, in order to verify the inclusion criteria, and register some variables that must be under control of the investigator (Willems et al., 2005, Hills et al., 2001, Birtane and Tuna, 2004), such as absence of: (1) acute foot pain and deformities, (2) severe lower extremity trauma, (3) lower extremity surgery like prosthesis operations of the hip, knee, ankle or foot, (4) leg length discrepancies, (5) cooperation problems, including eye, ear or cognitive disorders, and (6) diabetes related peripheral neuropathy. None of the women had premature menopause (NAMS, 2008).

This subset is part of the study “*Shape up during Menopause*” wich is a program that aims to develop exercise and health promotion in a group of PW. The program is developed by the University of Trás-os-Montes and Alto Douro, in partnership with the Vila Real health sub-Region and with the Portuguese Institute of Sport. The sample was collected in the Vila Real County, between the months of November 2005 and March 2006, through different advertising means, like regional newspapers, leaflets, posters, internet, among others.

The study was performed in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the University of Trás-os-Montes and Alto Douro. All subjects signed an informed consent form.

2.2 Instrumentation/Procedures

Weight (W), skeletal muscle (SM) and fat free mass were evaluated by octapolar bioimpedance spectroscopy analyzer (InBody 720, Biospace, Korea) and height (H) with the stadiometer seca 220 (Hamburg, Germany). Measurements were performed by the same technician in the morning and following a standard methodology (Chumlea and Sun, 2005, Heyward and Wagner, 2004). Technical errors of variables were determined by two repeated measures, in a subgroup of ten postmenopausal women (W, 0.06 kg; SM, 0.21 kg; free fat mass, 0.20 kg; H, 0.09 cm).

The cut-off point for obesity using the body mass index ($BMI=W/H^2$) was 25.5 kg/m^2 (Sardinha and Teixeira, 2000) and skeletal muscle mass index (SMI = SM/W x 100) was calculated resorting to the formula proposed by Janssen et al. (2002). Sarcopenia was assumed in subjects whose SMI was equal or inferior than -one standard deviation above the sex-specific mean for young adults (aged 18-39). Based on the combination of obesity and sarcopenia cutoff points, subjects were further classified into three groups: non obese - non sarcopenic (NO-NS, n= 50), obese - non sarcopenic (O-NS, n=167) and sarcopenic-obese (S-O, n= 22). None of the participants was non obese-sarcopenic. Obesity classification was based in the BMI and not in the %FM because the InBody 720 validity is still not entirely clarified in the literature (Medici et al., 2005, Gibson et al., 2008, Völgyi et al., 2008).

A footscan pressure plate (1m × 0.4 m, 8192 sensors, 253 Hz, RSscan International, Lammerdries, Belgium) was used and for each trial, a footprint was obtained, based on the peak pressure, being divided according to the predefined geometric criteria in ten anatomical pressure areas with the scalable mask automatically provided (Footscan software 7.1, RSscan international) under supervision of the researcher. These areas (Figure 1) were: medial and lateral heel (HM, HL), metatarsal areas (M1, M2, M3, M4, M5), midfoot (MF), hallux (T1) and the foot toes (T2-5).

- Insert Figure 1 –

Subjects were allowed a period of 10 min where they could practice walking at a self selected speed over the pressure platform. We didn’t control de gait velocity because although a prescribed walking speed might help to compare the pressure patterns of different subjects it would prevent the generation of a natural walking pattern. On the other hand the use of a metronome may cause an unnatural stride (Rosenbaum and Becker, 1997).

Each subject was tested using the 2-step protocol (Bus and Lange, 2005) and were instructed to walk until the end of the walkway (9 m), after the platform contact (3-4 steps). Three to five repeated trials (Bus and Lange, 2005) were collected by subject. A trial was discarded if the stance duration was higher than ±5% of that participant average stance duration (Lay et al., 2006, Gabriel et al., 2008), if the foot contact with the pressure platform was incomplete, or if the participant targeted the platform.

To evaluate the trial-to-trial consistency, intra class correlations (ICC) between five trials were calculated (Duhamel et al., 2004) in a sample group of 50 postmenopausal women. In agreement with Wearing et al. (Wearing et al., 1999) 0.75 and 0.90 were set as limits for a good to very good reliability of the measurements.

2.3 Data analysis

Absolute and relative temporal data (i.e. instants on which the regions make contact and instants on which the regions end foot contact; *FFC - first foot contact*, instant the foot made first contact with the pressure platform; *TCT- total foot contact time*; *FMC- first metatarsal contact*, instant when one of the metatarsal heads contacted the pressure platform; *FFF- forefoot flat*, the first instant all metatarsal heads made contact with the pressure platform; *HO- heel off*, instant the heel region lost contact with the pressure platform and; *LFC- last foot contact*, last contact of the foot on the platform), peak pressure data, absolute impulses (mean pressure × loaded contact time) and relative impulses (absolute impulse×100/sum of all impulses) were calculated for all ten regions (Willems et al., 2005). Total foot contact (absolute and relative) was divided into four phases (Figure 2): initial contact phase (ICP; FFC → FMC), forefoot contact phase (FFCP; FMC → FFF), foot flat phase (FFP; FFF→ HO) and forefoot push off phase (FFPOP; HO→ LFC).

- Insert Figure 2 –

Two medio-lateral impulse ratios were calculated for each subject (Ratio 1=[*(*HM+M1+M2*)*−*(*HL+M4+M5*)*]/sum of absolute impulse underneath all areas; Ratio

2=(M1−M5)/sum of absolute impulse underneath all metatarsal heads). Ratio 1 describes the impulse distribution in the whole foot and ratio 2 the impulse distribution in the forefoot.

Dynamic arch index was calculated resorting to the peak pressure footprint (Figure 3) as the summed footprint without the toes divided into three equal parts, calculated as the ratio of the midfoot contact area to the total contact area (De Cock et al., 2006).

- Insert Figure 3 –

2.4 Sample size

The study was designed to have a desired minimum power for the statistical tests of 0.80, with an effect size of 0.40 at the 0.05 level of significance. The minimum number of subjects required for each group was determined to be twenty two. However, it must be reminded that this study is an observational and not a randomized study.

2.5 Statistical analysis

Statistical analysis was developed with the SPSS program (version 16.0, SPSS Inc, Chicago, Illinois) and 5% of statistical significance was established. Data was expressed in average ± standard deviation and we proceeded to the comparison of the variables average between the three groups through the *ANOVA* or Kruskal-Wallis test. After identifying differences in Kruskal Wallis, Mann-Witney test was used for all the possible pairwise comparisons. Because we have three pairwise comparisons, it was needed to consider the chance of type I error. To protect against this error we used *Bonferroni correction*. This involved dividing the desired level of significance by the number of comparisons (level of significance/ number of groups). For a comparison to be considered significant, it must have a significance level of .017, not .05.

3. Results

Intra class correlation coefficients for peak pressure and absolute impulses are given in Table 1.

- Insert Table 1 –

All variables had an average ICC above 0.75 (except for absolute impulses in toe 2-5, 0.68). The highest ICC coefficients were found for HM and HL and the lowest ICC values for the Toe 2-5 and the M5.

Sarcopenic obese PW (Table 2) have higher values ($p \leq 0.01$) of weight and BMI than their counterparts but lower height and SMI. In free fat mass and SM only differences ($p \leq 0.01$) between NO-NS and O-NS ($p \leq 0.01$) were identified, with the O-NS women showing higher levels.

- Insert Table 2 –

Comparing to the NO-NS and O-NS groups, S-O women showed higher maximal peak pressure values in the Midfoot, higher absolute impulses in the Heel (HM and HL) metatarsals M2-M5 and Midfoot. In this last region relative impulses are also higher in the S-O group ($p < 0.01$). The combination of excess fat with reduced muscle mass induces in this women (comparing to the NO-NS, $p \leq 0.05$), higher maximal peak pressures in every metatarsals, both heel areas (HM e HL) and prominent levels of absolute impulses in metatarsal 1.

In the absence of sarcopenia, obese women present higher maximal peak pressures and absolute impulses ($p \leq 0.01$) in the level MF, HL and M1, 4 and 5. Absolute impulses in the metatarsals 2 and 3 and the relative impulses at the MF level, also tend to be more relevant ($p=0.00$) in these women, denoting a reduction in the relative impulse in the T1 area.

- Insert Table 3 –

Obese sarcopenic PW have a longer ($p \leq 0.01$) total contact time than the NO-NS group (Table 4). In FMC differences were identified ($p \leq 0.01$) for the same groups, although in FMC% differences ($p \leq 0.01$) were seen between all groups with S-O women presenting a later FMC. In HO and HO% differences ($p \leq 0.01$) were registered, with S-O denoting a later heel off, comparing to the NO-NS.

In what concerns the phases, ICP and ICP% is later ($p \leq 0.01$) for NO-NS women, FFP and FFP% is longer ($p \leq 0.01$) for S-O women and the same happened in FFPOP%.

In the first contact time differences in the variables M4 ($p \leq 0.01$), M5 ($p \leq 0.017$) and MF ($p \leq 0.01$) were identified, with the NO-NS presenting higher contact time than the S-O group. Eventhough in relative first contact time NO-NS presented higher values ($p \leq 0.01$) for M1, M2, M3, M4, M5 and MF. In the end contact variables, differences ($p \leq 0.01$) and T2-5 ($p \leq 0.017$) were observed between groups in all of them, namely with S-O showing a later end contact than the NO-NS group. As for the relative end contact variables differences were essentially observed between the S-O group and the O-NS that presented a later relative end contact.

- Insert Table 4 –

4. Discussion

In our study cohort of PW it was denoted a high incidence of obesity (189/239) although only 22 subjects had sarcopenia I (SMI within -one to -two standard deviations of young adult values) and none presented sarcopenia II, perhaps due to the relatively young adult sample (Janssen et al., 2002, Rolland and Vellas, 2009).

In the obese non sarcopenic PW the plantar pressure during natural walking differ from the non O-NS group. In a general way the absolute loading on the plantar surface of O-NS is higher. In the S-O group these deviant characteristics are even clearer. Although they don't represent a "frailty syndrome" or a "frailty phenotype" (Fried et al., 2001) PW with sarcopenic obesity are more likely to report subsequent functional fitness disability (Moreira et al., 2008) and reveal a process of "fat and muscle mass tissue aggravation condition" as we pass from the healthier group (NO-NS) to the unhealthier group (S-O).

Our results demonstrate that the O-NS group of PW had a lower SMI comparing to non O-NS and BMI aggravated when combined with sarcopenia, which might place sarcopenic obesity PW at risk of functional impairment and disability (Zoico et al., 2004) as a result of repetitive loading on the feet and other parts of the lower extremity (Hills et al., 2001) and a frailty condition as a consequence of lower muscle mass and quality (Cesari et al., 2006), comparing with both NO-NS and O-NS groups.

When we compared the ten anatomical areas, in the three groups of PW, our results demonstrate that the gait of PW that are obese without the presence of sarcopenia (comparing to NO-NS) have distinctive characteristics. These can be summarized as follows: (1) higher peak pressure values under the (M1, M4 and M5) metatarsal areas, midfoot and HL, (2) higher loading of absolute impulses underneath all the metatarsal areas (M1, M2, M3, M4 and M5), midfoot and heel (HM and HL), (3) lower relative impulse underneath T1 and higher underneath HM, (4) a higher relative first contact in

M4 and M5, (5) diminished relative first contact time in M4 and M5, (6) higher FFP and FFP%, and finally (7) lower FMC% and ICP%.

The gait characteristics are worsened when the obesity is combined with sarcopenia, namely (comparing to NO-NS): (1) higher peak pressure values under the (M1, M2, M3, M4 and M5) metatarsal areas, midfoot and heels (HM and HL), (2) higher loading of absolute impulses underneath all the metatarsal areas (M1, M2, M3, M4 and M5), midfoot and heel (HM and HL), (3) lower relative impulse underneath T1 and higher underneath HM, (4) higher relative first contact in M5, (5) diminished, first contact in M4, M5 and MF and relative first contact in all the metatarsal areas (M1, M2, M3, M4 and M5) and midfoot, (6) higher end contact in all the metatarsal areas (M1, M2, M3, M4 and M5), midfoot and heel (HM and HL) and a higher relative end contact in the metatarsal areas (M2, M3 and M4), (7) lower FMC, FMC%, ICP, ICP%, FFP% and FFPOP%, and finally (8) higher FFP and TCT.

Data from the present study also show that the obese sarcopenic group of PW presented higher absolute and relative loading impulses than the O-NS. Previous results are in agreement with Hills et al (Hills et al., 2001) who reported a clear higher peak pressure under the heel, midfoot and metatarsal areas in obese subjects. In our sample the same has happened with midfoot, where the peak pressure was higher and an additional aggravation was notorious with the S-O group. Those facts might be due both to affected midfoot through mechanisms of adaptation to weight bearing vertical force acting in the plantar arch due to obesity (Birtane and Tuna, 2004) and physical disability as a consequence of sarcopenia (Roubenoff, 2000).

The midfoot loading is higher in peak pressure and absolute impulse in the presence of combined obesity and sarcopenia, presumably because of the greater body weight acting both statically (during stance) and dynamically (during foot unroll in walking) on the longitudinal foot arch, it is interesting to see that dynamic arch index does not differ between groups. It seems that in a functional manner there is an effective loading although it is not detected by dynamic arch index. Although structure modification is not observed, an overload on those anatomical areas exists. A relative larger midfoot contact area could mask the higher plantar loading in obesity and sarcopenia, but this is not the case.

We divided the heel in two areas (medial and lateral) that conferred more precision to the analyses, and only in the HL differences were observed denoting a laterally pressure distribution either in the presence of sarcopenic obesity or obesity only placing those women at risk of discomfort and pain in the lower extremity causing an altered gait pattern in an attempt to avoid or minimize discomfort. In the metatarsal areas we didn't find exactly the same results that Hills et al (Hills et al., 2001) reported, because differences were only apparent in M1, M4 and M5. The loading from plantar impulses in the O-NS and S-O groups were significantly higher in our study. In O-NS and S-O the absolute impulse was higher in every area except for T1 and T2-5, comparing with NO-NS group, suggesting that the increase in the time loading is not contributing to the higher impulse.

In S-O women the absolute impulses loading is not significantly different in toes and therefore physical activity and rehabilitation programs should focus on other anatomical areas of the foot. In the relative impulse differences were only registered between NO-NS and the O-NS group, with the second denoting greater loads in T1 and midfoot. These findings are consistent with the notion that due to a higher BMI the efficiency of the locomotor pattern is affected (Schrager et al., 2007). The two medio-lateral impulse ratios in our sample demonstrate that impulse distribution is not significantly lateralized in foot loading transport and support broad and particularly in the metatarsal area. The lack of differences might be explained by the fact that the ratios were calculated considering absolute impulse per total foot rollover contact, differing from the study of Willems (Willems et al., 2005) where the ratios were calculated considering pressure values at five instants for phases of foot rollover contact.

Sarcopenic obese group displayed a significant later relative end time in all considered areas (toes, metatarsals, midfoot and heels), comparing to NO-NS group and these differences were consistent with a diminished relative first contact time in M4 and M5 metatarsal areas and in midfoot. In the same way, total contact time and HO was longer and FMC occurred later in S-O, compared to NO-NS women. These facts indicate that relative stance phase in these areas is higher in S-O comparing to NO-NS, possibly because S-O are more susceptible to frailty due to the amount of adiposity and poor muscle quality (Villareal et al., 2004) conditioning their basic daily activity tasks (Villareal et al., 2005) like walking. Knowing that sarcopenia is a process of muscle loss related to age, even without the presence of a clinical condition (Newman et al., 2003) our findings are consistent with Scott et al (Scott et al., 2007) who emphasize an age related difference in foot pressure patterns.

Our findings need to be interpreted in the light of certain study limitations. The first issue is the absence of sarcopenic PW without obesity, which limited our research and conclusions, a second issue is the lack of PW with sarcopenia 2 that might be the consequence of the relatively young adult sample in our study.

Additional studies should consider the influence of the menopause features like hormone therapy, nature and time of menopause and its relation with frailty. Research on the biomechanic parameters of plantar pressure in PW must also consider other walking velocities besides normal cadence, since velocity can influence plantar pressure (Burnfield et al., 2004), other slopes further than level walking, because walking slope can influence plantar pressure (Lay et al., 2006), foot structural and postural characteristics complementary to the study examine, because foot structural and postural characteristics can influence plantar pressure (Razeghi and Batt, 2002) and finally, prospective studies of related risk factor of falling in this population and the relation of the aforementioned parameters shall be done.

5. Conclusions

This study is the first to examine the effect of obesity solely and the combined effect of obesity and sarcopenia in PW plantar pressure. Our data suggest that sarcopenic obesity affects the plantar pressure during normal walking in PW. Namely, S-O PW exhibit higher plantar pressure during walking comparing to NO-NS. The highest pressure increases in S-O were found in the metatarsal areas, midfoot and heels. This overload can cause discomfort and pain in the foot deriving an irregular movement, which may cause injuries in the soft tissues and muscle. Sarcopenic obese PW also displayed a higher stance phase comparing with NO-NS denoting frailty susceptibility due to both obesity and poor muscle quality, facts that might limit their basic daily activity tasks, such as walking.

Our finding seems clinically relevant. The observed changes in the plantar pressure of obese sarcopenic PW may indirectly be the cause of many painful symptoms in the lumbar spine and pelvic region, since women tend to adopt abnormal defensive compensatory standing and walking attitudes.

For the professionals that deal with the prevention of muscle skeletal injuries in the physical activity these findings have implications for pain and discomfort in the lower extremity in the sarcopenic obese PW. In particular, professionals must take into account that the walking ability may be affected, posing difficulties to participation in activities of daily living.

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Suggested Reviewers:

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Taking into account the quality of the work done in biomechanics related to exercise and health using plantar pressures parameters with a strong scientific contribution for the state of the art in that field of knowledge, we suggest him as a reviewer

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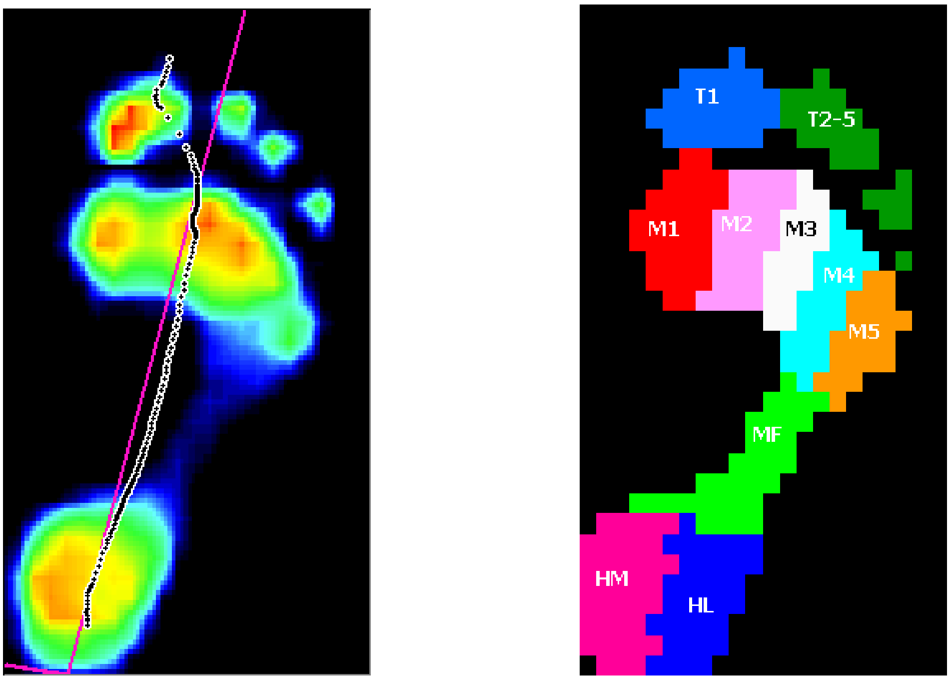
Taking into account the quality of the work done in biomechanics, namely in the foot biomechanics during human locomotion, with a strong scientific contribution for the state of the art in that field of knowledge, we suggest him as a reviewer.

Figure(s)



a b

Figure 1. Peak pressure footprint (a) with the location of ten anatomical important areas (b) (Footscan Software 7.1, RSscan International).

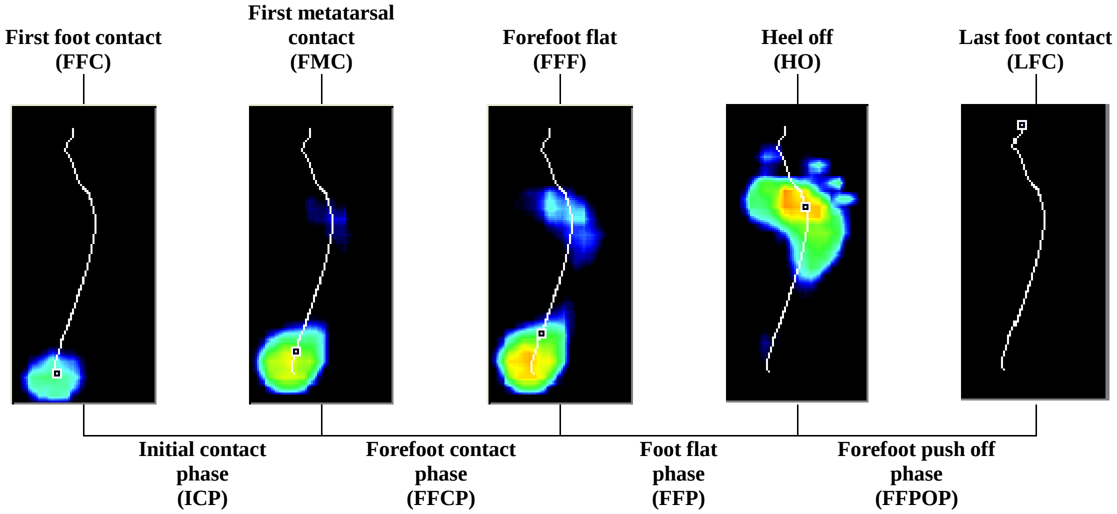
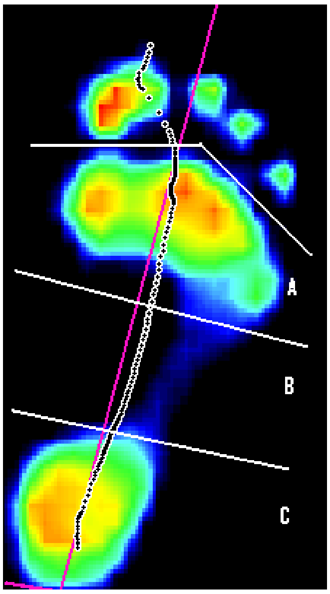


Figure 2. Five distinct instants and phases relative to total foot contact.



$$AI=B/(A+B+C)$$

Figure 3. The summed footprint without the toes is divided into three equal parts. Dynamic arch index (AI) is calculated as a ratio of the midfoot area (B) to the total foot contact area (A+B+C).

Table 1
Intra class correlation (ICC) values of peak pressure and absolute impulse of ten anatomical areas (HM, medial heel; HL, lateral heel M1-5, metatarsal areas; MF, midfoot, T1, hallux; T2-5, foot toes)

n = 50	Peak Pressure (N/cm^2)	Absolute Impulse (Ns/cm^2)
T1	0.95	0.90
T2-5	0.89	0.68
M1	0.94	0.89
M2	0.97	0.95
M3	0.98	0.96
M4	0.95	0.90
M5	0.85	0.75
MF	0.93	0.92
HM	0.99	0.97
HL	0.99	0.97

Table 2

Sample description (mean and standard deviation) according to the considered groups.

	Non obese Non sarcopenic (n= 50)	Obese Non sarcopenic (n= 167)	Sarcopenic Obese (n= 22)	Kruskal-Wallis Significance	Mann-Witney
Age (years)	56.34 ± 5.38	57.53 ± 6.75	58.39 ± 7.67	0.56	
Weight (kg)	57.02 ± 6.26	70.82 ±8.62	84.05 ± 11.46	0.00	a*↑, b*↑, c*↑
Height (cm)	156.64 ± 6.38	155.01 ± 4.65	151.97 ± 4.04	0.01	a*↓, b*↓, c*↓
Body mass índex (kg/m^2)	23.16 ± 1.59	29.58 ± 3.20	36.37 ± 3.80	0.00	a*↑, b*↑, c*↑
Fat-free mass (kg)	39.05 ± 4.91	41.67 ± 4.28	41.37 ± 5.44	0.00	a*↑
Skeletal muscle mass (kg)	21.06 ± 2.95	22.74 ± 2.61	22.45 ± 3.23	0.00	a*↑
Skeletal muscle mass índex (%)	36.94 ± 3.11	32.23 ± 2.50	26.68 ± 0.65	0.00	a*↓, b*↓, c*↓
Dynamic arch índex (%)	23.27 ± 8.49	23.70 ±7.70	23.22 ± 8.49	0.97	

Differences between groups: (a) NO – NS and O - NS; (b) NO – NS and S – O; (c) O – NS and S - O; *p<=0,01; Value increased (↑) or decreased (↓) significantly

Table 3

Mean and standard deviation for the peak pressure, absolute impulse, ratios (1 and 2) and relative impulse underneath the ten anatomical areas (n=238).

	Non obese Non sarcopenic (n= 50)	Obese Non sarcopenic (n= 167)	Sarcopenic Obese (n= 22)	Test (Sig.) Anova/KW	Bonferroni/ MW
PmaxT1 (N/cm^2)	10.61 ± 5.19	10.31 ± 4.69	11.14 ± 6.13	£0.94	
PmaxT2-5 (N/cm^2)	4.21 ± 2.99	4.79 ± 3.72	4.66 ± 3.14	£0.67	
PmaxM1 (N/cm^2)	12.18 ± 7.36	14.03 ± 7.00	15.70 ± 7.54	£0.01	a*↑, b*↑
PmaxM2 (N/cm^2)	20.02 ±8.26	21.79 ± 7.70	25.11 ± 7.96	£0.02	b*↑
PmaxM3 (N/cm^2)	19.25 ± 6.92	21.63 ± 7.30	25.18 ± 9.88	§4.92 (0.01)	b*↑
PmaxM4 (N/cm^2)	11.76 ± 5.08	14.25 ± 5.23	16.44 ± 5.48	£0.00	a*↑, b*↑
PmaxM5 (N/cm^2)	7.69 ± 5.50	9.13 ± 5.16	11.69 ± 5.58	£0.00	a*↑, b*↑
PmaxMF (N/cm^2)	2.11 ± 1.62	3.54 ± 2.34	5.36 ± 2.53	£0.00	a*↑, b*↑, c*↑
PmaxHM (N/cm^2)	17.48 ± 5.13	19.36 ± 5.61	20.36 ± 4.98	£0.03	b*↑
PmaxHL (N/cm^2)	15.98 ± 4.70	18.70 ± 5.41	20.26 ± 5.96	£0.00	a*↑, b*↑
AbsImpulsT1 (Ns/cm^2)	1.70 ± 1.15	1.71 ± 1.10	2.20 ± 1.46	£0.41	
AbsImpulsT2-5 (Ns/cm^2)	0.62 ± 0.59	0.73 ± 0.75	0.83 ± 0.73	£0.51	
AbsImpulsM1 (Ns/cm^2)	2.21 ± 1.58	2.83 ± 1.64	3.66 ± 2.13	£0.00	a*↑, b*↑
AbsImpulsM2 (Ns/cm^2)	3.93 ± 1.79	4.55 ± 1.67	6.13 ± 2.21	£0.00	a*↑, b*↑, c*↑
AbsImpulsM3 (Ns/cm^2)	3.97 ± 1.81	4.63 ± 1.76	6.01 ± 2.31	£0.00	a*↑, b*↑, c*↑
AbsImpulsM4 (Ns/cm^2)	2.62 ± 1.45	3.36 ± 1.58	4.33 ± 1.29	£0.00	a*↑, b*↑, c*↑
AbsImpulsM5 (Ns/cm^2)	1.54 ± 1.29	2.01 ± 1.50	2.92 ± 1.50	£0.00	a*↑, b*↑, c*↑
AbsImpulsMF (Ns/cm^2)	0.36 ± 0.32	0.77 ± 0.67	1.39 ± 0.85	£0.00	a*↑, b*↑, c*↑
AbsImpulsHM (Ns/cm^2)	3.77 ± 1.42	4.32 ± 1.31	5.31 ± 2.00	£0.00	a*↑, b*↑, c**↑
AbsImpulsHL (Ns/cm^2)	3.62 ± 1.33	4.42 ± 1.46	5.66 ± 2.77	£0.00	a*↑, b*↑, c*↑
Ratio 1	0.30 ± 0.08	0.30 ± 0.09	0.28 ± 0.11	§0.35 (0.70)	
Ratio 2	0.05 ± 0.13	0.06 ± 0.12	0.03 ± 0.12	§0.51 (0.60)	
RelImpulsT1 (%)	8.25 ± 8.29	5.85 ± 3.23	5.73 ± 3.83	£0.05	a*↓
RelImpulsT2-5 (%)	4.51 ± 12.80	2.48 ± 2.15	2.21 ± 1.93	£0.78	
RelImpulsM1 (%)	9.74 ± 7.40	9.70 ± 4.81	9.41 ± 4.43	£0.65	
RelImpulsM2 (%)	17.13 ± 7.75	15.54 ± 3.88	15.73 ± 3.56	£0.37	
RelImpulsM3 (%)	17.18 ± 7.21	15.70 ± 3.78	15.57 ± 4.61	£0.56	
RelImpulsM4 (%)	11.36 ± 7.18	11.21 ± 3.42	11.36 ± 2.63	£0.45	
RelImpulsM5 (%)	6.90 ± 7.98	6.64 ± 3.98	7.75 ± 4.28	£0.18	
RelImpulsMF (%)	2.40 ± 6.23	2.57 ± 2.02	3.86 ± 2.74	£0.00	a*↑, b*↑, c**↑
RelImpulsHM (%)	16.54 ± 7.17	15.02 ± 3.77	13.80 ± 3.85	£0.06	
RelImpulsHL(%)	16.07 ± 7.21	15.29 ± 3.99	14.58 ± 4.49	£0.40	

Differences between groups: (a) NO – NS and O - NS; (b) NO – NS and S – O; (c) O – NS and S - O
§, One Way ANOVA; £, Kruskal wallis test, *≤0.01, **≤0.017
Value increased (↑) or decreased (↓) significantly
MW (Mann-Witney), Sig. (Significance), KW (Kruskal-Wallis)

Table 4
Mean and standard deviation for the absolute and relative values of total contact time, total contact time, first metatarsal contact, forefoot flat, heel off, first contact time and end contact for the ten anatomical areas (n= 238).

	Non obese Non sarcopenic (n=50)	Obese Non sarcopenic (n=167)	Sarcopenic Obese (n=22)	Test (Sig.) Anova/KW	Bonferroni/ MW
Total contact time (ms)	645.18 ± 72.34	672.47 ± 86.83	721.75 ± 100.99	£0.03	b*↑
First metatarsal contact (ms)	142.77 ± 50.64	129.76 ± 60.24	110.83 ± 65.50	£0.02	b*↓
Forefoot flat (ms)	271.64 ± 62.79	253.48 ± 79.38	235.41 ± 69.47	§1.99 (0.14)	
Heel off (ms)	361.38 ± 72.88	386.54 ± 83.32	445.01 ± 109.05	£0.01	b*↑, c*↑
Initial contact phase (ms)	142.77 ± 50.64	129.76 ± 60.24	110.83 ± 65.50	£0.02	b*↓
Forefoot contact phase (ms)	128.87 ± 52.61	123.72 ± 58.16	124.59 ± 59.66	£1.00	
Foot flat phase (ms)	89.75 ± 69.55	133.07 ± 77.67	209.60 ± 86.31	£0.00	a*↑, b*↑, c*↑
Forefoot push off phase (ms)	283.80 ± 43.90	285.93 ± 41.98	276.75 ± 59.30	£0.79	
First metatarsal contact (%)	22.30 ± 7.96	19.19 ± 8.36	14.75 ± 59.30	£0.00	a*↓, b*↓, c*↓
Forefoot flat (%)	42.28 ± 8.96	37.59 ± 10.51	32.69 ± 8.72	§7.72 (0.00)	a*↓, b*↓
Heel off (%)	55.68 ± 7.09	57.05 ± 6.73	61.24 ± 8.37	§4.92 (0.01)	b*↑
Initial contact phase (%)	22.30 ± 7.96	19.19 ± 8.36	14.75 ± 6.64	£0.00	a*↓, b*↓, c*↓
Forefoot contact phase (%)	19.98 ± 7.99	18.40 ± 8.31	17.94 ± 9.86	§0.78 (0.46)	
Foot flat phase (%)	13.40 ± 9.70	19.47 ±10.34	28.55 ± 9.29	£0.00	a*↑, b*↑, c*↑
Forefoot push off phase (%)	44.32 ± 7.09	42.95 ± 6.73	38.76 ± 8.37	£0.03	b*↓, c**↓
First contact T1 (ms)	325.63 ± 100.45	347.45 ± 98.65	322.19 ± 91.75	§1.37 (0.26)	
First contact T2-5 (ms)	304.18 ± 131.76	314.77 ± 142.90	377.83 ± 147.56	£0.04	
First contact M1 (ms)	243.76 ± 73.48	228.37 ± 82.52	208.69 ± 63.67	§1.59 (0.21)	
First contact M2 (ms)	184.44 ± 58.32	174.59 ± 69.11	155.12 ± 72.86	£0.09	
First contact M3 (ms)	165.44 ± 60.63	155.28 ± 71.50	135.67 ± 68.12	£0.11	
First contact M4 (ms)	178.33 ± 69.24	155.95 ± 74.49	130.75 ± 74.12	£0.01	b*↓
First contact M5 (ms)	204.16 ± 76.32	182.16 ± 85.69	158.86 ± 93.40	£0.04	b**↓
First contact MF (ms)	92.79 ± 45.89	81.13 ± 41.50	63.04 ± 39.07	£0.02	b*↓
First contact HM (ms)	0.00 ± 0.00	0.04 ± 0.49	0.00 ± 0.00	£0.33	
First contact HL (ms)	0.00 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	£0.15	
End contact T1 (ms)	642.94 ± 73.29	670.13 ± 86.96	719.98 ± 101.96	£0.02	b*↑
End contact T2-5 (ms)	629.97 ± 69.55	657.04 ± 85.46	696.57 ± 88.52	£0.04	b**↑
End contact M1 (ms)	605.54 ± 69.09	635.98 ± 82.54	684.63 ± 96.21	£0.01	b*↑
End contact M2 (ms)	614.46 ± 70.94	641.68 ± 84.39	697.73 ± 98.09	£0.01	b*↑
End contact M3 (ms)	613.22 ± 70.46	639.35 ± 84.24	696.39 ± 97.09	£0.01	b*↑, c**↑
End contact M4 (ms)	603.54 ± 71.33	628.92 ± 83.62	686.89 ± 95.73	£0.01	b*↑, c*↑
End contact M5 (ms)	571.66 ± 76.27	594.77 ± 87.57	654.23 ± 94.43	£0.01	b*↑, c*↑
End contact MF (ms)	415.01 ± 110.68	437.91 ± 101.11	504.27 ± 117.00	£0.02	b*↑
End contact HM (ms)	360.43 ± 72.33	384.85 ± 83.01	441.43 ± 108.72	£0.01	b*↑, c**↑
End contact HL (ms)	358.19 ± 72.86	383.97 ± 83.36	442.14 ± 107.76	£0.01	b*↑, c*↑
First contact T1 (%)	55.27 ± 39.70	51.74 ± 13.86	45.32 ±14.87	£0.16	
First contact T2-5 (%)	47.29 ± 18.91	47. 06 ± 20.45	52.52 ± 21.20	£0.41	
First contact M1 (%)	42.90 ± 41.38	33.81 ± 11.48	28.95 ± 9.00	£0.00	b*↓
First contact M2 (%)	32.44 ± 30.93	25.88 ± 9.67	20.96 ± 8.07	£0.00	b*↓, c**↓
First contact M3 (%)	29.76 ± 33.23	22.90 ± 9.76	18.19 ± 7.17	£0.01	b*↓
First contact M4 (%)	32.41 ± 38.00	22.97 ± 10.18	17.38 ± 7.43	£0.00	a*↓, b*↓, c*↓
First contact M5 (%)	36.10 ± 35.22	26.89 ± 11.90	21.26 ± 10.58	£0.00	a*↓, b*↓
First contact MF (%)	16.09 ± 16.41	12.02 ± 5.78	8.33 ± 4.13	£0.00	b*↓, c*↓
First contact HM (%)	0.00 ± 0.00	0.01 ± 0.07	0.00 ± 0.00	£0.33	
First contact HL (%)	0.00 ± 0.00	0.00 ±0.00	0.00 ±0.00	£0.15	
End contact T1 (%)	99.21 ± 1.17	99.34 ± 1.13	99.38 ± 1.08	£0.49	
End contact T2-5 (%)	97.27 ± 1.66	97.40 ± 2.02	96.33 ± 2.82	£0.17	
End contact M1 (%)	93.51 ± 2.48	94.29 ± 1.99	94.53 ± 1.85	§1.67 (0.19)	
End contact M2 (%)	94.86 ± 1.97	95.09 ± 2.28	96.33 ± 1.41	£0.00	b*↑, c*↑
End contact M3 (%)	94.67 ± 1.97	94.74 ± 2.28	96.15 ± 1.32	£0.00	b*↑, c*↑
End contact M4 (%)	93.17 ± 2.36	93.19 ± 2.31	94.85 ± 1.80	£0.01	b*↑, c*↑
End contact M5 (%)	88.18 ± 4.36	88.01 ± 4.09	90.31 ± 2.52	£0.02	b*↑, c*↑
End contact MF (%)	63.91 ± 13.91	64.26 ± 11.05	69.33 ± 10.71	§ 1.55 (0.22)	
End contact HM (%)	55.61 ± 7.45	56.60 ± 6.63	60.46 ± 8.47	£0.05	
End contact HL (%)	55.26 ± 7.58	56.46 ± 6.73	60.59 ± 8.29	£0.02	b*↑, c*↑

Differences between groups: (a) NO – NS and O - NS; (b) NO – NS and S – O; (c) O – NS and S - O
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