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Change of Pronation Angle of the Subtalar Joint has Influence on Plantar Pressure Distribution

Alteração do Ângulo de Pronação da Articulação Subtalar tem Influência na Distribuição de Pressão Plantar: Um Estudo Preliminar

João Otacilio Libardoni dos Santos[1]
Eliane Fátima Manfio[2]
Felipe Pivetta Carpes[3]
Ewertton de Souza Bezerra[1]
Rudnei Palhano[4]
Aluisio Otavio Vargas Avila[4]

Abstract – Several studies have investigated the relationship between heel pronation with plantar pressure during gait. With a degree of variability and influence of the footwear, usually excessive pronation is associated with higher mechanical loads. However, larger loads are commonly associated with pronation. This study aims to compare the plantar pressure distribution among individuals with different pronation angles of the subtalar joint angle during gait with controlled speed. The maximum angle of the subtalar joint was determined by capturing images in the frontal plane and the pressure plant peaks were acquired by EMED pressure platform. The pronated group showed pressure plant peaks significantly higher in the lateral heel area (18%; p=0.031), medial heel (17%, p=0.034), lateral midfoot (30%; p=0.032) and medial midfoot (41%; p=0.018) when compared to the control group. Excessive pronation of the subtalar joint caused changes in plantar pressure distribution, and an increase in pressure plant peaks, especially in the heel and midfoot regions. This demonstrates the need for a specific care of this population, mainly because the increased pressure plant peaks is related to pain in the feet and onset of injuries.

Key words: Foot; Gait; Pressure; Pronation.

Resumo – *Diversos estudos investigaram a relação da pronação da articulação subtalar com a pressão plantar na marcha. Com certo grau de variabilidade e influência do calçado, geralmente uma pronação excessiva está associada a cargas mecânicas mais elevadas. Contudo, popularmente se associa qualquer índice de pronação com aumento das cargas. Neste estudo buscamos comparar a distribuição de pressão plantar entre indivíduos com diferentes comportamentos do ângulo de pronação da articulação subtalar durante a marcha com velocidade controlada. O ângulo máximo de pronação da articulação subtalar foi determinado por meio da aquisição de imagens no plano frontal e os picos de pressão plantar foram adquiridos através da plataforma de pressão EMED. O grupo pronado apresentou picos de pressão plantar significativamente mais elevados na região do calcanhar lateral (18%; p=0,031), do calcanhar medial (17%, p=0,034), do mediopé lateral (30%; p=0,032) e do mediopé medial (41%; p=0,018) quando comparado ao grupo controle. A excessiva pronação da articulação subtalar provocou alterações na distribuição de pressão plantar, com aumento nos picos de pressão plantar, principalmente nas regiões do calcanhar e do mediopé. Isto demonstra a necessidade de um cuidado especifico em relação e este público, principalmente pelo aumento dos picos de pressão plantar estar relacionado com dores nos pés e com o surgimento de lesões.*

Palavras-chave: *Marcha; Pé; Pressão; Pronação.*

1 Federal University of Amazonas. Laboratory of Human Performance. Manaus, AM. Brazil.

2 Feevale University. Novo Hamburgo, RS. Brazil.

3 Federal University of Pampa. Center for Health Sciences. Applied Neuromechanics Group. Uruguaiana, RS. Brazil.

4 Brazilian Institute of Technology for Leather. Footwear and Artifacts. Biomechanics Laboratory. Novo Hamburgo, RS. Brazil.

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INTRODUCTION

The pronation movement of the subtalar joint is necessary because it assists in the attenuation of impact forces during the phase of body weight support during gait[1], and results from the combination of eversion, dorsiflexion and abduction of the subtalar and mediotarsal joint[2]. For satisfactory impact attenuation, the pronation movement will have an amplitude of approximately 3º to 8º[3,4], whereas amplitudes greater than these characterize excessive pronation, causing greater load on the joint[5,6].

Excessive pronation of the subtalar joint affects the alignment of foot, ankle, leg, pelvis and lumbar region, causing changes in kinetic[7] and kinematic[8] biomechanical parameters during the gait support phase. Because it is a movement performed in a closed kinetic chain, it changes joint torques, reduces rigidity and alters stresses imposed on the structures of the lower limbs and lumbar-pelvic complex[9].

This atypical pattern of movement of the subtalar joint may also lead to an increase in magnitude, velocity and duration of internal rotation of the lower limbs (knee and / or hip) by means of the mechanical interdependence between rotations of the talus and tibia in the talocrural joint[9]. This alteration in alignment exists as a function of a compensatory movement on the triplanar axis of the subtalar joint, which results in a change in the normal alignment in any part of the foot[10].

Although subtalar pronation is related as a parameter of structural overload[9], it is not the only biomechanical variable affected, since plantar pressure undergoes direct changes as a consequence of excessive movements of this joint[11]. Plantar pressure measurements are commonly used to investigate running and gait adaptations, as it is sensitive to neuromuscular and neurological adaptations[12]. Thus, changes in the plantar pressure distribution may indicate abnormal functioning of the subtalar joint[13]. Our hypothesis is that individuals with excessive subtalar pronation (greater than 8º)[3,4] will have higher plantar pressure peaks. Therefore, the aim of this study was to compare the plantar pressure distribution among individuals with different pronation angle behavior of the subtalar joint during gait.

METHODOLOGICAL PROCEDURES

Twenty-one men (27 ± 8 years, 178 ± 6 cm, 76 ± 10 kg), without neurological and musculoskeletal involvement, participated in the study. Participants were classified into 2 groups according to the maximum pronation angle of the subtalar joint (PASmax) determined up to 35% in the gait support phase[3,4]. All participants signed the free and informed consent form approved by the Ethics Committee of Research on Human Beings of the State University of Santa Catarina (184/06).

The variables selected for this study were: Maximum Pronation Angle of the subtalar joint (PASmax) and plantar pressure peaks (PPP) of the foot[14]. First, the pronation of the subtalar joint was calculated by the difference between the relative angle between tibiocalcaneal segments at the initial contact and the maximum relative angle between tibiocalcaneal segments that occurs up to 35% of the gait support phase, calculated in relation to the 100% of the contact phase[15]. The maximum angular value of PAS found during the movement was considered. The anatomical reference points to obtain PAS were arranged as suggested by literature[2] and illustrated in Figure 1a:

- Point A: 20mm from the ground in the central region of the calcaneus;
- Point B: 50 mm from the ground in the central region of the calcaneus;
- Point C: in the region of the calcaneus tendon, at the height of the lateral malleolus; and
- Point D: 150mm above Point C, in the center of the leg.

The calcaneus segment was determined by points A and B and the tibia segment by points C and D (Figure 1b).

The acquisition of kinematic data referring to PAS used a cinemetry system (Spica Technology Corporation ™, Spica Technology Corporation ™, Hollis, USA) with a MotionVision DALLSTAR CA-D6 model camera (Spica Technology Corporation ™, Hollis, USA), operating at sampling rate of 955 Hz, and positioned perpendicular to the movement (frontal plane) 30 cm above the ground. Data processing was performed by DMAS6® software (Spica Technology Corporation ™, Hollis, USA).

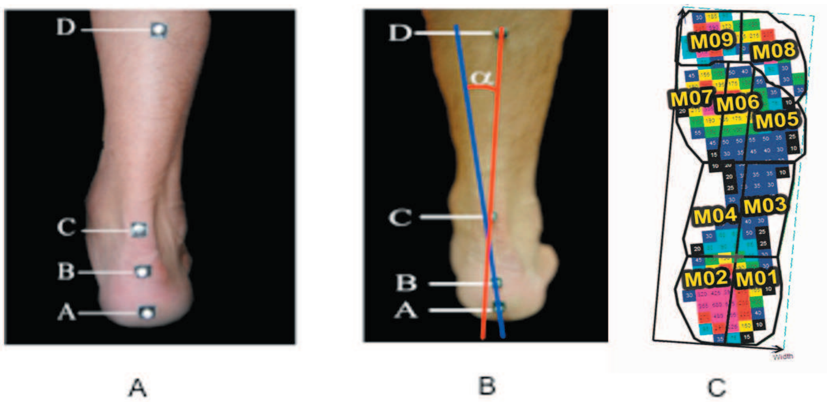

Figure 1 - Location of reference points (A); Relative angle (α) between tibiocalcaneal segments (B); Plantar pressure distribution plantargram divided into 9 regions of the foot (C01) (M01 - lateral heel region, M02 - medial heel region, M03 - mid lateral foot region, M04 - medial midfoot region; M05 – metatarsus region III-V, M06 - metatarsus region II, M07 - metatarsus region I, M08 finger - region II-V, M09 - finger region I).

For calibration of the measurement system, a calibrator of 198 mm in length, 194 mm in depth and 206 mm in height was used, where 13 points were defined. Calibration was performed after recognition of the points marked in the calibrator, and the measurements between points were automatically recognized by the calibration software. After the recognition of the 13 points, the calculated error was less than 1.8 mm. The calibration of the system was redone (filming and scanning the calibrator) always before the beginning of collections or whenever the positioning was changed. To filter data, a 10-10-point interpolation medium-mobile filter was used (Spica Technology Corporation ™).

A pressure platform (Emed-XR, Novel, München, Germany), with sampling rate of 100 Hz was used for the acquisition of kinetic data of plantar pressure distribution (PPP). To control the gait speed (5 km / H ± 5%) during data collection, a set of 4 photocells arranged at a distance of 3m from each other was used, and the pressure platform was positioned in the center of the photocell disposition.

For kinetic data processing (PPP), a mask system was used in the Novel Gmbh® software (Novel, München, Germany). These masks divided the foot into 9 regions, being: lateral heel region (M01), medial heel region (M02), lateral midfoot region (M03), medial midfoot region (M04), metatarsus region III-V (M05), metatarsus region II (M06), metatarsus region I (M07), finger region II-V (M08) and finger region I (M09) (Figure 1c).

On a single day of evaluation, subjects were instructed to walk barefoot at a controlled speed of 5 km / h ± 5%, straight on a walkway (13 m x 1.2 m). After 7 attempts to familiarize with the data collection environment, each subject performed 7 more valid attempts (right foot in contact with the working area of the pressure platform) at controlled speed. To find out when the heel touched the ground, the Spica Technology Corporation ™ system was aligned with the Novel Emed-XR system. Alignment between acquisition systems was accomplished by LED (signal light) of the Novel Emed-XR system that was activated by the heel touch (initial contact) on the sensed platform. The LED emitted a light signal when the capacitive sensors of the Novel Emed-XR platform are loaded with loads greater than 10 kPa (NOVEL, 2006). From the moment the LED was activated, the beginning of the PASmax data analysis was considered. Data were normalized for each participant, considering the first value of the pronation angle of the subtalar joint (initial contact) being 0 (zero).

To verify the normality of data distribution, the Shapiro-Wilk test ($p \leq 0.05$) was used. The Levene test was applied to verify the equality of variance. To evaluate possible differences between groups, the Student's t-test was used for independent samples. Significance level of <0.05 was applied for all tests. Analyses were performed in the SPSS 21.0 for Windows software (IBM, Armonk, New York, USA). The effect size was calculated by $d = M1-M2 / \sigma$, proposed with Cohen[16].

RESULTS

To ensure that the groups were selected according to the study proposal, comparisons of mean PASmax values between groups were performed, finding statistically significant differences ($p = 0.001$). Thus, participants were classified as follows: group with pronation of the normal subtalar joint (Control group n = 11) with PASmax <8° (6.3 ± 0.9°) and group with excessive subtalar joint pronation (pronated group; n = 10) with PASmax> 8° (10.7° ± 2.0°).

Higher plantar pressure peaks were concentrated in the same areas (metatarsus II, medial heel and lateral heel) in both groups. However, pronated group presented significantly higher plantar pressure peaks in the lateral heel region (18%, p = 0.031), medial heel (17%, p = 0.034), lateral midfoot (30%, p = 0.032) and medial midfoot (41%; p = 0.018) when compared to the control group (Table 1).

The size effect for variables lateral and medial heel, lateral and medial midfoot showed great effect for the pronated group, evidencing that such condition places this group 30% above the 50th percentile of the control group. Although variables finger II-V and finger I had small effect, variables metatarsus I, II, III and IV showed average effect, evidencing that the condition with pronation is about 19% above the 50th percentile of the control group.

Table 1. Values for peak plantar pressure (PPP) for the Control Group and pronated group in the different foot regions (Mean ± standard deviation)

Foot regions	Peak Plantar Pressure (kPa)		ES	p
	Control group	Pronated group		
Lateral Heel (M01)	373.81 ± 54.96	453.80 ± 98.35	1.05	0.031*
Medial Heel (M02)	391.21 ± 62.32	468.57 ± 91.46	1.01	0.034*
Lateral Midfoot (M03)	90.76 ± 29.24	129.14 ± 45.60	1.05	0.032*
Medial Midfoot (M04)	78.48 ± 28.80	133.41 ± 63.31	1.19	0.018*
Metatarsus III-V (M05)	342.64 ± 42.91	405.76 ± 140.89	0.68	0.172
Metatarsus II (M06)	410.96 ± 74.27	470.32 ± 92.25	0.72	0.119
Metatarsus I (M07)	277.37 ± 82.30	311.40 ± 82.11	0.41	0.355
Finger II-V (M08)	122.01 ± 57.15	116.77 ± 52.72	0.11	0.830
Finger I (M09)	358.92 ± 112.33	348.88 ± 125.86	0.08	0.849

* Significant differences between control group and pronated group (p <0.05); ES = effect size

DISCUSSION

The aim of this study was to investigate whether excessive pronation of the subtalar joint may influence the plantar pressure distribution. Our main hypothesis was that increased pronation of the subtalar joint alters plantar pressure, leading to higher plantar pressure peaks due to excessive pronation, reflecting in increased joint overload. Our results confirm the hypothesis, since excessive pronators presented higher plantar pressure peaks in the heel (medial and lateral) and midfoot (medial and lateral).

The increase in plantar pressure peaks in the pronated group may have occurred due to the alteration of joint torques, amplitudes of joint movements, reduction of stiffness and length presented by the lower limb, which is characteristic of this pattern of movement [9]. As the lower limbs act in a closed kinetic chain, the knee, hip and lumbosacral joints and trunk positioning may have altered their degrees of movement as a result of changes in the subtalar joint. It is believed that this is possible because it is known that the degree of pronation tends to affect the valgus knee degree, and the higher the amount of pronation, the greater the amount of valgus knee in the support phase[17]. In addition, increased pronation leads to increased flexion, adduction and internal rotation of the hip. When this occurs, the pelvis rotates anteriorly and elevates the rotation forward toward pronation[3]. Thus, it is inferred that these kinematic alterations change the distribution of forces on the ground and consequently modify the plantar pressure distribution.

More specifically, the increase in plantar pressure peaks observed in this study in the pronated group may be associated with an inefficient functioning of the subtalar joint (responsible for the transformation of the tibial rotation into pronation), which is characteristic in individuals who exhibit excessive pronation movement during gait[7,18]. This inefficiency may be related to myoligamentar deficits, since the ankle ligaments counting on the help of the tibialis anterior, tibialis posterior, gastrocnemius and soleus muscles, are the main responsible for avoiding excessive pronation[17]. Hintermann; Nigg[19] argue that changes in pressure distribution may be associated with pronounced and prolonged excessive movements of heel pronation during gait that cause increased stress in the medial region of the foot, modifying pressures in the lateral and medial heel region.

Also, regarding the influence of changes in the kinematics patterns of the lower limbs in the kinetic aspects of gait[7,11], it was verified that changes in the normal biomechanics of the foot / ankle complex significantly influenced the patterns of plantar pressure distribution. There may also be an association between the kinematics of lower limbs (knee) and alteration in the plantar pressure distribution, increasing the risk of developing pain, discomfort and pathologies, especially in individuals who practice repetitive activities and with greater intensity[19].

Another important aspect of this study is that individuals in the control group and in the pronated group had similar patterns of plantar pressure distribution, such as higher plantar pressure peaks in the same areas (Metatarsus II, Medial Heel and Lateral Heel) (Table 1), which demonstrates that it is not possible to differentiate individuals with different eversion angles using only the qualitative analysis of a plantar pressure distribution plantigram or equipment that does not allow a precise quantitative evaluation of kinetic plantar pressure data. This behavior in the plantar pressure distribution shows that as the foot is a flexible structure, with movements that can occur independently in the hindfoot, midfoot and forefoot regions, these structures adjust according to postural changes and adaptation needs of the locomotor apparatus to demands generated during locomotion.

The present study presents certain limitations that should be considered in future studies: anatomical misalignments of lower limbs such as tibial varus, hindfoot varus, and forefoot varus have not been controlled, as well as aspects related to the foot anatomy such as cavus and flat foot and even ligament hyperfloxidation.

CONCLUSION

Excessive pronation of the subtalar joint caused changes in the plantar pressure distribution during gait, with a significant increase in plantar pressure peaks, especially in the heel and midfoot regions. This demonstrates the need for specific care in relation to this public, mainly because increased plantar pressure peaks is related to foot pain and the onset of injuries.

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CORRESPONDING AUTHOR
João Otacilio Libardoni dos Santos
Federal University of Amazonas,
Human Performance Laboratory,
Physical Education and
Physiotherapy Faculty
Avenue General Rodrigo Octavio
Jordão Ramos, nº 3000, Coroado.
CEP: 69077-000. Manaus, AM,
Brazil.
Email: jlibardoni@yahoo.com.br