ORIGINAL RESEARCH

Mandible Position and Chewing Preference Side Do Not Alter Plantar Support in Children Aged 4–11 Years

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Abstract

Introduction: Mandible positioning can cause global postural adaptations. Physiotherapists and dentists try to relate the mandible position and chewing side to plantar support; however, this indication is uncertain.

Objectives: To check the existence of a relationship between mandible position, preferred chewing side, age, and plantar support in children.

Materials and methods: This is a cross-sectional study with 93 children, aged between 4 and 11 years. Photogrammetry was used to confirm the mandibular positions (centralized, to the right, and to the left), and baropodometry was used to measure plantar support. The mandibular displacement distance to the right and left was evaluated, and the plantar support in the three mandibular positions was compared as a function of age (4–7 and 8–11 years) and preferred chewing side.

Results: There was greater mandibular displacement in left laterality [13 (9–19) cm] compared to right laterality [7 (3.50–12.00) cm] ($p < 0.01$). Mandibular position did not alter mean pressure, maximum pressure, or plantar support surface ($p > 0.05$). With the mandible centralized, higher mean pressure, maximum pressure, and surface area were observed in the left foot ($p < 0.01$). Older children showed greater mandibular displacement to the left ($p < 0.01$). No differences were observed for the variables of plantar support as a function of age ($p > 0.05$) and chewing side ($p > 0.05$). There was a moderate to strong correlation between age, body mass, height, and plantar surface area ($0.63 < r < 0.83$; $p < 0.05$) and between mean and maximum pressures of plantar support ($0.58 < r < 0.89$; $p < 0.05$).

Conclusion: Mandibular position, age, and preferred chewing side do not influence plantar support in children.

Keywords: Comprehensive healthcare, Photogrammetry, Postural balance, Vertical dimension.

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Introduction

The human body has the ability to adopt postural alterations and direct muscle activity to counteract the force of gravity.[1] Maintaining an orthostatic posture in a stable position is only possible through precise neuromuscular coordination,[2] with postural adjustment mechanisms involving muscle activations controlled by the central nervous system (CNS) and mediated by integrated multisensory inputs (visual, vestibular, and somatosensory).[3]

Although Solovykh et al. claim that only approximately 2% of postural balance is influenced by the stomatognathic system,[4] proprioceptive input from occlusion plays a vital role in maintaining adequate postural control.[5] In response to these stimuli, muscle contractions occur that seek better balance, with a direct relationship to the position of the skull and spine. It is believed that mandibular movements and positions may be associated with postural changes, since the sensorimotor system of the mandible is capable of modulating and stabilizing postural control.[6] It should be noted that other factors could also interfere with mandibular position and displacement and plantar support, such as intrinsic factors (bone growth, crossbite, midline deviation between the dental arches, oral breathing) and extrinsic factors (use of pacifiers and bottles, thumb sucking, chewing side preference, fractures, and lower limb injuries). In addition, it is claimed that afferent signals from dental occlusion, external disturbances, or pathological conditions can affect body balance.[7]

Studies indicate that changes in jaw positions have an effect on postural stability,[8,9] and in conditions of permanence of postural alterations, the muscles will be able to move the jaw to a more comfortable position.[10] Therefore, mandibular movements and positions can trigger postural reflexes to correct deviations and keep the body in balance. As a consequence of postural adjustments, alterations in plantar support may occur to favor postural balance,[11] and in the plantar pressure.[12]

The relationships between the mandible, postural control, and plantar support were presented by Valentino et al., who detected correlations between the occlusal plane and activation of the muscles of the plantar arches in young adults.[13] Cuccia and Caradonna state that a change in mandibular position can lead to alterations in proprioceptive and periodontal afferents, with influence on the oscillatory pressure center of the body.[3] In addition, malocclusion and its treatments can influence body posture, foot contact with the ground, and body center of mass.[14] On the contrary, Ferrario et al.,[15] Perinetti,[16] and Perinetti

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et al.,[17] did not find differences between postural parameters, mandibular resting position, and tooth intercuspation. Manfredini et al. state that in the literature there is no conclusion regarding the influence of mandibular position on the area of foot inclination.[18]

Despite clinical practice pointing out the possibility of interrelationships between mandibular position and plantar support, this relationship has not yet been confirmed, since the results presented to date are conflicting, the studies present methodological bias, and few are directed at children. Thus, the aim of the present study was to check the existence of a relationship between mandibular position, preferred chewing side, age, and plantar support in children. The initial hypothesis was that plantar support would be greater on the side of mandibular displacement and the preferred chewing side, and that older children would have greater plantar support.

Materials and Methods

Study Design and Setting

This is a cross-sectional study in the area of motor control and biomechanics, with healthy children aged 4–11 years, and was approved by the University's Research Ethics Committee (Opinion No. 4,346,542). As the study was conducted with children, those responsible for them were instructed about the study, signed the informed consent form, and were present during the evaluations. In addition, the children were guided and questioned, and consented to participate in the study.

The children were evaluated at the school or at the dental office, in a previously prepared room with good lighting and a temperature maintained between 26 and 28°C. Only the child, the legal guardian, and the researchers were in the room at the time of data collection. The evaluations were carried out in 2019 during the regular school period.

Participants

The sample calculation was performed using data from the study "reliability of measurements of plantar support and postural control in children aged 4–12 years—analysis by baropodometry.[19] The values considered for the analysis were maximum pressure of the right plantar support (1.04 ± 0.48) and maximum pressure of the left plantar support (1.25 ± 0.53), which established a sample of 93 children.

Healthy children of both sexes, between 4 and 11 years old, right-handed or left-handed, who could be in normocclusion, distocclusion, or open bite, were included, recruited from dental offices and mainstream schools. Exclusion criteria included painful auditory, visual, vestibular, neurological, temporomandibular, or musculoskeletal disorders; pharmacological treatments; history of orthodontic treatment; difficulty moving the mandible to the right and/or left side; and those with anterior and posterior crossbite. Two female children were excluded due to previous lower limb fractures.

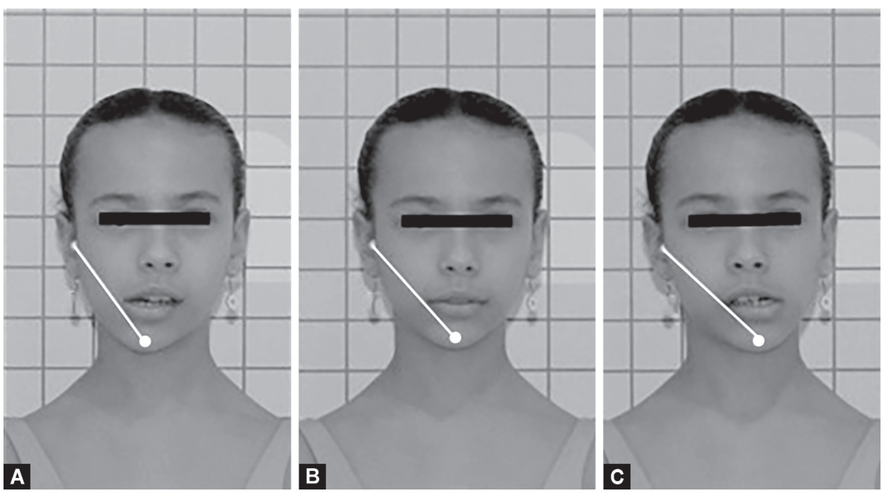
Data Collection

The sample characterization data (name, sex, age-group, body mass, and height) were obtained on the day of the evaluation and duly registered in the baropodometry software.

For the analysis of mandibular position, face photogrammetry was used, with markers located on the right tragus and mental symphysis, without any pain or discomfort.[20] The images were taken with the mandible centralized (Fig. 1B), lateralized to the right (Fig. 1A) and to the left (Fig. 1C).

To avoid possible biases, the sequence of mandibular positions (maximum intercuspation, right and left lateral) was previously established using the software, placed sequentially in sealed envelopes, and numerically sequenced. These envelopes were opened only at the moment of the evaluation. The child was familiarized with the mandibular positions in right and left laterality in maximum range of motion. After understanding the lateral mandibular positioning, the evaluation by photogrammetry was started.[21]

For the results of the mandibular displacement, the distance between the right tragus and the mental symphysis was established by means of linear lines using ImageJ® software (National Institutes of Health, United States of America), with the mandible in maximum intercuspation (centralized mandible), and with displacement to the right and to the left. To define the mandibular displacement, the difference between the distances found (in mm) was established—with the mandible centralized and positioned to the right (right distance = tragus-mental symphysis distance with mandible centered—tragus-mental symphysis distance with mandible on



Figs 1A to C: Positioning of markers and mandibular position used for analysis. (A) Mandible lateralized to the right; (B) Centralized mandible; (C) Mandible lateralized to the left the right), and then between the centered and left-positioned mandible (left distance = tragus-mental distance with centralized mandible—tragus-mental symphysis distance with mandible on the left). These differences were considered for the analyses. ImageJ® software was used to establish the measurements of distances in pixels, which were later transformed into cm using PixelConverter® software.

In each position of the mandible, in addition to the image for photogrammetry, analyses of plantar support were collected using the BaroScan® baropodometer (Londrina, Paraná, Brazil). For the baropodometer evaluation, the children were positioned in orthostatism, in a comfortable position, with their feet positioned as proposed by Bittar et al.[19] The plantar support variables considered for the analysis were mean pressure (kgf/cm^2), maximum pressure (kgf/cm^2), and plantar surface area (cm^2), bilaterally.

Three photogrammetry and baropodometry collections were performed, and the child remained on the baropodometer for 15 seconds for each mandibular position. At the end of each collection, the child got off, walked around freely, and was then directed to get on the baropodometer again for the next assessments, with a 1-minute interval between them. The mean of the three results for each mandibular position was considered for analysis.

After establishing the mandibular position, a single researcher performed the images for photogrammetry and a second researcher performed the collection with the baropodometer. At the end of the photogrammetry and baropodometry evaluations, each child was offered a cheesy roll, and the first bite established the preferred chewing side.

Data Analysis

The Shapiro–Wilk test analyzed the normality of the data, which are described as median (interquartile range). The Wilcoxon test compared the differences in mandibular displacement to the right and left, and the variables of plantar support with the mandible in these two positions. Friedman's test was used to compare the variables of plantar support with the mandible in the three positions (maximum intercuspation, lateralized to the right, and to the left). Comparison analyses of plantar support variables as a function of age (4–7 years and 8–11 years) and as a function of the preferred chewing side were performed using the Wilcoxon test. The significance level was set at 5%.

Analyses of correlations between age, body mass, height, mean pressure, maximum pressure, and surface area were conducted using Spearman's correlation coefficient. Correlations were considered insignificant ($r < 0.30$), weak ($r = 0.30–0.49$), moderate ($r = 0.50–0.69$), strong ($r = 0.70–0.89$), and very strong ($r > 0.90$).[22]

Results

In total, 93 children were evaluated—49 girls and 44 boys. These children were divided according to age from 4–7 years old (34 children: 17 girls and 17 boys) and from 8–11 years old (59 children: 32 girls and 27 boys). The results of sample characterization, plantar support, and mandibular lateral displacement are shown in Table 1. Of the 93 evaluated children, 87.9% were right-handed. As expected, when divided by age-group, differences were established in age, body mass, and height. However, mandibular displacement was always greater on the left and in older children (Table 1).

The results of plantar support with the mandible centralized, displaced to the right, and to the left showed that there was no difference in mean pressure, maximum pressure, and plantar surface area (Table 2).

Thus, as the results established that mandibular position did not alter plantar support, the support between the right and left feet (mean pressure, maximum pressure, and plantar surface area) was compared only with the mandible in maximum intercuspation (centralized mandible). The results always established greater support on the left foot ($p < 0.01$) (Fig. 2).

For the total sample ($n = 93$), there was a moderate correlation between age-group, body mass, height, and the plantar surface area of support on the right and left limbs. Weak correlations were found between age-group, body mass, height, mean pressure, and maximum pressure of the support on the right and left (Table 3). In addition, the correlation between mean right foot pressure and maximum right foot pressure was $\rho = 0.85$ ($p = 0.000$), and between mean left foot pressure and maximum left foot pressure was $\rho = 0.89$ ($p = 0.000$).

Table 1: Results of sample characterization and comparisons according to age-group

	Total sample (n = 93)	*Children aged 4–7 years (n = 34)*	*Children aged 8–11 years (n = 59)*	*p**
Age years	8 (7–9)	6 (5–7)	8 (8–9)	0.000
Body mass (kg)	27 (21–34)	19.50 (17–22)	27 (24–32.25)	0.000
Height (m)	1.30 (1.21–1.41)	1.24 (1.15–1.33)	1.30 (1.16–1.43)	0.020
Mean pressure on right foot (kgf/cm^2)	0.14 (0.12–0.16)	0.14 (0.11–0.16)	0.13 (0.12–0.15)	0.78
Mean pressure on left foot (kgf/cm^2)	0.17 (0.15–0.22)	0.17 (0.15–0.19)	0.17 (0.15–0.21)	0.82
Maximum pressure on right foot (kgf/cm^2)	0.44 (0.34–0.59)	0.42 (0.31–0.61)	0.43 (0.35–0.58)	0.81
Maximum pressure on left foot (kgf/cm^2)	0.72 (0.53–0.94)	0.64 (0.52–0.85)	0.66 (0.53–1.02)	0.93
Surface area on right foot cm^2	42.11 (35.50–53.00)	37.94 (32.39–53.05]	40.28 (30.26–47.76)	0.82
Surface area on left foot cm^2	49.44 (40.18–59.81)	44.25 (38.75–61.03)	47.71 (35.35–59.66)	0.59
DLM right, mm	7 (3.50–12.00)	6 (4.75–1.25)	7.50 (3–15.75)	0.92
DLM left, mm	13 (9–19)	10 (6–13)	14 (7–20)	0.004

cm^2, square centimeters; differences established using the Wilcoxon test; DLM, distance from mandibular laterality; kgf, kilogram force; mm, millimeters; *p**, *p*-values for the comparison between ages; results presented in medians (interquartile range)

When the children were distributed according to the preferred chewing side, there was a difference in body weight, with greater weight in children chewing on the left ($p = 0.01$) (Table 4).

Discussion

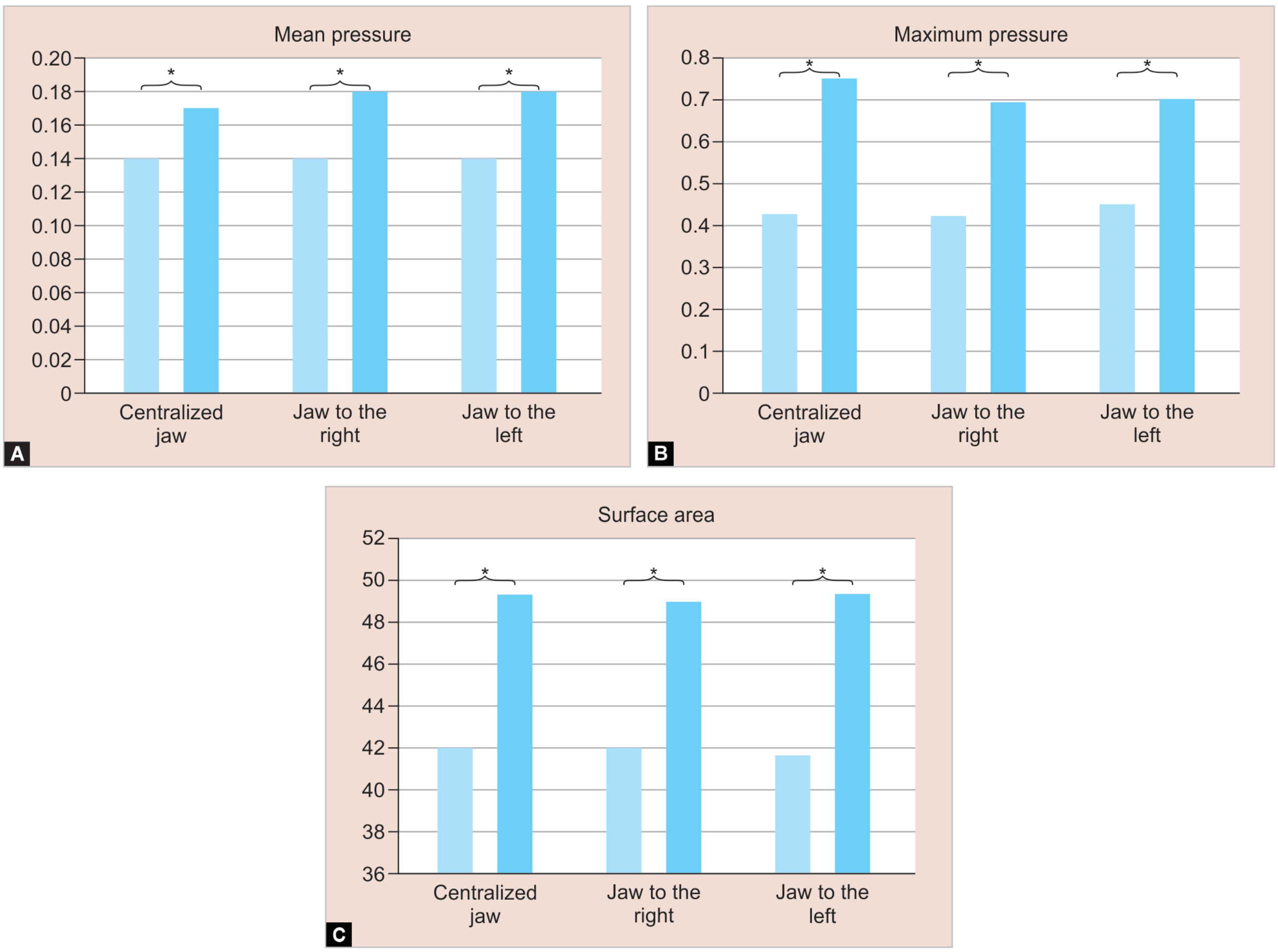
The present study was the first to analyze the relationship between mandibular position and plantar support in children between 4 and 11 years of age. The hypothesis that there could be an influence of mandibular position on plantar support was rejected, and no differences were found by age-group or preferred chewing side. However, in all analyses, there was greater mean pressure, maximum pressure, and plantar surface area for the left support.

To determine the influence of mandibular position on plantar support, it was necessary to measure mandibular lateral displacement. For this, photogrammetry was used,

Table 2: Comparisons of plantar support in children in different mandibular positions

	Mandible positioned to the right (n = 93)	*Centralized mandible (n = 93)*	*Mandible positioned to the left (n = 93)*	*p*
Mean pressure on right foot (kgf/cm^2)	0.14 (0.12–0.16)	0.14 (0.12–0.16)	0.14 (0.12–0.15)	0.45
Mean pressure on left foot (kgf/cm^2)	0.18 (0.15–0.21)	0.17 (0.15–0.22)	0.18 (0.15–0.21)	0.58
Maximum pressure on right foot (kgf/cm^2)	0.43 (0.34–0.62)	0.44 (0.34–0.59)	0.46 (0.35–0.60)	0.64
Maximum pressure on left foot (kgf/cm^2)	0.70 (0.53–0.92)	0.76 (0.53–0.94)	0.71 (0.52–0.93)	0.71
Surface area on right foot cm^2	42.11 (34.69–53.15)	42.11 (35.50–53.00)	41.70 (35.81–53.50)	0.45
Surface area on left foot cm^2	49.03 (40.08–61.24)	49.44 (40.18–59.81)	49.44 (40.89–60.73)	0.96

cm^2, square centimeters; differences established using the Friedman test; kgf, kilogram force; results presented in medians and interquartile range



Figs 2A to C: Results of comparisons of the (A) Mean pressure; (B) Maximum pressure; (C) Surface area between the right and left plantar support of children ($n = 93$); $^*p < 0.01$.

Table 3: Correlation analysis between anthropometric data and plantar support variables in children ($n = 93$)

	Age range (ρ; p-value)	*Height (ρ; p-value)*	*Body mass (ρ; p-value)*
Mean pressure on right foot (kgf/cm^2)	0.183; 0.079	0.150; 0.148	0.201; 0.053
Mean pressure on left foot (kgf/cm^2)	0.360; 0.000	0.271; 0.008	0.384; 0.000
Maximum pressure on right foot (kgf/cm^2)	0.219; 0.035	0.264; 0.010	0.271; 0.008
Maximum pressure on left foot (kgf/cm^2)	0.210; 0.043	0.216; 0.037	0.259; 0.012
Surface area on right foot (cm^2)	0.711; 0.000	0.645; 0.000	0.831; 0.000
Surface area on left foot (cm^2)	0.688; 0.000	0.632; 0.000	0.779; 0.000

cm^2, square centimeters; kgf, kilogram force; results established using the Spearman correlation coefficient

Table 4: Comparisons between anthropometric data and plantar support variables in children with right and left chewing preference

	Masticatory preference to the right (n = 54)	*Masticatory preference to the left (n = 39)*	*p*
Age	8 (7–9)	8 (8–9)	0.25
Body mass	25 (20–32)	29 (25–36)	0.01*
Height	1.26 (1.17–1.42)	1.30 (1.22–1.43)	0.51
Mean pressure on right foot (kgf/cm^2)	0.14 (0.12–0.17)	0.14 (0.12–0.16)	0.24
Mean pressure on left foot (kgf/cm^2)	0.17 (0.14–0.20)	0.18 (0.15–0.22)	0.24
Maximum pressure on right foot (kgf/cm^2)	0.43 (0.33–0.57)	0.46 (0.37–0.68)	0.22
Maximum pressure on left foot (kgf/cm^2)	0.64 (0.53–0.88)	0.75 (0.52–1.04)	0.19
Surface area on right foot (cm^2)	37.84 (29.50–47.61)	44.15 (36.21–53.51)	0.51
Surface area on left foot (cm^2)	47 (37.43–58.39)	52.29 (42.92–63.28)	0.29

cm^2, square centimeters; kgf, kilogram force; max, maximum; *$p < 0.05$

which presents good to excellent intra- and interrater reliability (ICC 0.65–0.99),[21] The difference in the distance between the points (right tragus and mental symphysis) with the mandible centralized, and lateralized to the right and to the left was measured. Photogrammetry of the face has been used to describe the distance between the eyes and the corners of the lips,[23–25] however, as the present study analyzed mandibular displacement, the points of the right tragus and mental symphysis were used, in an unprecedented way.

Due to the lateral positioning of the mandible, contrary to the established hypothesis, there was no difference in maximum pressure, mean pressure, and area of plantar support. Studies in adults have already shown that changing mandibular position, midline deviations, crossbite, or occlusal components do not alter plantar support.[26–30] However, the present study evaluated children to provide valuable, unprecedented results. It is believed that the lack of difference in the plantar support of children could be justified by the fact that the afferent mechanoreceptors respond mainly to the movements of the mandible, and not to its position.[30] Additionally, compensation mechanisms and bodily adaptations, in response to the child's growth and development, can occur in any structure (bones, muscles, joints, myofascial tissues, etc.) and balance without changing the plantar support. It is known that a child's body growth occurs asymmetrically, and that maintaining proper body posture requires more concentrated effort due to the physiological weakness of the muscles, which become more toned as the child grows and increases muscle activity. It also appears that spontaneous corrections of postural alterations may occur, as well as their aggravation during the period of postural development.[2] However, these adaptations and compensations have not yet been studied and evidenced by the literature.

Furthermore, in the results of the present study, factors such as age-group and chewing side preference did not interfere with mean pressure, maximum pressure, and plantar surface area. This analysis is important because altered dental occlusion related to the preferred chewing side can influence masticatory muscle activity and cause muscle asymmetry and disharmonious bone development.[31] However, despite the chewing side preference shown by the children, there was no influence on plantar support, which can be justified by compensations that may occur in other sensory systems distributed throughout the body.[11] Cenciarini and Peterka state that different sensory input forces cause the nervous system to recruit other sensory sources to stabilize the upright posture, which could justify the lack of alteration in the plantar support variables.[32] Thus, faced with external disturbances, such as asymmetry in the mandibular position, it is believed that other sensorimotor systems may act in an attempt to maintain balance and body posture.[1]

When observing only the plantar support results, regardless of the position of the mandible, the mean pressure, maximum pressure, and surface area were always higher on the left foot (Fig. 2), confirming the results of Bittar et al.[19] The greater plantar support on the left could be justified by the dominance of the right lower limb (the first to climb stairs or kick a ball) and greater support, stability, and support on the ground of the left lower limb. Of note, in the sample of the present study, 87.9% of the children were right-handed, indicating that the right lower limb would be the most mobile and the left lower limb would be responsible for the greatest support. On the other hand, the results of the present study contradict Cavanagh et al.[33] and Pineda-Lopez et al.,[34] who established symmetry in the plantar support of adults. This highlights the question about the change of plantar support in children (larger on the left) and adults (symmetrical), and about adaptations that can occur during growth. Future cohort studies could answer the question about changes in these support patterns from childhood to adolescence, and even adulthood.

There was a moderate to strong correlation between age-group, body mass, height, and the area of the plantar surface on the right and left. These results were expected, as greater age correlates with increased weight and height, leading to larger foot size and plantar surface area. However, this had not yet been presented in studies using baropodometry for children between 4 and 11 years old. Additionally, moderate to strong correlations were found between the mean and maximum pressures of the plantar support, indicating that these two variables do not both need to be evaluated, as they are highly correlated. Thus, future studies could use either the analysis of mean pressure or maximum pressure in their results.

The results of the present study established that mandibular position, age-group, and preferred masticatory side did not influence the plantar support of children aged 4–11 years. Therefore, the use of plantar stance assessment should be contraindicated for establishing any outcome related to mandibular position. However, it is important to highlight as a limitation that the results of plantar support were established with the mandible positioned laterally, without any movement. Future studies could analyze plantar support during the lateralization movement of the mandible, since posture and postural correction require dynamic biomechanical adjustments. Additionally, using a force platform, which is considered the gold standard for the analysis of postural control, could provide more comprehensive insights.

Conclusion

The children evaluated in the present study displaced their mandible more to the left. However, mandibular position, age-group, and preferred chewing side did not alter the mean pressure, maximum pressure, and surface area of the plantar support, which was always higher on the left foot. There was also evidence of a correlation between age, body mass, height, and the plantar surface area, as well as between the mean and maximum pressures of the plantar support.

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