Relationship of Footwear Comfort, Selected Size, and Lower Leg Overuse Injuries Among Infantry Soldiers

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Abstract

Introduction

High rates of musculoskeletal injuries such as plantar fasciitis and stress fractures have been observed among physically active military personnel. During service time, infantry soldiers use issued boots daily that should be a proper fit and provide comfort to effectively prevent injuries and decrease lower extremity pain. This study compares the subjective infantry boot size with optimal size and investigates perceived boot comfort for different boot parts among soldiers with and without a history of lower leg, ankle, and foot overuse injury.

Materials/Methods

During the cross-sectional study, 227 (males, $n=213$; females, $n=14$) active-duty infantry soldiers at a mean age of 29.5 years old, and with an average service time of 7.2 years were assessed for a history of overuse injury, footprint length, appropriate shoe size, and footwear comfort. Males with a history of overuse injury ($n=32$) and non-injured age-matched controls ($n=34$) were selected for detailed testing and establishing the possible relationship between footwear comfort and lower leg overuse injury.

Results

No relationship was found between footwear comfort and history of lower leg overuse injury. $N=38$ (57.6%) of study subjects were wearing an inappropriate shoe size daily. Inappropriate shoe size usage affected footwear comfort ratings significantly.

Conclusions

Study results showed that improper boot size was significantly related to comfort ratings but was not associated with a history of lower leg overuse injury.

Introduction

Most of the military personnel require high physical demands during service time. Typical injuries associated with physical training and prolonged load carriage are stress fractures, shin splints, patellofemoral pain, plantar fasciitis, and Achilles tendinopathy.[1–4]

Lower extremity injuries reduce military readiness and could even be a reason for medical discharge.[4] It has been reported that 41%-67% of sustained injuries among the military affect the lower extremities.[5–7] During training or actual combat scenarios, military personnel uses military boots that protect the shank and foot from environmental hazards such as irregular and uneven terrain.

Footwear comfort has been defined as a combination of several factors including adequate fitting, internal temperature, humidity environment, plantar pressure distribution, and ground impact force.[8–10]

Clinical effects of poor-fitting or uncomfortable footwear are pressure-induced skin lesions and toenail problems.[11, 12] Footwear comfort is associated with reduced running energy expenditure and it has been proposed as an important factor for all movement-related lower extremity injuries.[13, 14] Associations of chronic foot disorders (e.g. pes planus, hallux valgus) and acute injuries (ankle fracture or sprain) with military boot usage, as well as military boot functional needs were established previously. [15, 16] This is the first study that compares the subjective infantry boot fit with optimal fit and investigates perceived boot comfort for different boot parts among infantry soldiers with and without a history of lower extremity overuse injury.

Infantry soldiers of Land Forces form one of the biggest military branches of the Latvian Army. As standard, two pairs of military boots that protect the distal shank and foot are issued to infantry soldiers for hot and cold weather conditions, respectively. Providing infantry soldiers with comfortable boots that meet their functional needs has the potential to reduce overuse injuries and, additionally, the previous lower extremity overuse injury impact on comfort rating was assessed.

Methods

We carried out a study on designed in two stages: stage I - cross-sectional study and stage II case-control study. For details, see Fig. 1 *Flow chart of the study design*. In total, 227 (16%) of all active-duty infantry soldiers of Latvian Land Forces (males, n = 213; females, n = 14) were randomly selected for participation in our study during the annual medical check-up at the Latvian National Army Logistic Command Military Medical Support Centre. Their mean age was 29.5 ± 7.1 years old (range 20–49 years), service time 7.2 ± 6.4 years (range 0.5–25 years). Study population characteristics are shown in Table 1.

Table 1
Cross-sectional study population characteristics

	Total (n = 227)	Males (n = 213)	Females (n = 14)
Age, years (SD)*	29.5 (7.2)	29.4 (7.0)	32.1 (8.3)
Service time, years (SD)	7.2 (6.4)	7.1 (6.4)	8.3 (6.5)
History of total lower extremity overuse injury, % (n)	42.7 (n = 97)	43.2 (n = 92)	35.7 (n = 5)
History of lower leg and foot overuse injury, % (n)	15.0 (n = 34)	15.0 (n = 32)	14.3 (n = 2)
Foot blisters after long marching, % (n)	46.3 (n = 105)	46.5 (n = 99)	42.9 (n = 6)
Usage of foot orthotics, % (n)	4.9 (n = 11)	4.7 (n = 10)	7.1 (n = 1)
*Standard deviation (SD) is given in brackets.			

During an interview, we asked soldiers about the history of musculoskeletal injuries during the last six months and military footwear comfort. Musculoskeletal injuries were classified into two groups: acute and overuse injuries. Acute injuries were classified by ICD-10 [17] codes S00-T32. Overuse injuries were defined as injuries caused by repetitive or forceful tasks occurring as a result of repeated overstretching or overloading.[18] Such injuries as an anterior or posterior tibial syndrome (ICD-10 code M76.8), plantar fasciitis (M72.2), Achilles tendonitis (or bursitis, M76.6), peroneal tendinitis (M76.7), and stress fractures (M84.3) were classified as overuse injuries. For both types of injury, body regions were classified in the same manner as in the Barell injury matrix.[19] We assessed the footwear comfort rating for six dimensions: overall comfort, forefoot cushioning, arch cushioning, heel cushioning, arch support, heel support, according to a previously used method.[20] A visual analogue scale with a ten-centimeter length was used. The left end was labelled as ‘not comfortable’ (0) and the right end was labelled as ‘best comfort’ (10).

For the second stage of our study, we have invited 32 (14%) subjects with a history of lower leg, ankle, and foot overuse injury and 34 (15%) age-matched non-injured subjects for more detailed testing. Visual foot skin inspection and bare footprint length were additionally assessed. The presence of any blisters, corns, or calluses, as well as ingrown toenail and subungual haematoma, was documented according to the classification by Carr & Cropley. [21] Characteristics of the case-control study population are shown in Table 2.

Table 2
Case-control study population characteristics

	Total (n = 66)	Subjects with prior OI* (n = 32)	Non-injured subjects (n = 34)	P value [†]
Age, years	29.7 (5.5)	29.0 (5.7)	30.5 (5.3)	0.12
Height, m (SD [‡])	1.81 (0.13)	1.81 (0.13)	1.81 (0.13)	0.96
Weight, kg (SD)	81.3 (12.9)	81.3 (13.3)	81.2 (12.6)	0.96
Foot length, mm (SD)	274 (13)	275 (13)	273 (13)	0.19
Usage of foot orthotics, % (n)	(n = 4)	12.5 (n = 4)	0	0.04
Foot blisters after long marching, % (n)	57.6 (n = 38)	53.1 (n = 17)	61.8 (n = 21)	0.16
Foot skin lesions, % (n)	(n = 14)	(n = 6)	(n = 8)	0.58
Toenail problems, % (n)	(n = 18)	(n = 14)	(n = 4)	0.01
*OI – overuse injury. [†] One-way ANOVA test results; significant results are marked in bold. [‡] Standard deviation (SD) is given in brackets.				

For footprint length assessment, participants were asked to stand in a relaxed manner on a pressure platform (2 m×0.4 m×0.02 m, RSscan International, Belgium). Plantar pressure analysis software (Footscan v.7.11, RSscan International) was used to detect precise footprint length in millimeters (for details see Fig. 1). The footprint width was not analyzed. To detect the correct shoe size, bare footprint length was converted to shoe size using the metric footwear sizing - Mondopoint system. [22] We have compared the used self-selected shoe size with a suitable shoe size according to the bare footprint length.

The size of issued military boots is self-selected by the soldier based on their previous shoe fitting experience, each size has only one width and half-sizes have not been provided. Given that the average annual air temperature in Latvia is + 5.9°C [23], and for most of the year soldiers use boots for hot weather conditions, we only assessed the footwear comfort rating for this type of issued infantry boot. See Fig. 2 *Infantry boot*.

Statistical analysis was performed using the SPSS 22.0 software package. For group difference, assessment nonparametric tests were applied. Quantitative variables are presented as means with standard deviation; categorical variables are presented as frequencies if not stated otherwise. The significance level was set to $p < 0.05$ (two-tailed).

Results

Footwear comfort rating

Footwear comfort rating was assessed for all study participants ($n = 227$). Footwear comfort rating differences between gender groups were independent of the previous history of overuse injury. The highest overall footwear comfort rating was 6.7 in non-injured males group. The lowest rating 5.2 was observed for the heel cushioning among the non-injured females group. Mean footwear comfort ratings among females were lower across all dimensions, but the difference with the male group was not statistically significant (see Table 3).

Table 3
Mean military footwear comfort ratings

	Males (n = 213)		Females (n = 14)		P-value [‡]
	With prior OI* (n = 92)	Non-injured (n = 121)	With prior OI* (n = 5)	Non-injured (n = 9)	
Overall comfort	6.3 (1.8) [†]	6.7 (1.7)	5.6 (2.1)	6.1 (2.2)	0.16
Forefoot cushioning	6.0 (1.9)	6.4 (1.8)	5.6 (1.7)	5.7 (2.0)	0.12
Arch cushioning	6.1 (1.8)	6.2 (2.0)	5.6 (1.8)	6.1 (1.7)	0.67
Heel cushioning	6.2 (1.8)	6.2 (2.0)	5.6 (1.3)	5.2 (2.0)	0.84
Arch support	6.0 (1.9)	6.4 (1.9)	6.0 (1.7)	5.7 (1.9)	0.19
Heel support	6.2 (1.9)	6.7 (1.8)	5.8 (1.6)	6.0 (2.4)	0.05
*OI – overuse injury; [†] Standard deviations are given in brackets; [‡] One-way ANOVA test results comparing injured and non-injured groups.					

Footwear sizing analysis

In total, n = 66 male subjects were additionally tested to assess the relationship between footwear comfort and lower leg overuse injury. For the additionally tested group, self-selected military footwear sizes were converted to millimeters using the Mondopoint system and then compared with footprint length measurement from Footscan software. As a result, 57.6% (n = 38) of all study subjects daily were wearing an inappropriate shoe size: 30.3% among subjects with a history of overuse injury (n = 20) and 27.3% among subjects without a history of overuse injury (n = 18). Only six subjects wore bigger shoe sizes, and others (n = 31) used a smaller shoe size than it would be recommended according to their foot measurement. Self-selected shoe sizes were statistically significantly different among groups (p = 0.04). See Table 4 for details.

Table 4
Military footwear sizing preferences

	Total (n = 66)	Subjects with prior OI* (n = 32)	Non-injured subjects (n = 34)	P value [†]
Self-selected EU[§] shoe size, (SD)	43 (1.5)	43.5 (1.6)	43 (1.4)	0.04
Measured EU shoe size, (SD)	43.6 (1.6)	43.9 (1.6)	43.4 (1.5)	< 0.01
Suitable shoe size usage, % (n)	42.4 (n = 28)	37.5 (n = 12)	47.1 (n = 16)	0.16
Inappropriate shoe size usage, % (n)	57.6 (n = 38)	62.5 (n = 20)	52.9 (n = 18)	
*OI – overuse injury. [†] Chi-square test results; significant results are marked in bold. [‡] Standard deviation (SD) is given in brackets.				
[§] EU – European shoe size.				

Lower extremity overuse injury and comfort rating

Subjects who wore the wrong shoe size in both (injured and non-injured) groups showed lower military footwear perceived comfort ratings across all dimensions, independent of previous lower extremity overuse injury. For most of the comfort dimensions, the difference between injured and non-injured groups was statistically significant. Detailed results are shown in Table 5.

Table 5
Military footwear comfort rating comparison among study subjects

	Subjects wearing inappropriate shoe sizes (n = 38)		Subjects wearing suitable shoe sizes (n = 28)		$\chi^2(1)$	P value [†]
	With prior OI* (n = 20)	Non-injured (n = 18)	With prior OI* (n = 12)	Non-injured (n = 16)		
Overall comfort	6.69 (1.22)	6.91 (1.11)	7.29 (1.04)	7.28 (1.33)	5.23	0.02
Forefoot cushioning	6.24 (1.57)	6.18 (1.78)	7.00 (0.98)	6.59 (1.72)	4.17	0.04
Arch cushioning	6.24 (1.57)	6.15 (1.79)	6.88 (1.36)	6.53 (2.00)	3.61	0.06
Heel cushioning	6.29 (1.38)	6.26 (1.52)	6.92 (1.38)	6.66 (1.66)	5.06	0.03
Arch support	5.90 (1.79)	6.15 (1.74)	6.75 (1.59)	6.63 (1.88)	4.38	0.04
Heel support	6.38 (1.61)	6.47 (1.58)	7.58 (1.02)	7.19 (1.18)	11.07	<0.01
OI – overuse injury. [†] Kruskal Wallis test results; standard deviation is given in brackets. Significant results are marked in bold.						

Discussion

An infantry soldier's feet are regularly exposed to great forces and are constantly adapting to various environments. Footwear is an important external factor that can change lower limb biomechanics and improve gait economy. Foot health and footwear comfort are crucial for the military readiness of infantry soldiers. Shock absorbance and stability on uneven terrain are also very important military footwear features. Footwear shock-absorbance study results among Israeli infantry recruits showed that soldiers who used basketball shoes during basic training had a lower incidence of overuse injuries of the foot (18%) compared with those who wore infantry boots (34%). The authors of the study concluded that the basketball shoes' shock attenuation reduced foot overuse injuries, but not injuries at other lower extremity locations.[24] Recently, it has been postulated that military footwear specifically made for prolonged standing and marching, adverse weather conditions, and with a proper fit may be effective in preventing injuries and decreasing lower extremity pain.[25, 26]

To the author's knowledge, this is the first attempt to systematically evaluate perceived footwear comfort for different dimensions in a relationship with previous foot overuse injury among infantry soldiers. The present study assessed military boot comfort ratings and footwear fit among infantry soldiers with and without a history of lower extremity overuse injury. However, the overuse injury definition used widely is not uniform, we used the definition that emphasizes a mechanism of gradual onset and underlying pathogenesis of repetitive microtrauma as it has been recommended by Roos et al.[27] Previous military

footwear research performed in 1976 focused on different lower extremity disorders, both acute (ankle fractures) and overuse injuries (heel contusions, toe paresthesia, and retrocalcaneal bursitis), and military boot comfort data for different boot dimensions remained unknown.[15, 16] Since that time military boot design and materials have been researched and significantly changed which should contribute to better perceived comfort and a standardized military footwear comfort evaluation tool is needed.

Footwear comfort measures are difficult to compare with other studies due to methodological differences. Perceived comfort perception in our study was measured using a visual analogue scale, not only for overall comfort but also for cushioning and the support of different foot parts.[20] Muniz et al. reported only overall footwear comfort among Brazilian army recruits that varied from 5.5 to 7.7 points, with higher comfort provided by softer midsole and lower boot weight.[28] Paisis et al. investigated perceived comfort among the Greek army and study results showed that participants also preferred walking with the lightest weight boot. It has been reported that reduced weight, increased stiffness, and construction of military boots could be beneficial for higher footwear comfort.[29] Types of military footwear materials, shock-absorbing possibilities, and footwear weight were not assessed in our study.

Footwear sizes in the Latvian Land Forces are self-selected by the soldier. Footwear sizes vary among different producers and soldier footwear size choice is based on previous experience, which can be wrong. Study findings conducted among infantry of Canadian Land Forces showed that personnel footwear was not fitted properly according to foot length and width.[30]

We compared self-selected footwear sizes with recommended footwear sizes (based on footprint length). For size conversion, we used a universal Mondopoint footwear size measurement system, which is made on a statistically constructed human foot and uses foot length in millimeters. Our study findings showed 56% of study participants wore inappropriate shoe sizes and these results are consistent with the previously mentioned study.[30] Wearing incorrectly sized footwear is a common problem and it has been associated with foot pain and foot disorder.[31] The fit of the shoe has been associated with skin disorders of the foot such as corns and calluses. In our study, foot skin disorders were not prevalent among both study groups, and recently it has been postulated that corns and calluses could be indicative of the asymmetrical behavior of the lower limbs during gait. [32] Toenail disorders, which could be a result of the tight toe box of footwear [21], were more prevalent among subjects with prior overuse injury who used an inappropriate shoe size. Highly rated footwear comfort is possible if the proper fit is provided, and our study results show moderately low comfort ratings.

Our study subjects who were using inappropriate shoe sizes showed statistically significantly lower military footwear perceived comfort ratings across all dimensions, and these results are partly consistent with previous findings. It has been reported that inappropriate shoe fit could lead to discomfort and also contribute to lower extremity overuse injury due to gait adaptations.[33] Our study results showed no relationship between footwear comfort ratings and lower extremity injury history. Grier et al. have identified that changing the type of footwear did not lower injury incidence, although poor footwear fit and cushioning were associated with foot pain and discomfort. According to our study results, subjects

wearing the wrong shoe size reported lower footwear comfort ratings. To potentially increase footwear cushioning and comfort, insoles have been recommended.[25]

These study findings should be considered in the context of study limitations. The cross-sectional study design is a limitation due to the inability to establish causal sequences and recall bias of history of injury, and a relatively small study population. Grouping of the case-control study also depends on participant honesty, and it has been reported that approximately half of the injuries among military populations are not usually reported to medical personnel.[34] One more limitation is that one type of infantry boot comfort rating was assessed, for hot weather conditions only. Despite these limitations, the strength of this research is that it comes from a relatively homogeneous population and helps to gain more understanding of military footwear fit and comfort comparing previously injured and non-injured infantry soldiers groups.

According to our study, proper fit is an important factor that leads to more comfortable military footwear usage. To provide better footwear comfort it is recommended to issue adequate military footwear size according to foot measurement using footprint length analysis or a Brannock device. The findings from this study could also provide valuable information on footwear comfort to other users of work boots.

Conclusions

To the authors' knowledge, this is the first study of subjective infantry boot fit and comfort among infantry soldiers considering a history of lower extremity overuse injury. Study results showed that inappropriate infantry boot size significantly affects footwear comfort ratings. History of previous lower extremity overuse injury was not related to either shoe size selection or footwear comfort ratings. Based on our study results, we recommend footprint length assessment for proper footwear size selection.

Declarations

Ethics approval and consent to participate

Participation was voluntary. All study participants provided written informed consent. Ethical approval was obtained from the Ethics Committee of Rīga Stradiņš University (No. 40/26.10.2017).

Consent for publication

Not applicable.

Availability of data and materials

Datasets analysed in this study are not publicly available because Latvian National Army Logistic Command Military Medical Support Centre did not permit data sharing. Request to access the datasets

should be directed to the corresponding author.

Competing interests

The authors have no competing interests to declare.

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Authors' contributions

DN contributed to the whole study (research design, literature review, data collection, and analysis, writing the manuscript). NV contributed to the research design and data collection. AS contributed to the data analysis and manuscript writing. All the authors read and approved the final manuscript.

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Figures

Figure 1

Flow chart of the study design.

Figure 2

Infantry boot.