



INVESTIGATION OF PLANTAR PRESSURE AND PLANTAR IMBALANCES IN THE STATIC PHASE OF KARATE DO ATHLETES

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Abstract

The study aims to investigate the parameters offered by the baropodometric examination on a group of athletes practicing the martial art Karate Do (20 subjects, 16 girls and 4 boys, average age 13.55 ± 2.74 , height $163 \text{ cm} \pm 8.47$, weight $54.50 \text{ kg} \pm 8.84$, BMI (body index mass) of 20.46 ± 2.90 and seniority in sports activity of $5.27 \text{ years} \pm 2.74$). The purpose of the research is to determine the changes related to the value of the plantar surfaces, the pressures for the dominant and non-dominant lower segments, the positioning of the pressure center in relation to the support polygon and the imbalances in the sole of the foot. The testing was performed using the FreeMed baropodometric platform and the FreeStep by Sensor Medica software, in the last week of February 2021, at the Research Center for Human Performance within the Faculty of Physical Education and Sports, “Dunărea de Jos” University from Galați. Results: Placing the maximum pressure point / P.max in the forefoot area is an exception, only one case being reported with this distribution, the rest having P.max located at the rearfoot level. Comparison of the averages between the variables recorded for the left foot vs. the right foot highlights higher values of the dominant / right foot, but these differences are significant only for the values of the plantar pressure in the forefoot area and for the total load on the entire plantar surface / total load ($p < .05$). The comparison between the averages of the surfaces and the loads of each separate foot (for the forefoot and rearfoot areas) highlights major differences only for the values of the contact surfaces, the forefoot area being significantly larger than the rearfoot area ($p < .05$). Close average values with small and insignificant differences are reported for each foot between the forefoot and rearfoot areas when comparing the body pressure / load percent and weight ratio percent, indicating a balanced pressure distribution between the front and back area for each leg. The investigation was also useful by detecting the existing imbalances at the plantar level, for one or both legs, being also reported cases of hollow, flat and mixed foot. These plantar disturbances can negatively affect all the overlying / upper joints, but especially the body posture, thus being able to cause pain in the lumbar region, limiting the performance activity and causing even the withdrawal of the athletes. We recommend that after identifying the syndromes at the ankle joint, to implement personalized plantar supports, which should be introduced in sports shoes in order to balance the architecture of the foot sole.

Keywords: karate do, plantar pressures, baropodometric analysis, load, rearfoot, forefoot, maximum pressure,

INTRODUCTION

Karate Do can be seen as a way of life, a way for self-improvement, practitioners acquiring virtues such as: patience, respect for others, courage, humility, moral strength / fortitude, requiring an adequate distancing, essential for self-control (1,2). The personality traits of these practitioners are signaled by (3): self-discipline and self-control, extraversion, emotional stability, friendship, activism, practical intelligence, combativeness, quick thinking and creativity.

With all its beneficial effects physically and mentally, there are reported a number of problems related to the manifestation of temporomandibular disorders, for elite

practitioners of Karate Do and for those in mixed martial arts, compared to the number of cases encountered among amateur athletes from the same sports disciplines (4). The link between the change in plantar pressure and the existence of TMD (temporomandibular disorder) is highlighted by (5), subjects suffering from this disease, manifesting the misalignment of the musculoskeletal system, an increased and significant load on rearfoot and a lower distribution on forefoot, compared to asymptomatic ones.

Devices for measuring the plantar distribution and plantar pressure at the feet provide relevant information for scientific research on the biomechanics of movement,

diagnosis of various diseases of the musculoskeletal system, static and dynamic disturbances, load of body weight on different areas or points of the foot (6,7).

The use of the baropodometric platform allows the appreciation of the progress in the manifestation of the balance for different branches of sport, as a result of the implementation of the various techniques and training methods proposed, highlighting their efficiency, as for example in the case of university judo programs (8). The study of authors (9) highlights the usefulness of the baropodometric examination in detecting foot problems for high-performance table tennis players.

In the case of football / soccer players, the relationship between static plantar pressure and the incidence of stress fractures in the 5th metatarsal is identified; in the case of midfielders a higher incidence is recorded. There are no significant differences in plantar pressure between players who had and those who did not have fractures, but the forefoot angle relative to rearfoot is significantly higher for those who had fractures (10).

The measurement of foot plantar pressure is useful in the scientific planning of the training process in martial arts, because the distribution of body load indicates whether the technique of performing technical procedures is correct or if errors occur, highlighting clear correlations between the foot plantar pressure and the speed of movement, the corrections made in time limiting the wrong assimilation of the execution technique (11).

The use of the baropodometric platform requires standardization and an optimized calibration, in order to objectify the research and to increase its clinical and scientific value for studies that analyze feet dysfunctions but also for research in related fields (12). The identification of differences in the distribution of plantar pressure between women and men (healthy adults) in the static and dynamic examination indicates in all cases a distribution of the maximum load on the medial area of the foot, but women have a significantly higher load on the big toe, toes and median side of the leg compared to men (13).

Maintaining the balance by ensuring a support base as large as possible and lowering the center of gravity is important in the execution of movements in motor activities, being conditioned by the state of kinesthetic, visual and vestibular analyzers (14). The authors (15) bring to the attention of specialists the need to evaluate postural control and weight distribution on plantar surfaces, as a premise for improving the recovery / rehabilitation programs of athletes. The appearance of physical overloads and injuries can cause negative compensatory mechanisms in athletes (movements of the pressure center / CoP to the area of strong stress, pain in these areas, deficiencies of the periarticular muscles

involved in performing movements and maintaining joint stability).

The static analysis of plantar pressure for adolescents suffering from adolescent idiopathic scoliosis (AIS) reveals significant increases in these values compared to healthy ones, both in terms of total mean values and at the level of each foot (16). The authors (17) also analyze the existing correlation between static plantar loading pressure and spinal coronal balance for children with (AIS) especially with the contact area in the forefoot area and the load ratio of forefoot. Static and dynamic baropodometry is also useful in classifying BMD (bone mineral density) conditions that indicate manifestations of osteopenia and osteoporosis, being a variant of non-invasive investigation of muscle and bone decline (18). The authors (19) report significant changes in plantar pressure in adults with hip osteoarthritis (OA / hip osteoarthritis) in the sense that they show a lower load on heels / rearfoot than healthy ones during static examination (standing still / standing). The use of baropodometry allows the identification of the connections between the dysfunctions of the musculoskeletal system and the visual problems, in those with unstable binocular vision being signaled significant differences between the total areas of the left leg vs. right leg, forefoot area, forefoot load and rearfoot load, according to (20).

The postural stability is low when the examination of subjects is done with maximum mouth opening, when there is a lower load of the left calcaneus and a higher load on the left 5 metatarsal head, and the highest values are obtained for the testing situation at the time of swallowing (maximum intercuspation), according to (21). The relationship between plantar load values and the presence of joint hypermobility in women is demonstrated by (22) and higher peak pressures and higher average total pressure values are recorded on the non-dominant leg, compared to women who do not have joint hypermobility, so plantar pressure can be used as a detection and prevention tool for those with hypermobility.

For women suffering from pelvic pain and healthy ones, similar values of plantar pressure of the left and right surfaces are recorded, as for forefoot and rearfoot (23).

The influence of body mass on plantar distribution in children aged 7-12 years, divided into 4 groups (underweight, normal weight, overweight and obese) is studied by (24). In the case of all categories studied, rearfoot is the surface with the highest pressure value. On the right leg the girls load significantly more load in the rearfoot area, compared to the boys. Significant differences are reported between the groups of normal and overweight for the distribution of the load on the entire plantar surface, and in obese people there are

significant differences between the loads on the left leg vs. the right leg. There are no significant differences between the 4 groups for the loading on the forefoot area, respectively rearfoot. The distribution of plantar pressures in obese children vs. the normal weight is studied by (25), strong loads and significant differences in lateral forefoot and midfoot were reported. The values of plantar pressure and weight distribution for active puberty children vs. the sedentary ones do not differ significantly, instead the active ones have better performances for the balance tests and a correct posture, according to (26).

The asymmetrical loading of the body (by holding a bag or a 4 kg backpack on the right / left side) will generate muscle imbalances in the trunk, with its inclination in the opposite direction to the load, and the increase in plantar pressure was recorded on the loaded lower limb, with significant differences between both loading variants (left-right), so the asymmetric loading will affect the body posture and the distribution of the plantar load, according to (27).

Material and method

The purpose of the research is the determination of changes related to the value of the plantar surfaces, the pressures for the dominant and non-dominant lower limbs, the positioning of the pressure center in relation to the support polygon and the imbalances in the sole of the foot, as a result of practicing the martial art Karate Do, in order to optimize the training process in this sport.

Participants

The studied group consists of 20 performance athletes - Karate Do practitioners, with the following characteristics: 16 girls and 4 boys, with the average age of 13.55 ± 2.74 , height of $163 \text{ cm} \pm 8.47$, weight $54.50 \text{ kg} \pm 8.84$, BMI (body mass index) of 20.46 ± 2.90 and seniority in sports activity of 5.27 ± 2.74 . The BMI values indicate a normal weight for 14 cases, 5 cases have underweight values (below the threshold of 18.5) and only one case falls for the overweight rating (greater than 25). The dominant leg for all the subjects tested is the right leg. All the investigated subjects are members of the Kazumi Sports Club from Focșani City, Vrancea County, two of the girls are members of the national Karate team. Prior to the study, the tested group was informed about the purpose and procedure of the research and the need for the agreement to process and protect personal data.

Procedures

The testing was performed using the FreeMed baropodometric platform by the specialist, in the last week of February 2021, at the Research Center for Human Performance within the Faculty of Physical Education and Sports, "Dunărea de Jos" University from

Galati. During that time interval, the members of the Karate Do team were in full preparation for participating in the National Karate Championship, with 3 2-hour workouts planned weekly (and 2 national team athletes performing 4 workouts) but on the day of testing (27.02 .2021) they did not exert physical effort, so the results obtained cannot be explained by the immediate / acute effect of some adaptations to physical exercises, but are a cumulative and lasting effect of the stimuli planned for long periods of time (training mesocycles and macrocycles in the practiced sport activity).

The FreeMed By Sensor Medica baropodometric device, with the usage details provided by (28) facilitated the static examination of the subjects and recorded the following data, separately for each leg (left and right): surface (cm^2) for forefoot and rearfoot areas, body load (load%) for forefoot and rearfoot, percentage distribution of the weight of each foot on the forefoot and rearfoot areas (Weight ratio R/F%), total surface (cm^2) for the whole plantar surface, load (load) in kg and percentage for the whole plantar surface, the pressure peak (P. Max) in gr/cm^2 at the level of each sole, respectively the average pressure (P. Avg) in gr/cm^2 at the level of each sole. Other data provided for each leg concerns podalic angle and podalic axis ($^\circ$), length and width (mm). The position / projection of the pressure center (C) and its distance from the right/left foot, the orientation and possible misalignment of the pressure center (cm), as well as the misalignment L-R ($^\circ$) of the 2 plantar surfaces are determined and represented graphically. An advantage offered by the software used is the interpretation of the data of each investigated subject and their synthesis in an individual report, which includes: position / location of the pressure center (C) inside the polygon / support area, alignment of the pressure centers for the right / left foot, back / forward foot orientation, location of the maximum pressure point for each foot, uniform or uneven distribution of weight on the left / right foot, comparative loading on forefoot and rearfoot areas, symmetry or asymmetry of total plantar surfaces, symmetry or comparative asymmetry between forefoot and rearfoot areas.

The statistical – mathematical analysis was made using the IBM SPSS software version 20, calculating the central tendency indicators for the anthropometric data and test results, the normality distribution curve by the Shapiro – Wilk test, the parametric procedures for analyzing the differences between the averages on paired samples (student test) and the size effect (Cohen's d) for paired samples, according to (29–32). The confidence interval has been set to 95% ($p < 0.05$). The large volume of data resulting from the study does not allow the presentation and interpretation of all variables recorded, for this reason this paper summarizes the individual

results provided by the software, with the problems of plantar load distribution and positioning the center of pressure, to which are added comparisons between the pairs formed, in particular for the distribution of the load on each foot, the differences between the value of the maximum pressure, the differences in the plantar surfaces and the differences in the load between the forefoot and the rearfoot on the 2 feet and at the level of each foot. The study of the correlations between the anthropometric data and the results of the baropodometric evaluation test in the static phase, as well as the analysis of variance by age groups in the tested group will be statistically processed and presented in a future study. The limitations of the study result from the relatively small number of subjects due to the investigated sports specialization, given the fact that a true and representative analysis of gender differences cannot be performed, due to the small number of boys.

Results

Table 1 summarizes the individual values provided by the software, the red color indicating the major differences and obvious imbalances, the yellow the average differences and imbalances, and black are the results in which there are minor differences or they are missing compared to those data.

The positioning of the body pressure center (C) in the support polygon is obviously off-center in 4 cases / 20% (2 right and 2 left), it is slightly off-center for 7 athletes / 35% (6 right and 1 left) and centered for 9 cases / 45% (4 forward-facing and 5 backward-facing).

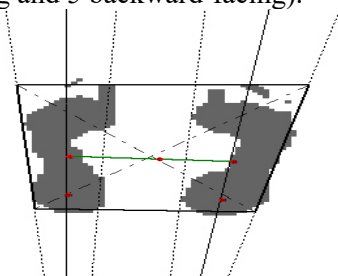


Figure 1. Centered positioning variant of a subject's center of pressure (C), Misalignment (C) = 0.57 cm, with a slight posterior orientation (P)

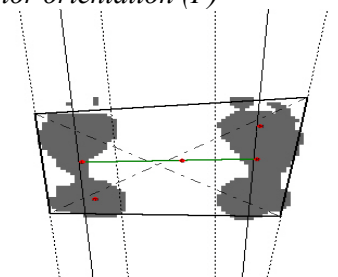


Figure 2. Off-center positioning variant of a subject's center of pressure (C), Misalignment (C) = 2.69 cm, with straight (RG) and forward (A) orientation

The positioning of the pressure centers of each left/right foot indicates a perfect alignment in only 4 cases / 20%

of athletes, and 16 athletes / 80% have misalignments at this level (in 7 cases the left foot is oriented forward and the right backward, in 9 cases the left is oriented backwards and the right forward).

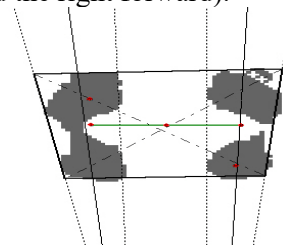


Figure 3. Perfect alignment of pressure centers Misalignment L-R = 0°

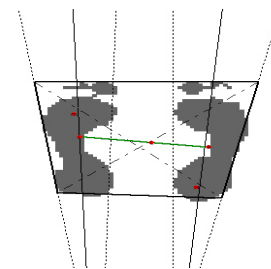


Figure 4. Variant of misalignment of pressure centers Misalignment L-R = 7°

The location of the maximum pressure (P.Max) is in 10 cases/50% on the left leg in the back/in the left retropodal part, in 9 cases / 45% on the right foot in the back/in the right retropodal part and only one athlete presents the location on the right foot in the front/in the right forefoot part, the latter case, we highlight it as atypical (normally the pressure tip is distributed on the back of the foot). These results are somewhat atypical, because the maximum pressure point is usually distributed on the dominant leg, a plausible explanation being that of training for ambidextrous executions, this aspect being a basic concern in the training process, where working with reverse guard / non-dominant segment ensures a superior adaptation to the actual situations in the fight and diversified chances of application of the technical procedures, aspect mentioned by (33). The transfer of the maximum pressure for half of the subjects on the non-dominant leg can also be interpreted as a mechanism of adaptation to specific efforts, where the kicks with the dominant foot imply unipodal stability and implicitly an increase of the pressure on the supporting leg (most often the non-dominant).

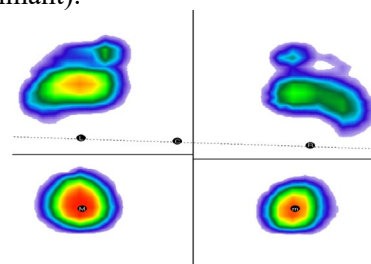


Figure 5. Location of the maximum pressure point of a subject (In the left retropodal part, Pmax = 676g/cm²)

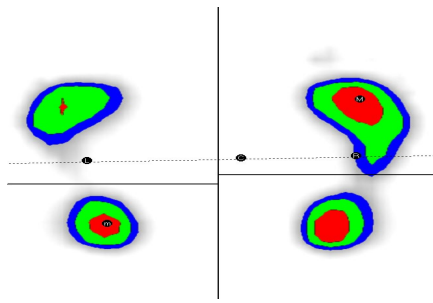


Figure 6. Location of the maximum pressure point (In the right forefoot part, $P_{max} = 580\text{g/cm}^2$)

The balanced distribution of the body weight (with maximum 3% difference in load between the lower limbs) is present for 8 athletes / 40% of cases, and 12 athletes / 60% have an excessive load (overload) on one of the lower limbs (3 subjects on the left leg and 9 subjects on the right foot).

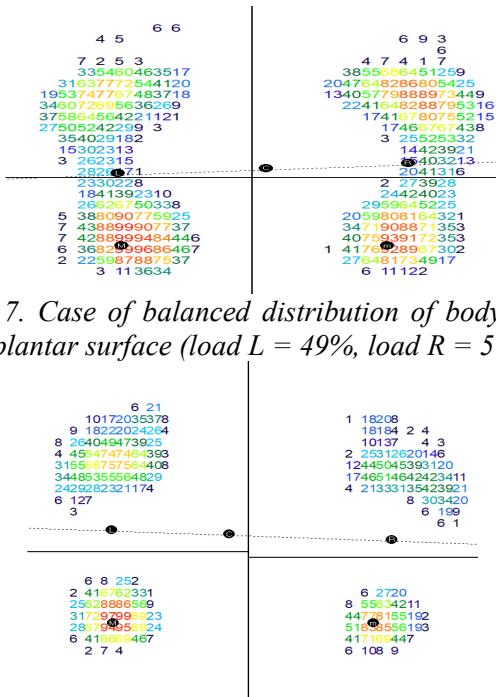


Figure 7. Case of balanced distribution of body weight on the plantar surface (load $L = 49\%$, load $R = 51\%$).

Weight loading for each foot on the front / forefoot vs. rear / rearfoot indicates few cases of balanced distribution, noting that on the rear (heel) a higher percentage load is normal ($55\% \pm 3\%$), relatively equal values for the front / rear indicating an excessive load on the forefoot area. For the left leg sole only 5 athletes (25%) have a balanced load between the front and the back (Weight ratio R/F%), in other 4 cases (20%) there is a slight load on the front and in another 11 cases (55%) major differences (8 with excessive loading on the front and 3 on the rear). For the right leg sole only 4 athletes (20%) have a balanced load, in other 3 cases (15%) they have slight differences in load (2 on the front and one on the back) and for another 13 cases (65%) major

differences are obtained (11 with excessive load on the front and 2 on the rear).

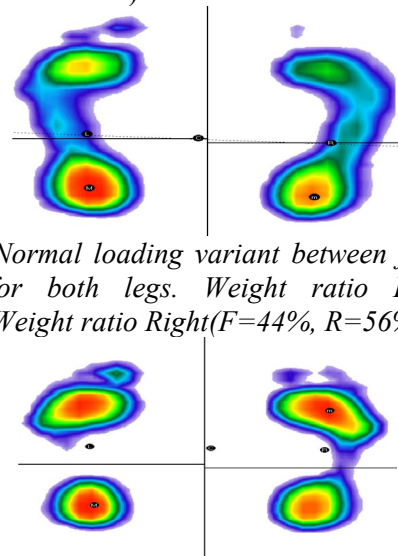


Figure 9. Normal loading variant between forefoot and rearfoot for both legs. Weight ratio Left($F=47\%$, $R=53\%$), Weight ratio Right($F=44\%$, $R=56\%$).

The relative symmetry of the plantar surfaces is present for 9 athletes / 45% (for 5 cases the surface of the left plant is larger, in 4 cases the right one), in 3 cases a moderate asymmetry is reported / 15% (for 2 cases the surface is larger for the right sole and one for the left sole) and in 8 cases / 40% there are differences that signal obvious asymmetries (3 athletes with a larger left sole surface, 5 with the right one). The small differences or the equality between the anterior surfaces of the feet / forefoot for the left vs. the right sole are obtained for 8 athletes, ie 40% of them (there are also 4 cases of identical surfaces), in 2 cases (10%) there are average differences and in 10 situations (50%) the differences are big (with 5 cases where the surface is larger for the left sole and also 5 cases where the surface is larger for the right sole). The small differences between the posterior surfaces of the sole / rearfoot are registered for only 6 athletes (30%), in 5 cases (25%) medium differences are reported and for 9 athletes (45%) large differences are found (in 8 cases on the right sole are obtained larger areas and only in one case on the left sole).

Figure 10. Excessive loading on the front / forefoot for both legs. Weight ratio Left($F=60\%$, $R=40\%$), Weight ratio Right($F=60\%$, $R=40\%$).

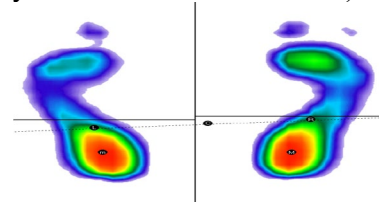


Figure 11. Symmetry variant of the values of the total plantar surfaces, at forefoot and rearfoot level. (Total surface: $L=118\text{cm}^2$, $R=120\text{cm}^2$), (Forefoot surface: $L=64\text{cm}^2$, $R=63\text{cm}^2$), (Rearfoot surface: $L=54\text{cm}^2$, $R=56\text{cm}^2$).

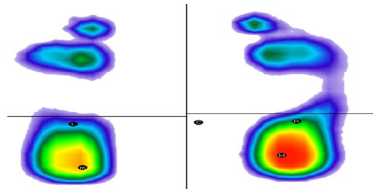


Figure 12. Asymmetry variant of the values of the total plantar surfaces, at forefoot and rearfoot level. (Total surface: L=140cm², R=167cm²), (Forefoot surface: L=67 cm², R=87 cm²), (Rearfoot surface: L=74 cm², R=80 cm²).

The analysis of the photos provided by the software (regarding the surface area, the plantar arch and the distribution of the plantar pressures for the group of investigated athletes) within the Physiotherapy Center of the F.E.F.S. Galați, allowed the centralization of data on imbalances encountered in the sole of the foot: 8 subjects (40%) are cases with normal bilateral leg, 6 cases (30%) have mixed leg - one of the legs is normal, the other is hollow, in 3 cases (15%) are encountered bilateral hollow foot, and also in 3 cases we signal the presence of the bilateral flat foot, some of these variants being illustrated in fig. 13-15.

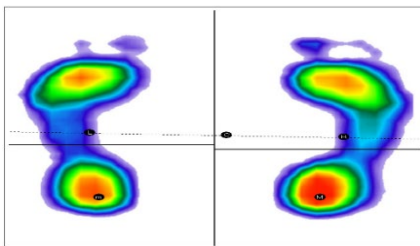


Figure 13. Pressure distribution and plantar surface area for a normal bilateral foot case.

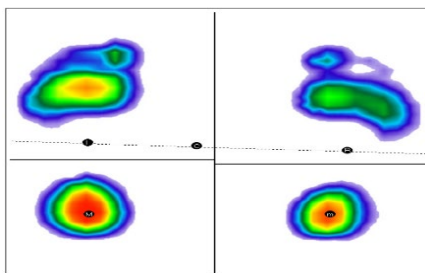


Figure 14. Pressure distribution and plantar surface area for a bilateral hollow foot case.

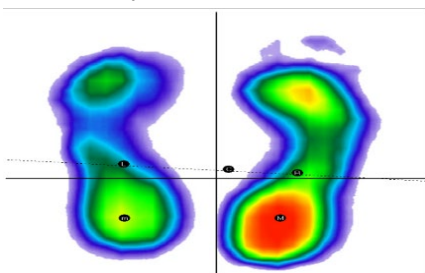


Figure 15. Pressure distribution and plantar surface area for a bilateral flat foot case.

Table 2 shows the mean values of the main variables provided by the analysis software, the difference between them for the left and right leg, the values of the student test (t) for the data pairs and the size of the effect (practical influence of the independent variable represented by training programs) on dependent variables / analyzed parameters). It is observed that for 10 of the 11 pairs of analyzed variables, the average values related to the right/dominant leg are higher than those related to the left leg, but this difference is not statistically significant except for 3 pairs of variables: (forefoot right load percent and forefoot left load percent, with $t = -2.667$, $P = .015$ and a size effect = .596, value indicating an average effect); (total right load percent and total left load percent, with $t = -2.287$, $P = .034$ and a size effect = .514, a value that also indicates an average effect); (total right load kg and total left load kg, with $t = -2.173$, $P = .043$ and a size effect = .485 value which indicates a weak size effect). For the other 7 pairs (including differences in maximum pressure / Pmax and average pressure / Pavg) only insignificant differences and values indicating weak or no effects are found.

Only in the case of the load on the left rear leg (rearfoot left weight ratio percent) the values are higher than the percentage load on the right rear leg (rearfoot right weight ratio percent), but the difference between the averages is also insignificant.

Table 3 identifies the differences between forefoot and rearfoot sole areas in terms of area / surface and distributed pressure, separately for each foot. For both legs are found significantly higher values for the forefoot surface (for the left are obtained differences corresponding to a $t = 9.891$, with $P = .000$ and strong size effect = 2.221, and for the right there are differences corresponding to a $t = 10.688$, $P = .000$ and strong size effect = 2.389). Regarding the load percentage, higher values are found for the left leg for the rear / rearfoot area, and for the reverse right leg, for the forefoot area, but the differences between the forefoot and rearfoot are not significant. We find the same situation for both legs for the pair forefoot weight ratio percent and rearfoot weight ratio percent, with relatively equal and statistically insignificant values, which shows the balance in the weight distribution on each leg, between the forefoot and the rearfoot area. This aspect is in stark contrast to the reference values highlighted by (34), for which adults aged 18-65 have a higher distribution in the rearfoot area (55%) and a lower distribution in the forefoot area (45%), considers this aspect as an adaptation mechanism to the physical demands of Karate Do.

DISCUSSION

The analysis of studies related to baropodometric evaluation, presented by various specialists on different samples (performance athletes, subjects not engaged in

physical activities or people with different diseases) indicates that the results differ greatly depending on the characteristics of the studied group, lifestyle and different types of demands specific to physical activities generating other values of pressures and their distribution on the sole surface.

The study of (35) made on 30 moderate-speed male runners after a 60-minute workout showed a trend in foot pronation and an increase in total support area, contact area, and pressures for the medial heel and second metatarsal head, as an effect of stress on the sole areas used during the effort. The static plantar pressure values differ depending on the specialization of the runners, being found on both legs, higher results of PPD (plantar pressure distribution) in sprinters compared to recreational runners, with peak values for the area of the medial metatarsal bone, for the lateral and lower heel (36). Arch index (AI) values are lower in the case of sprinters, with more frequent cases when suffering from patellofemoral pain.

The analysis of changes in plantar pressure on contact with the ground while walking for Tai Chi practitioners (Tai Chi gait) indicates a low impact force on the foot and a uniform distribution of body weight load between forefoot and rearfoot, but a large medial-lateral displacement of the CoP of the foot is found, according to (37).

The study of (38) on a group of 12 young men (24.3 years old, physically active and without affections of the lower limbs and with the dominance of the right leg) demonstrated that additional body load (with values of 10-20-30% of body weight) and unplanned interruption of walking generates increases in the maximum pressure of the right dominant foot, with increased pressures on the forefoot, midfoot and rearfoot areas and increasing the chances of injuries and collapse of the plantar arch.

The plantar load distribution values for elite fighters (10 subjects with an average age of 23.6 years) are analyzed by (39), which do not obtain significant differences between the left foot. vs. the right one, so the dominant leg is not important in fights. However, significant correlations are observed between the anthropometric parameters (weight and height) and high values of plantar pressure: for the medial and lateral area of the right heel, respectively for the lateral area of the left heel.

A comparison of the distribution of plantar pressure between Iran's female kata and kumite groups is made by (40), which identifies that uneven foot use will generate variations in plantar pressure between the dominant and non-dominant segments. The kumite group (which also has higher muscular force demands) registers higher pressures for the metatarsal areas 2,3,4,5, and the plantar pressure on the dominant leg is higher than the non-

dominant one for the big toe area and toes 3,4,5, and for the metatarsal area 2 is less obvious.

The influence of traditional karate training on the kinesthetic component and plantar pressure of athletes aged 9-19 is investigated by (41). Karateka athletes have lower values in all variables tested compared to the control / non-athletes group, having superior postural stability, with a short length of projection of the center of gravity on the ground, but do not show symmetrical loading of plantar areas for subjects who suffered injuries on lower limbs.

The importance of optimal plantar pressure in the correct execution of Karate Do shots for athletes aged 21-24 is highlighted by (42), the information being useful in the process of correcting the stages of learning and improving the execution technique.

The influence of Brazilian martial art capoeira on the distribution of plantar pressure, postural balance, biomechanical profile and muscle strength showed that for balance and strength no significant differences are reported compared to the control / non-practitioners group of capoeira, but there are significant differences for load distribution at the level of the forefoot load% and total load%. Capoeira practitioners tend to manifest an asymmetric profile in the distribution of plantar pressure, with its increase on the dominant limb (43). For an increased athletic performance, lower limbs have a very important task (44) when performing an efficient technical procedure.

The higher values of plantar pressure on the dominant foot are also confirmed by our study, being in agreement with the findings of the other materials analyzed, which refer to athletes who practice different forms of martial arts.

CONCLUSIONS

The study indicates individual differences for the subjects investigated for most of the analyzed variables; an aspect that should be mentioned is the placement of the maximum pressure point on the non-dominant leg / left leg for half of the group, due to its intense use as a support leg for blows with the dominant / right leg. Placing the maximum pressure point / P.max in the forefoot area is an exception, only one case being reported with this distribution, the rest having P.max located at the rearfoot level. However, the comparison of the averages between the variables recorded for the left leg vs. the right leg highlights upper values of the dominant / right foot, but these differences are significant only for the values of the plantar pressure in the forefoot area and for the total load on the entire plantar surface / total load. The comparison between the surface averages and the loads of each separate foot (for the forefoot and rearfoot areas) highlights major differences only for the

values of the contact surfaces, the forefoot area being significantly larger than the rearfoot. Close average values, with small and therefore insignificant differences are reported for each foot between the forefoot and rearfoot areas when comparing the body pressure distribution / load percent and the weight ratio percent, which indicates a balanced distribution of pressure between the front and rear areas for each foot. We can say that there is a greater distribution of weight on the front / forefoot, compared to people not involved in sports, who usually have higher load values on the rearfoot area.

The investigation was also useful by detecting existing imbalances at the plantar level, for one or both legs, being reported cases of hollow, flat or mixed foot. These plantar disturbances can negatively influence all the overlying / upper joints, but especially the body posture, thus being able to cause pain in the lumbar region, limiting performance activity and even the withdrawal of the athletes. We recommend that after evaluating and identifying the syndromes of the sole of the foot, to implement individualized plantar supports, which must be introduced into sports shoes in order to improve the plantar imbalances encountered, especially where we encounter discrepancies between the sole of the left and right foot. Early detection of imbalances in the architecture of the sole of the foot is considered to be a basic pillar in this sport, an aspect achievable through a well-structured evaluation done by a specialist.

As future perspectives, we aim to evaluate and detect in this age category, the influence of plantar imbalances on body posture in order to implement an individualized recovery protocol.

Declaration of conflict of interests

There is no conflict of interest for any of the authors regarding this paper.

Informed consent

Parental consent was obtained for each child after explaining the nature of the assessments, while ensuring that they were strictly anonymous and confidential. They were informed that they had the right to stop the experiment without prejudice. This study was conducted with the consent of the Karate Do coaches.

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Author contribution

The authors of this article have equal contribution and equal rights over it.

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Table 1 – Centralization of the individual results offered by the baropodometric platform

Crt. No.	Sex	Age	Weight kg	Height cm	Position of pressure center (C)	Position of pressure centers L/R	Location of maximum pressure (M)	Distribution of weight L/R(% and kg)	Weight ratio R/F %	Leg surfaces L/R	Front surfaces differences L/R	Back surfaces differences L/R	Diagnostic of the legs
1	F	14	52	161	Off-centered, left orientation Misalignment C = 1,28 cm (LF/P)	L-front, R-back Misalignment L-R= 4°	In the left retropodal part. P.Max =640 gr/cm ²	Load L=55% Load L=29kg Load R=45% Load R=23kg	Left(F=47%, R=53%) Right(F=44%, R=56%)	L=120cm ² R=112 cm ²	Forefoot L=70 cm ² R=60 cm ²	Rearfoot L=50 cm ² R=52 cm ²	Normal bilateral leg
2	F	16	56	170	Centered, back orientation, Misalignment C = 0,27 cm (P)	L-back, R-front Misalignment L-R= 4°	In the left retropodal part. P.Max =505 gr/cm ²	Load L=49% Load L=27kg Load R=51% Load R=29kg	Left(F=47%, R=53%) Right(F=55%, R=45%)	L=132cm ² R=128 cm ²	Forefoot L=74 cm ² R=72 cm ²	Rearfoot L=58 cm ² R=56 cm ²	Normal bilateral leg
3	F	11	58	155	Slightly off-centered, right orientation Misalignment C = 0,67 cm (RG/P)	L-front, R-back Misalignment L-R= 5°	In the right retropodal part. P.Max =655gr/cm ²	Load L=46% Load L=27kg Load R=54% Load R=31kg	Left(F=50%, R=50%) Right(F=48%, R=52%)	L=127cm ² R=124 cm ²	Forefoot L=72 cm ² R=72 cm ²	Rearfoot L=55 cm ² R=52 cm ²	Normal bilateral leg
4	M	15	57	184	Centered, forward orientation, Misalignment C = 1,30 cm (A)	L-back, R-front Misalignment L-R= 3°	In the left retropodal part. P.Max =575gr/cm ²	Load L=49% Load L=28kg Load R=51% Load R=29kg	Left(F=52%, R=48%) Right(F=63%, R=37%)	L=121cm ² R=144 cm ²	Forefoot L=72 cm ² R=90 cm ²	Rearfoot L=49 cm ² R=54 cm ²	Mixed leg (hollow left leg, normal right leg)
5	F	13	50	157	Centered, forward orientation, Misalignment C = 1,38 cm (A)	Alignment L-R=0°	In the right retropodal part. P.Max =556gr/cm ²	Load L=49% Load L=24kg Load R=51% Load R=26kg	Left(F=60%, R=40%) Right(F=55%, R=45%)	L=128cm ² R=115cm ²	Forefoot L=76 cm ² R=66 cm ²	Rearfoot L=52 cm ² R=48 cm ²	Mixed leg (normal left leg, hollow right leg)
6	F	10	47	149	Centered, backward orientation, Misalignment C = 1,00 cm (P)	L-spate, R-fata Misalignment L-R= 3°	In the right retropodal part. P.Max =547gr/cm ²	Load L=48% Load L=23kg Load R=52% Load R=24kg	Left(F=32%, R=68%) Right(F=38%, R=62%)	L=118cm ² R=120cm ²	Forefoot L=64 cm ² R=63 cm ²	Rearfoot L=54 cm ² R=56 cm ²	Normal bilateral leg
7	F	11	48	159	Slightly off-centered, right orientation Misalignment C = 1,09 cm (RG/P)	L-back, R-front Misalignment L-R= 4°	In the left retropodal part. P.Max =590gr/cm ²	Load L=45% Load L=22kg Load R=55% Load R=26kg	Left(F=41%, R=59%) Right(F=51%, R=49%)	L=104cm ² R=119cm ²	Forefoot L=61 cm ² R=68 cm ²	Rearfoot L=44 cm ² R=51 cm ²	Mixed leg (hollow left leg, normal right leg)
8	F	16	61	160	Off-centered, right and forward orientation Misalignment C = 2,69 cm (RG/A)	L-back, R-front Misalignment L-R= 3°	In the right forefoot part P.Max =580gr/cm ²	Load L=43% Load L=26kg Load R=57% Load R=35kg	Left(F=58%, R=42%) Right(F=62%, R=38%)	L=113cm ² R=134cm ²	Forefoot L=68 cm ² R=82 cm ²	Rearfoot L=45 cm ² R=52 cm ²	Mixed leg (normal left leg, flat right leg)
9	F	11	45	160	Off-centered, left and forward orientation Misalignment C = 1,98 cm (LF/A)	L-front, R-back Misalignment L-R= 3°	In the left retropodal part. P.Max =676gr/cm ²	Load L=58% Load L=26kg Load R=42% Load R=19kg	Left(F=55%, R=45%) Right(F=55%, R=45%)	L=98cm ² R=91cm ²	Forefoot L=62 cm ² R=59 cm ²	Rearfoot L=36 cm ² R=32 cm ²	Hollow bilateral leg
10	F	12	47	163	Slightly off-centered, right and forward orientation Misalignment C = 0,97 cm (RG/A)	L-back, R-front Misalignment L-R= 3°	In the left retropodal part. P.Max =498gr/cm ²	Load L=54% Load L=25kg Load R=46% Load R=22kg	Left(F=45%, R=55%) Right(F=54%, R=46%)	L=114cm ² R=133cm ²	Forefoot L=63 cm ² R=76 cm ²	Rearfoot L=51 cm ² R=58 cm ²	Mixed leg (hollow left leg, normal right leg)
11	B	12	42	152	Centered, forward orientation, Misalignment C = 0,52 cm (A)	L-front, R-back Misalignment L-R= 3°	In the right retropodal part. P.Max =496gr/cm ²	Load L=46% Load L=19kg Load R=54% Load R=23kg	Left(F=55%, R=45%) Right(F=54%, R=46%)	L=110cm ² R=118cm ²	Forefoot L=67 cm ² R=70 cm ²	Rearfoot L=43 cm ² R=48 cm ²	Normal bilateral leg
12	B	14	78	167	Slightly off-centered, right orientation Misalignment C = 1,24 cm (RG/P)	L-front, R-back Misalignment L-R= 5°	In the right retropodal part. P.Max =675gr/cm ²	Load L=39% Load L=30kg Load R=61% Load R=48kg	Left(F=49%, R=51%) Right(F=46%, R=54%)	L=151cm ² R=168cm ²	Forefoot L=91 cm ² R=96 cm ²	Rearfoot L=60 cm ² R=72 cm ²	Flat bilateral leg

13	B	13	74	178	Off-centered, right and backward orientation Misalignment C = 3,20 cm (RG/P)	L-back, R-front Misalignment L-R= 0°	In the right retropodal part. P.Max =759gr/cm ²	Load L=44% Load L=33kg Load R=56% Load R=41kg	Left(F=31%, R=69%) Right(F=30%, R=70%)	L=140cm ² R=167cm ²	Forefoot L=67 cm ² R=87 cm ²	Rearfoot L=74 cm ² R=80 cm ²	Flat bilateral leg
14	F	15	56	163	Centered, backward orientation, Misalignment C = 0,57 cm (P)	L-front, R-back Misalignment L-R= 4°	In the right retropodal part. P.Max =620gr/cm ²	Load L=45% Load L=25kg Load R=55% Load R=31kg	Left(F=48%, R=52%) Right(F=46%, R=54%)	L=120cm ² R=133cm ²	Forefoot L=69 cm ² R=75 cm ²	Rearfoot L=52 cm ² R=58 cm ²	Normal bilateral leg
15	F	13	53	160	Slightly off-centered, right and forward orientation Misalignment C = 1,69 cm (RG/A)	L-front, R-back Misalignment L-R= 7°	In the right retropodal part. P.Max =569gr/cm ²	Load L=44% Load L=23kg Load R=56% Load R=30kg	Left(F=65%, R=35%) Right(F=52%, R=48%)	L=118cm ² R=119cm ²	Forefoot L=69 cm ² R=69 cm ²	Rearfoot L=49 cm ² R=50 cm ²	Normal bilateral leg
16	F	14	52	170	Centered, forward orientation, Misalignment C = 1,32 cm (A)	L-back, R-front Misalignment L-R= 3°	In the left retropodal part. P.Max =583gr/cm ²	Load L=53% Load L=28kg Load R=47% Load R=24kg	Left(F=55%, R=45%) Right(F=57%, R=43%)	L=106cm ² R=104cm ²	Forefoot L=65 cm ² R=64 cm ²	Rearfoot L=41 cm ² R=40 cm ²	Hollow bilateral leg
17	F	17	50	169	Slightly off-centered, left and backward orientation Misalignment C = 0,82 cm (LF/P)	Alignment L-R=0°	In the left retropodal part. P.Max =436gr/cm ²	Load L=51% Load L=26kg Load R=49% Load R=24kg	Left(F=48%, R=52%) Right(F=47%, R=53%)	L=142cm ² R=129cm ²	Forefoot L=80 cm ² R=70 cm ²	Rearfoot L=62 cm ² R=59 cm ²	Flat bilateral leg
18	F	16	54	170	Centered, forward orientation, Misalignment C = 1,04 cm (A)	Alignment L-R=0°	In the left retropodal part. P.Max =538gr/cm ²	Load L=48% Load L=26kg Load R=52% Load R=28kg	Left(F=60%, R=40%) Right(F=60%, R=40%)	L=116cm ² R=124cm ²	Forefoot L=74 cm ² R=74 cm ²	Rearfoot L=42 cm ² R=50 cm ²	Mixed leg (hollow left leg, normal right leg)
19	F	12	51	162	Slightly off-centered, right and backward orientation Misalignment C = 1,51 cm (RG/P)	Alignment L-R=0°	In the right retropodal part. P.Max =788gr/cm ²	Load L=44% Load L=22kg Load R=56% Load R=29kg	Left(F=43%, R=57%) Right(F=40%, R=60%)	L=95cm ² R=108cm ²	Forefoot L=54 cm ² R=58 cm ²	Rearfoot L=41 cm ² R=49 cm ²	Hollow bilateral leg
20	F	16	59	157	Centered, backward orientation, Misalignment C = 1,15 cm (P)	L-back, R-front Misalignment L-R= 6°	In the left retropodal part. P.Max =649gr/cm ²	Load L=52% Load L=31kg Load R=48% Load R=28kg	Left(F=36%, R=64%) Right(F=49%, R=51%)	L=138cm ² R=122cm ²	Forefoot L=76 cm ² R=70 cm ²	Rearfoot L=62 cm ² R=52 cm ²	Normal bilateral leg

Table 2 – The average values obtained and the significance of the differences between the left and right foot

Indicators		Mean	Mean difference	Std. Deviation	t	Sig. (2-tailed)	Size effect
Pair 1	forefoot_left_surface	69,7000	-2,40000	8,76836	-1,224	,236	,273
	forefoot_right surface	72,1000					
Pair 2	forefoot left load percent	23,2500	-3,05000	5,11422	-2,667	,015*	,596
	forefoot right load percent	26,3000					
Pair 3	forefoot left weight ratio percent	48,8500	-1,45000	6,41113	-1,011	,325	,226
	forefoot right weight ratio percent	50,3000					
Pair 4	rearfoot left surface	51,0000	-2,50000	5,52030	-2,025	,057	,452
	rearfoot right surface	53,5000					
Pair 5	rearfoot left load percent	24,4500	-,65000	8,12582	-,358	,724	,080
	rearfoot right load percent	25,1000					
Pair 6	rearfoot left weight ratio percent	51,1500	1,45000	6,41113	1,011	,325	,226
	rearfoot right weight ratio percent	49,7000					
Pair 7	total left surface	120,5500	-5,05000	13,12080	-1,721	,101	,384
	total right surface	125,6000					
Pair 8	total left load percent	47,7000	-4,60000	8,99356	-2,287	,034*	,514
	total right load percent	52,3000					
Pair 9	total left load kg	25,8500	-2,80000	5,76377	-2,173	,043*	,485
	total right load kg	28,6500					
Pair 10	total left Pmax	553,2000	-20,65000	86,14142	-1,072	,297	,239
	total right Pmax	573,8500					
Pair 11	total left Pavg	215,2000	-12,00000	30,95328	-1,734	,099	,387
	total right Pavg	227,2000					

*(p<,05)

Table 3 – Significance of differences between forefoot and rearfoot indicators for each foot

Indicators		Mean	Mean difference	Std. Deviation	t	Sig. (2-tailed)	Size effect
Pair 1	forefoot_left_surface	69.7000	18.7000	8.4548	9.891	.000*	2,211
	rearfoot left surface	51.0000					
Pair 2	forefoot right surface	72.1000	18.6000	7.7825	10.688	.000*	2,389
	rearfoot right surface	53.5000					
Pair 3	forefoot left load percent	23.2500	-1.2000	8.9947	-.597	.558	.129
	rearfoot left load percent	24.4500					
Pair 4	forefoot right load percent	26.3000	1.2000	10.5361	.509	.616	.137
	rearfoot right load percent	25.1000					
Pair 5	forefoot_left_weight_ratio_percent	48.8500	-2.3000	18.3793	-.560	.582	.130
	rearfoot left weight ratio percent	51.1500					
Pair 6	forefoot_right_weight_ratio_percent	50.3000	.60000	16.5319	.162	.873	.184
	rearfoot right weight ratio percent	49.7000					

*(p<,05)