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ORIGINAL RESEARCH

# Plantar pressure parameters, type and sensitivity of the foot in recruits: a prospective study

*Parâmetros da pressão plantar, tipo e sensibilidade do pé em recrutas: um estudo prospectivo*

*Parámetros de la presión plantar, tipo y sensibilidad de pies de reclutas: un estudio prospectivo*

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**ABSTRACT |** This study aimed to evaluate the characteristics of plantar pressure, type of foot and plantar sensitivity of recruits during the period of compulsory military service. Sixty individuals who performed compulsory military service were assessed for plantar pressure (EPS LoranEngineering baropodometer, Bologna, Italy) and plantar sensitivity to superficial touch (esthesiometer – Semmes-Weinsten Monofilaments) at three different times: March (baseline), June (after 16 weeks of training) and September (after 36 weeks of military training). Antero-posterior and latero-lateral weight bearing, mean pressure, maximum pressure, foot contact area, foot typology were evaluated. and plantar sensitivity. The data were analyzed using the chi-squared test, Anova repeated measures and Friedman test with Bonferroni pos hoc ($p<0,05$). There was an increase in contact area ($p=0,001$) and mean pressure of both feet ($p<0,001$). As for the typology, an average of 60% of the individuals have the dominant foot of the normal type, while the non-dominant foot are cavus (50.3%), that is, the same subjects presented different typologies of the foot. Regarding plantar sensitivity, there was a difference in the midfoot region over training time ($p=0.001$ in the dominant foot and $p=0.009$ in the non-dominant foot). These results demonstrated that there was an increase in average pressure and total foot contact area, and also plantar sensitivity alterations throughout the mandatory military period.

**Keywords |** Foot; Pressure; Mechanoreceptor.

**RESUMO |** Este estudo teve como objetivo avaliar as características da pressão plantar, tipo e sensibilidade do pé em recrutas durante o período do serviço militar obrigatório. Sessenta indivíduos que prestaram o serviço militar obrigatório foram avaliados para pressão plantar (baropodômetro EPS LoranEngineering, Bolonha, Itália) e sensibilidade plantar ao toque superficial (estesiômetro de Semmes-Weinsten) em três momentos distintos: março (linha de base), junho (após 16 semanas de treinamento) e setembro (após 36 semanas de treinamento militar). Foram avaliadas a descarga de peso ântero-posterior e latero-lateral, pressão média, pressão máxima, área de contato do pé, tipologia de pé e sensibilidade plantar. Os dados foram analisados pelo teste do Qui-quadrado, anova de medidas repetidas e pelo teste de Friedman com pos hoc de Bonferroni ($p<0,05$). Houve aumento na área de contato ($p=0,001$) e na pressão média de ambos os pés ($p<0,001$). Quanto a tipologia, aproximadamente 60% dos indivíduos possuíam o pé direito do tipo normal, enquanto o pé esquerdo era do tipo cavo (50,3%); ou seja, mesmos sujeitos apresentaram diferentes tipologias do pé. Em relação a sensibilidade plantar, houve diferença na região do médio pé ao longo do treinamento ($p=0,001$ no pé dominante e $p=0,009$ no pé não dominante). Esses resultados demonstram que houve aumento da pressão média e área total de contato do pé, bem como alterações na sensibilidade plantar da região do médio pé ao longo do serviço militar obrigatório.

**Descritores |** Pé; Pressão; Mecanorreceptores.

**RESUMEN |** Este estudio tuvo como objetivo evaluar las características de la presión plantar, el tipo de pie y la sensibilidad en los reclutas durante el período de servicio militar obligatorio. Sesenta individuos que realizaron el servicio militar obligatorio fueron evaluados para presión plantar (baropodómetro EPS LoranEngineering, Bolonia, Italia) y sensibilidad plantar al tacto superficial (estesiómetro

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Semmes-Weinsten) en tres momentos diferentes: marzo (línea base), junio (después de 16 semanas de entrenamiento) y septiembre (después de 36 semanas de entrenamiento militar). Se evaluaron descarga de peso anteroposterior y laterolateral, presión media, presión máxima, área de contacto del pie, tipología del pie y sensibilidad plantar. Los datos se analizaron mediante el test de chi-cuadrado, el ANOVA de medidas repetidas y el test de Friedman con Bonferroni pos hoc (p <0,05). Hubo un aumento en el área de contacto (p=0,001) y en la presión media de ambos pies (p <0,001). En cuanto a la tipología, aproximadamente el 60% de los individuos tenían el pie dominante de tipo normal, mientras que el pie no dominante era de tipo cavo (50,3%); es decir, los mismos sujetos presentaron diferentes tipologías del pie. En cuanto a la sensibilidad plantar, hubo una diferencia en la región del mediopié durante el entrenamiento (p=0,001 en el pie dominante y p=0,009 en el pie no dominante). Estos resultados demuestran que hubo un aumento en la presión media y el área total de contacto del pie, así como cambios en la sensibilidad plantar en la región del mediopié durante el servicio militar obligatorio.

Palabras clave | Pie; Presión; Mecanorreceptores.

## INTRODUCTION

Musculoskeletal injuries are one of the main causes of soldiers' incapacity and inability to make a military career[1]. A high rate of lower limb injuries has been reported especially in young recruits[2–5]. Activities that present risk of injuries include running and walking over long distances, associated with physically demanding tasks, such as carrying combat equipment additional loads[4,5].

The fatigue of long-distance marches in combination with cargo carriage is considered an important risk factor for lower limb overuse injuries in military personnel[4,5]. Carrying extra loads increases the foot plantar pressure[6,7], which in turn increases bone stress applied to the region, predisposing to injuries[8]. Parameters such as elevated arch[9], increased load on metatarsals[6,10,11], and greater pressure peaks on the heel[12] were identified as risk factors for fractures.

Blisters on the feet are also common lesions with regard to soldier march[4,13] and any change in stiffness in the soles of the feet reduces the sensitivity of the region[14,15]. The reduction in plantar skin sensitivity alters parameters in the distribution of plantar pressure[16,17], and gait parameters are also changed as a protective mechanism[18,19]. This change in load distribution can aggravate pre-existing foot imbalances, increasing the risk of lower limb injuries[20].

In recruits, the risk of lower limb injuries may be even greater considering that many of them experience a rapid increase in the level of physical activity during military training, representing in many cases the first contact of young individuals with regular physical activity[4]. Considering that there is an association between changes in pressure variables and type of foot with a higher risk of injuries in military recruits[9,12]. quantifying the changes in these variables and in plantar sensitivity is important to assess the influence of high-demand physical activities on these characteristics. The objective of this study was to evaluate plantar pressure parameters, type and sensitivity of the foot in recruits during the period of compulsory military service.

## METHODS

This is an observational longitudinal study, with a convenience sampling consisted of 82 young men performing compulsory military service at a Mechanized Cavalry Squadron, who enlisted in the Brazilian Army in March 2018. The study was approved by the Research Ethics Committee and followed the standards of CNS Resolution No. 466/2012. All subjects agreed to participate in the study and signed the Informed Consent Form. Participants who had already undergone surgery and/or had moderate and severe injuries in the hip, knee or ankle region, or who presented this injury severity throughout the study, were excluded. In the first evaluation, musculoskeletal complaints were investigated using the Nordic Musculoskeletal Questionnaire[21], as well as previous injuries and surgeries in the lower limbs through a structured interview developed for the research. Previous injuries were classified according to the period of absence from physical activities: minor injuries correspond to absence of 1 to 7 days; moderate injuries, absence of 8 to 28 days, and severe are those injuries that removed the individual from activity in an interval longer than 28 days[22].

In this first stage, three subjects were excluded because they had already presented knee ligament injuries, and 79 recruits were evaluated. Throughout the study, there was an additional sample loss of 19 subjects: two due to military service withdrawal and 17 due to not attending one of the

subsequent evaluations. Thus, the sample consisted of 60 eutrophic individuals, aged 18.14 ± 0.35, with no history of injuries, previous surgery or significant changes in the lower limbs, feet and ankle according to the Nordic questionnaire[21].

When recruits join the army, they perform military physical training four to five times a week. This training is subdivided into phases – introductory, basic, qualification and preparation – so that each phase follows a progression of load and volume for cardiorespiratory, resistance and muscle strength improvement according to the army's physical and military training manual[23]. In the first three phases, there is a greater physical requirement for the recruit to be able to meet the military demands. In the last stage of training, physical exercises are performed in a lower intensity and volume, preparing the recruit for the dismissal from military service. Based on these phases, three evaluations were performed after each of the three initial phases of training. Thus, the subjects were evaluated in three moments during the period of military physical training: March 2018 (baseline- AV1), June 2018 (after 16 weeks of training- AV2) and September 2018 (after 36 weeks of training- AV3). All evaluations were performed by the same evaluators previously trained for the collection procedure.

For BMI evaluation, a scale using a stadiometer (Welmy brand, W2000A, Brazil) was used, with a resolution of 0.5 cm for height measurement and 0.1 kg for body mass measurement. In AV1, recruits were asked about injuries, previous surgeries and musculoskeletal symptoms through a structured interview and the Nordic Musculoskeletal Questionnaire[21]. This instrument consists of multiple or binary choices regarding the occurrence of musculoskeletal symptoms in all anatomical areas of the body, considering the 12 months and seven days preceding the interview, as well as withdrawal from routine activities. Recruits who presented injuries with no activities for more than 28 days were considered to have severe injuries to their lower limbs and were excluded from the study[22].

In this initial evaluation, the International Physical Activity Questionnaire (IPAQ) was also applied to identify recruits' previous physical activity levels[24]. IPAQ is a questionnaire with 27 questions that allows estimating the weekly time spent in physical activities of moderate and vigorous intensity, in different contexts such as: work, transportation, domestic tasks and leisure, and also the time spent in passive activities performed in a sitting position. Subsequently, this information is used for calculation in specific formulas for each section of physical activity (work, transportation, housework, leisure and sports), with results expressed in metabolic equivalents (METs) at three levels of activity: walking, moderate and vigorous. These results then produce a final score classifying the respondent as presenting low, moderate and high physical activity levels[24]. In order to calculate recruits' scores, answers of the printed version of the questionnaire were recorded on its electronic version (http://www.webipaq.com.br).

In order to evaluate foot sensitivity to superficial touch, a set of Semmes-Weinstein monofilaments with 6 monofilaments was used. Plantar sensitivity was analyzed according to the monofilament thickness classification, allowing a numerical score for each color of the thread: 0.05 g for green; 0.2 g for blue; 2.0 g for violet; 4.0 g for dark red; 10 g for orange and 300 g for magenta red. The greater the thickness of the wire, the lower the capacity for local sensory perception and, consequently, the lower the sensitivity. Plantar sensitivity was evaluated with recruits lying in supine position and instructed to inform the examiner where they felt the filament when it was placed at any point on the foot. The evaluation of foot regions was performed at random among the subjects[25]. and pressure was applied on specific points in the plantar region. These points are recommended to assess the impairment of superficial tactile sensitivity in foot regions[25,26]. On the plantar surface at the medial point of the hindfoot; on the midfoot between the medial arch and the lateral arch; on the 1st, 3rd and 5th metatarsal heads, and on the 1st, 3rd and 5th toes (Figure 1A). To determine the forefoot, midfoot and hindfoot sensitivity (Figure 1B), the mean of the values found in the points of each region was analyzed.

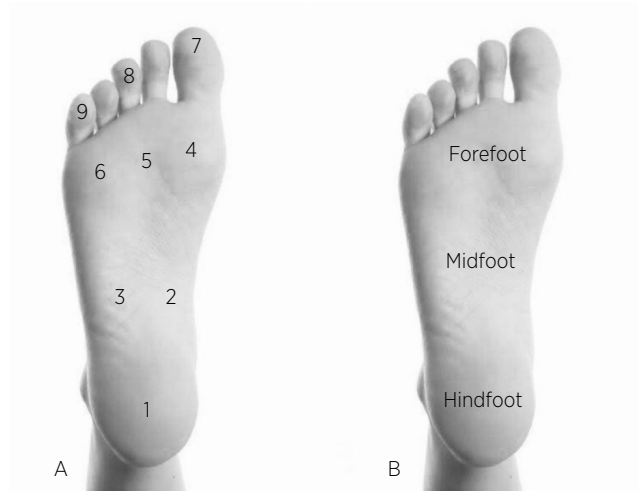


Figure 1. Illustration of sensitivity evaluation points (A) on the plantar surface at the medial point of the hindfoot (1); between the medial arch (2) and the lateral arch of the midfoot (3); on the 1st, 3rd and 5th metatarsal heads (4 to 6) and on the 1st, 3rd and 5th toes (7 to 9). Illustration B shows foot subdivisions used to determine sensitivity per foot region

To measure plantar pressure parameters, an electronic baropodometry system (EPS-R1, Loran Engineering, Bologna, Italy) was used. This system contains an active surface of 480 × 480 mm, dimensions of 675 × 540 × 5 mm, 2304 resistive sensors and an acquisition frequency of up to 100Hz. The subjects remained barefoot, in a static position, with their feet hip-width apart and the upper limbs along the body. The recruits performed the test with heads directed forward , eyes open and looking fixedly at a point marked one meter away, at the height corresponding to the glabellar point, for 20 seconds. Each subject performed the test three times, and the mean value of the three repetitions was used for analysis. Data were analyzed using Biomech® software, and the characteristics evaluated were type of foot (normal, flat or hollow) and plantar distribution (anterior-posterior and latero-lateral). The plantar distribution variables were presented in percentage (%), average and maximum pressure (kPa), and foot contact area ($cm^2$).

### Statistical analysis

Statistical analysis was performed using Statistical Package for the Social Sciences for Windows v.22.0 (IBM, Chicago, IL, USA). Variables normality was evaluated by the Shapiro-Wilk test. Repeated measures ANOVA was used to compare parametric variables, and the Friedman test applied for non-parametric variables. For categorical variables, the comparison between data was performed using the Chi-square test. Bonferroni post hoc test was used for differences between the evaluations. The level of significance adopted was 5% ($p < 0.05$).

## RESULTS

Table 1 presents the recruits' anthropometric data. There was an increase in recruits' body mass in the third evaluation in relation to the first and second evaluations ($p < 0.001$), which was also reflected in a difference in BMI ($p=0.008$). Regarding the presence of musculoskeletal changes in AV1, 18.64% of the 60 recruits evaluated reported knee pain, and 15.25% presented ankle/foot pain. In addition, 75% had a high level of physical activity (n=45), 15% a moderate level (n=9), and 10% a low level (n=6).

The results of the baropodometry variables are shown in Table 2. There was a reduction in the total foot contact area in AV2 in relation to AV1, and an increase in the area in AV2 in relation to AV3 in both feet ($p=0.001$). In addition, there was an increase in the average pressure of both feet in AV1 in relation to AV3 ($p < 0.001$).

Table 1. Anthropometric characteristics of the 60 recruits evaluated in three moments during the first year of military physical training: baseline (AV1), after 16 weeks of training (AV2), and after 36 weeks of training (AV3). Data presented as mean ± standard deviation

| | AV1 | AV2 | AV3 | P |
|---|---|---|---|---|
| Body mass (kg) | 71.78 ±14.15[a] | 72.17 ± 11.72[b] | 73.23 ± 12.42 | 0.000 |
| Height (m) | 1.71 ± 0.06 | 1.71 ± 0.06 | 1.71 ± 0.05 | 0.153. |
| BMI ($kg/m^2$) | 24.30 ± 4.22[a] | 24.61 ± 3.29[b] | 24.92 ± 3.61 | 0.008. |

BMI: body mass index; [a]: significant difference between AV1 and AV3; [b]: difference between AV2 and AV3.

Table 2. Baropodometry variables of the dominant (D) and non-dominant (ND) feet of the 60 recruits evaluated in three moments during the first year of military physical training: baseline (AV1), after 16 weeks of training (AV2), and after 36 weeks of training (AV3). Data presented as median (25% -75%).

| | AV1 | AV2 | AV3 | P |
|---|---|---|---|---|
| Previous weight bearing (%) | 49.2. (46.24-52.95) | 50.12 (44.33-58.03) | 47.92 (42.10-56.05) | 0.265 |
| Posterior weight bearing (%) | 50.8 (43.14-53.75) | 49.88 (41.97-55.39) | 52.06 (43.94-57.89) | 0.281 |
| D lateral weight bearing (%) | 49.92 (48.53-51.54) | 49.73 (47.73-52.10) | 49.76 (47.49-51.95) | 0.803 |
| ND lateral weight bearing (%) | 50.08 (48.45-51.47) | 50.27 (47.89-55.52) | 50.23 (48.05-52.51) | 0.647 |
| D foot total area ($cm^2$) | 106.33 (95-119) | 102.67 (91-117.91)[bc] | 104.16 (93-116.91) | 0.001 |
| ND foot total area ($cm^2$) | 104.83 (94.9-115.6) | 99.83 (90.83-113.5)[bc] | 105.83 (92.41-116) | 0.001 |

(continues)

Table 2. Continuation

| | AV1 | AV2 | AV3 | P |
|---|---|---|---|---|
| D average pressure (kPa) | 61.43 (57.42-71.10)[a] | 64.05 (58.31-74.42) | 64.80 (60.23-74.82) | <0,001 |
| ND average pressure (kPa) | 62.47 (57.99-70.47)[a] | 68.78 (57.51-75.25) | 69.40 (59.01-76.04) | <0,001 |
| D Maximum pressure (kPa) | 238.32 (182.9-284.6) | 231.38 (205-263.2) | 235.17 (185.72-267.4) | 0.475 |
| ND Maximum pressure (kPa) | 232.95 (183.39-276.5) | 225.01 (193-254.8) | 222.98 (198.2-275.5) | 0.628 |

[a]: significant difference between AV1 and AV3; [b]:difference between AV2 and AV3; [c] difference between AV1 and AV2.

Table 3 shows the recruits' type of foot throughout evaluations. Most recruits presented the dominant foot as being of the normal type, while the frequency of non-dominant foot was similar between normal and hollow types. The comparison of the frequencies of types of foot was not different between the three evaluations performed for the dominant foot (p=0.051) and for the non-dominant foot (p=0.998), demonstrating stability of this variable.

As for the evaluation of plantar sensitivity, there were changes in the dominant (p=0.001) and non-dominant (p=0.009) midfoot region. In the dominant foot, there was an improvement in sensitivity in AV2 in relation to AV1 and worsening in AV2 in relation to AV3, returning to the baseline values (AV1). Regarding the non-dominant foot, there was a worsening in sensitivity from AV1 to AV3. Even with this difference between feet, the sensitivity remained preserved with values between 0.05 and 0.2 g (Table 4).

Table 3. Type of foot of the 60 recruits evaluated in three moments during the first year of military physical training: baseline (AV1), after 16 weeks of training (AV2), and after 36 weeks of training (AV3). Data presented in absolute value (percentage).

| | | AV1 | AV2 | AV3 | P |
|---|---|---|---|---|---|
| Dominant | Normal | 40 (66.7) | 35 (58.3) | 36 (60) | 0.051 |
| | Hollow | 30 (18) | 19 (31.7) | 17 (28.3) | |
| | Flat | 2 (3.3) | 6 (10) | 7 (11.7) | |
| Non-dominant | Normal | 27 (45) | 26 (43.3) | 27 (45) | 0.998 |
| | Hollow | 30 (50) | 31 (51.7) | 30 (50) | |
| | Flat | 3 (5) | 3 (5) | 3 (5) | |

Table 4. Values of plantar sensitivity of the dominant (D) and non-dominant (ND) feet of the 60 military recruits evaluated in three moments during the first year of military physical training:: baseline (AV1), after 16 weeks of training (AV2), and after 36 weeks of training (AV3). Data presented as median (25% 75%) of grams (g).

| | AV1 | AV2 | AV3 | p |
|---|---|---|---|---|
| D forefoot | 0.15 (0.1 -0.2) | 0.12 (0.05-0.2) | 0.17 (0.1- 0.2) | 0.057 |
| ND forefoot | 0.13 (0.1 -0.2) | 0.14 (0.05 -0.2) | 0.17 (0.1-0.2) | 0.121 |
| D midfoot | 0.10 (0.05- 0.18) | 0.05 (0- 0.12)[bc] | 0.10 (0.05- 0.2) | 0.001 |
| ND midfoot | 0.10 (0.05- 0.2) | 0.10 (0- 0.12)[c] | 0.12 (0.05- 0.2) | 0.009 |
| D hindfoot | 0.20 (0.08- 0.2) | 0.20 (0.05- 0.2) | 0.20 (0.2- 0.2) | 0.140 |
| ND hindfoot | 0.20 (0.2- 0.2) | 0.20 (0.2- 0.2) | 0.20 (0.2- 0.2) | 0.144 |

[b]: difference between AV2 and AV3; [c]: difference between AV1 and AV2.

## DISCUSSION

The main objective of this study was to investigate whether plantar pressure parameters, type and sensitivity of the foot would change in young recruits after the beginning of military training. It is important to highlight that the subjects were physically active when they started the military service and without significant injuries to their lower limbs according to IPAQ and Nordic questionnaires. This fact may have helped recruits in the transition to military physical training, since they already had a lifestyle that involved the practice of physical

and sports activities. Moreover, BMI values in the first evaluation were within normal limits. Although body composition has not been evaluated, it is presumed that this significant increase over the training period occurred due to the increase in muscle mass, a consequence of the type of training to which they were exposed[27].

The evaluation of the distribution of the anterior-posterior plantar pressure showed that the subjects presented values of anterior weight bearing above normality, and posterior weight bearing below it, according to the values of the study by Pormarino and Pormarino[28], which correspond to approximately 40% anterior and 60% posterior. These values are more discrepant in AV2, which suggests a process of physical adaptation that may be related to long distance running and to carrying military equipment additional loads especially in the first 16 weeks of military physical training. According to Andersen et al.[4], in general weight between 20-68 kg can be considered a typical additional equipment load that soldiers need to carry regularly. Previous studies suggest changes in these parameters in the static standing posture in recruits after military activity with prolonged cargo carriage[29] and in marathon runners after long distance runs[10].

As for foot contact area, there were changes throughout the evaluations, with a reduction from the second evaluation in comparison with the first, and an increase in relation to the third. Despite these changes, the values remained at approximately 100 $cm^2$, which can be considered normal[30]. These changes in contact area can induce the redistribution of plantar pressure under the foot, increasing peak pressure in other locations[31], which has been associated with fractures in the foot and ankle, especially in military recruits[9,12]. In our study, there was a gradual increase in average pressure values throughout evaluations, which can increase recruits' exposure to risk of injuries during mandatory military training.

With regard to type of foot, the dominant foot presented normal type predominance, while the non-dominant foot presented normal and hollow types. Hollow feet tend to have less movement of their structures, greater pressure on the hindfoot and lateral forefoot, decreasing their ability to attenuate shock[32]. The characteristics of plantar pressure are also different according to each type of foot[32], which may explain the different values in plantar pressures found in this study, considering foot typology differences in the same subject.

Differences in the evaluations of plantar sensitivity in the midfoot showed preservation of sensitivity on the dominant side and reduction on the non-dominant side at the end of 36 weeks of training. Despite these changes, recruits showed a normal sensitivity (0.05 to 0.2 g), corresponding to the first two evaluation monofilaments[25,26]. Thus, the differences in the distribution of plantar pressure cannot be attributed to changes in plantar sensitivity.

A limitation of the study is that there was not a control group without strenuous physical activities to evaluate these variables. In addition, recruits were not asked about usually wearing other shoes or about practicing physical activities parallel to military physical training. However, considering that recruits spend most of the day in the barracks performing activities during the mandatory service period, it can be considered that recruits in this sample wore the same shoes and performed the same activities for at least 36 hours a week.

Military physical training produced changes in baropodometry parameters and plantar sensitivity. There was a difference in the foot contact area and average pressure, as well as higher values of anterior weight bearing. In plantar sensitivity, the midfoot region showed preservation of sensitivity on the dominant side and reduction on the non-dominant side. These changes occurred essentially after the first weeks of training, a phase of greater physical demands and adaptation to military routine. It is believed that these changes occur due to the intensity of physical exercises in military training and may increase the risk of injury in this population.

## CONCLUSION

Mandatory military physical training generates changes in baropodometry characteristics and plantar sensitivity in recruits. There is an increase in average pressure and total foot contact area, as well as changes in plantar sensitivity in the midfoot region over 36 weeks of mandatory military service.

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