Research Paper

Muscle Activity During Running With New and Used Military Boots in Healthy and Pronated Feet Males

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ABSTRACT

Purpose: Footwear used by military individuals is essential to be scientifically evaluated during daily activities. This research aims to examine muscular activities while running with rubber's new boots compared to used boots in men with healthy and pronated feet.

Methods: Twenty-four men aged 20-25 years (12 men in the pronated group, and 12 men in the healthy group) participated in this research using the convenience sampling method. The subjects received two used and new boots. The boots were made of rubber. Electromyography (EMG) data of the dominant limb were collected while running at constant speed.

Results: The main effect of "boot type" for semitendinosus muscle activity ($P=0.018$, $\eta^2=0.248$) during the loading phase and tibialis anterior ($P=0.041$, $\eta^2=0.177$) during mid-stance.

Conclusion: Rubber boots mileage effect on selected muscle activities in men with and without pronated feet. The use of used rubber boots can increase running-related risk factors.

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Highlights

- Muscle activities were assessed during running with used and new boots in men with healthy and pronated feet.
- Rubber military boots affect selected muscle activities in men during running tasks.
- Use of used rubber military boots can increase the possibility of injury in pronated feet.
- It is advisable to replace your military boots after a prolonged period of intense use.

Plain Language Summary

Lower limb co-contraction increases energy expenditure during daily or sports activities. In this study, the effect of different types (three types) of military boots mileage was assessed on knee muscular co-contraction during running. Twenty-four healthy men (n=12) and pronated feet (n=12) received different new and used boots. They used these boots for 6 months. An electromyography (EMG) device was used to record EMG data of lower limb muscles. Pre and post-intervention, co-contraction values were calculated while running at constant speed. The use of used rubber boots can increase the possibility of injury in pronated feet.

Introduction

The demanding physical activity required of military personnel often leads to a significant number of injuries during the 8-week recruit training, with a reported incidence of these injuries ranging from 25% to 37% in men and 44.6% to 54.9% in women [1, 2]. The injuries that occur frequently among military personnel during training impact the lower extremities, with reported cases, including tibia stress fractures and metatarsal bones, as well as post-patch pain syndrome [3]. Military shoes are related to the possibility of injury due to poor cushioning [1, 4]. Individuals who work in military offices need to wear boots for daily activities [5]. Orr et al. proposed that most task volume for Australian soldiers consists of marching on hilly and uneven terrain, accounting for approximately 60%-70%, while only 25% of the tasks are performed on flat terrain [6]. Therefore, it is essential to evaluate muscle activity during running as a means to deduce potential alterations in military footwear. Muniz et al. discovered that shoes with thicker rubber midsoles were more successful in reducing impact, while lighter shoes with softer polyurethane midsoles were deemed the most comfortable [7]. Nevertheless, the impact of rubber military boots on lower extremity muscle function in individuals with foot pronation has not been scientifically investigated.

Pronated foot prevalence is about 21% [8, 9], and can be related to deformities of the lower extremity [10]. Thus, flat feet affect the timing and amplitude of activation of the lumbar-pelvic muscles and cause back pain or dysfunction in this region [11, 12]. On the other hand, a previous study found that about 19% of the students were normal, while about 82% of these individuals had lower limb abnormalities. Knee flexion at about 4% and leg supination at about 4% had the lowest frequency, while hallux valgus and knee varus showed the highest frequency at 54% and 39%, respectively [13]. For the military, races occur on different surfaces (e.g. in meadows, forests, dirt roads, and city streets). The surfaces differ in their flatness, stiffness, and flexibility, leading to specific responses of the neuromuscular system to the proper regulation of stiffness [14]. Runners adapt their leg stiffness to surface characteristics [15]. Stiffness can be associated with short stretch reflex response latency, joint angle, and fatigue [16].

Attempts have long been made to improve cushioning in running shoes [17]. However, the effect of military shoes on sports footwear was also assessed in other studies [18-20]. Most importantly, a specific type of outsole, such as rubber, has not been studied for running and sustained use. However, Brazilian Army recruits are given a rubber boot with a midsole when they enlist in the army. From 2013, boots supplied to recruits were lighter than in 2010 [21]. However, recruits may opt for a commercial shoe with a polyurethane material, commonly explained as comfortable [22]. Boots with rubber and polyurethane midsoles have already been evaluated, but no studies were found to compare long-term boots with rubber midsoles. Sinclair et al. [5] reported that a cellular material, such as polyurethane has sufficient cushioning

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Figure 1. New and used rubber military boots

Figure 2. Recorded muscle activity with rubber military boots during running

characteristics with smaller tear resistance, while rubber is more durable [23]. Thus, this study was conducted to compare muscular activities while running on the rubber's new military boots compared to the use of military boots in men with healthy and flat or pronated feet.

Materials and Methods

This cross-sectional research was quasi-experimental and laboratory. G^*Power software, version 3.1 was used to estimate the number of required samples based on a previous study for electromyography (EMG) variables [24]. This software suggested at least 12 participants to be included in the present study. A sample of 24 male people was selected using the convenience sampling method. A total of 12 subjects were in the group with the pronated foot and 12 healthy ones in the control group. In the healthy group, the exclusion criteria included a history of surgery and postural disorders.

Experimental procedures

Participants received new and used boots. Also, running trials were performed on an 18-m straight run path at constant velocity (about 3.2 m/s). Before the pre-test, we gave a new pair of military boots (Arsan Sanat Aghanezhad (private company), Rubber, made in Iran-Tabriz) for all subjects (Figure 1). Three running trials across the walkway were performed to familiarize the subjects with the laboratory environment. EMG activities of the dominant lower limb muscles were registered during running. Three running trials were assessed during each condition [25]. Maximum voluntary isometric contraction (MVIC) values were recorded for each muscle for the normalization process.

EMG

`Statistical analyses

Normal distribution was affirmed by the Shapiro-Wilk test. A two-way analysis of variance (ANOVA) with repeated measures test was applied in the statistical section with SPSS software, version 26 at an α level of 0.05. Partial eta-squared (η^2_p) was used to calculate effect size values.

Results

No significant main effect of demographic character was observed in both groups (P>0.05), (Table 1).

Effects of "boot" for ST muscle activity in loading were observed (P=0.018, η^2=0.248). Greater ST activity in new boots condition than in using one was observed (Table 2).

The main effects of "boot" for TA muscle activity at mid-stance were observed (P=0.041, η^2=0.177). Significantly greater TA muscle activity in new military boots condition than in used ones was observed (Table 3).

The results did not show a significant effect of boot, group, and boot-by-group interactions for the push-off phase (P>0.05) (Table 4).

Table 1. Anthropometric characteristics of both groups

Demography	Groups		P
	Healthy	Pronated	
Age (y)	21.57±2.34	20.25±1.36	0.991
Body height (m)	1.76±2.37	1.77±1.06	0.936
Body mass (kg)	65.35±4.25	69.48±3.26	0.899

PHYSICAL TREATMENTS

Discussion

This study was conducted to evaluate muscular activities while running on the rubber's new military boots compared to used military boots in men with healthy and pronated or flat feet. The study was the first to evaluate the compare muscle activity of the rubber's new military boots and use it on active male adults with pronate feet.

Our results showed that semitendinosus muscle activity increased significantly at the loading phase while using military boots. The rectus femoris has reportedly played a crucial role in hip flexion, as well as the gluteus medius and semitendinosus which extend the hip at the stance phase that produces forward drive in healthy individuals [32]. Previous studies have shown that shoe flexibility can improve running mechanics [33]. In addition, the semitendinosus can help hamstrings limit knee extension during the late swing phase [32]. Thus, increased support and compression pressure caused by wearing rubber boots appears to increase muscle contraction efficiency. Therefore, rubber military boots are not recommended for people with foot pronation. Our results showed that the TA activity increased during mid-stance in the combat boots under condition. Greater activity of the tibialis anterior muscle in the pre-activation result phase has been reported in greater TA stiffness when running on asphalt, consistent with stiffer surfaces causing stiffer, higher impact forces than less stiff ones when running [34]. In heel-to-toe walking, TA pre-activation is responsible for two actions, along with co-activation, it aids in plantar flexor activation, allowing for greater initial plantar flexor stiffness at the first moment of ground contact and acts as an absorber and corrector of pronation in the first thirty milliseconds after heel strike [34]. By changing the reactivation of the ankle muscles and possibly changing the kinematics of the legs, runners can adapt their stiffness to the stiffness of the surface, as is the case with running. Lower muscle stiffness results in less controlled foot position on the

Table 2. EMG data at loading phase

Variables (%MVIC)	EMG Variables of Rubber Military Boot				Sig. (η^2)		
	Healthy		Pronated		Main Effect Boot	Main Effect Group	Interaction: Boot×Group
	New	Used	New	Used			
TA	101.15±24.78	109.79±21.74	102.88±23.09	97.16±13.10	0.377 (0.039)	0.790 (0.004)	0.325 (0.048)
Gas-M	115.89±65.55	97.21±34.28	117.84±39.38	141.46±49.89	0.148 (0.102)	0.813 (0.003)	0.164 (0.095)
VL	69.75±33.34	60.19±16.82	49.94±15.83	62.70±23.25	0.291 (0.056)	0.822 (0.003)	0.129 (0.111)
VM	58.76±25.96	65.57±46.40	67.32±15.35	54.43±12.11	0.938 (0.001)	0.866 (0.001)	0.367 (0.041)
RF	31.81±10.27	30.92±4.97	32.39±11.19	31.26±10.43	0.724 (0.006)	0.944 (0.001)	0.849 (0.002)
BF	57.31±15.24	76.40±38.60	65.18±16.84	82.16±51.77	0.578 (0.016)	0.072 (0.153)	0.932 (0.001)
ST	68.44±19.94	74.13±16.38	60.12±23.89	57.86±19.09	0.018 (0.249)	0.549 (0.018)	0.555 (0.018)
Glut-M	98/.53±67.07	89.94±35.25	107.01±62.85	135.31±57.16	0.201 (0.081)	0.615 (0.013)	0.373 (0.040)

PHYSICAL TREATMENTS

Abbreviations: TA: Tibialis anticus; Gas-M: Medial gastrocnemius; BF: Biceps femoris; ST: Semitendinosus; VL: Vastus lateralis; VM: Vastus medialis; RF: Rectus femoris; Glut-M: Gluteus medius; MVIC: Maximum voluntary isometric contraction.

Table 3. EMG data at mid-stance

Variables (%MVIC)	EMG Variables of Rubber Military Boot				Sig. (η^2)		
	Healthy		Pronated		Main Effect Boot	Main Effect Group	Interaction: Boot×Group
	New	Used	New	Used			
TA	105.31±17.44	118.74±24.66	101.67±18.28	99.68±11.16	0.041* (0.177)	0.274 (0.060)	0.221 (0.074)
Gas-M	104.73±61.99	113.51±42.05	113.28±28.11	169.19±102.52	0.095 (0.133)	0.171 (0.091)	0.186 (0.086)
VL	69.24±39.57	53.82±16.82	55.12±19.52	58.26±21.13	0.393 (0.037)	0.501 (0.023)	0.164 (0.095)
VM	49.01±14.07	62.02±19.99	61.28±28.89	67.54±19.40	0.161 (0.096)	0.159 (0.097)	0.681 (0.009)
RF	34.53±13.13	31.06±8.07	31.69±11.06	29.90±10.11	0.175 (0.090)	0.393 (0.037)	0.905 (0.001)
BF	65.19±25.02	66.50±28.66	54.89±11.28	74.15±41.12	0.995 (0.001)	0.269 (0.061)	0.253 (0.065)
ST	62.66±311.34	64.53±15.20	61.13±11.23	63.17±17.84	0.281 (0.058)	0.314 (0.051)	0.306 (0.052)
Glut-M	103.95±79.56	106.99±71.83	109.52±70.31	114.14±65.76	0.467 (0.027)	0.321 (0.049)	0.555 (0.018)

PHYSICAL TREATMENTS

Abbreviations: TA: Tibialis anticus; Gas-M: Medial gastrocnemius; BF: Biceps femoris; ST: Semitendinosus; VL: Vastus lateralis; VM: Vastus medialis; RF: Rectus femoris; Glut-M: Gluteus medius; MVIC: Maximum voluntary isometric contraction.

surface and higher joint impact forces, which has been demonstrated in downhill fatigue [35]. Conversely, in healthy individuals, it was found that in the early stance phase, the muscles that control both trunk stabilization (spinal extensors) and knee stabilization (VM, VL, RF) were more activated [36]. In a previous study [37], it was reported that greater VL and MV activities are observed in the early stance phase, followed by ankle musculature co-contraction for stability influencing the descent enabled. However, no significant difference was observed in the activity of this muscle in the present study.

Some limitations of this study should be acknowledged. Firstly, we solely evaluate military boots' mileage on active males with foot pronation. Thus, it is advisable to explore other deformities, such as foot supination, in future

Table 4. EMG data at push-off

Variables (%MVIC)	EMG Variables of Rubber Military Boot				Sig. (η^2)		
	Healthy		Pronated		Main Effect Boot	Main Effect Group	Interaction: Boot×Group
	New	Used	New	Used			
TA	111.20±27.98	107.91±28.00	107.51±26.33	97.01±19.78	0.373 (0.040)	0.411 (0.034)	0.580 (0.016)
Gas-M	122.65±70.20	109.98±52.96	113.01±75.12	159.36±68.11	0.262 (0.063)	0.405 (0.035)	0.106 (0.125)
VL	61.78±20.11	50.47±11.23	63.59±27.30	61.29±23.56	0.204 (0.079)	0.420 (0.033)	0.342 (0.045)
VM	68.51±39.75	65.77±25.27	69.26±16.06	95.02±26.52	0.734 (0.006)	0.110 (0.743)	0.421 (0.033)
RF	30.12±6.30	30.23±5.94	28.73±15.11	29.16±12.33	0.141 (0.105)	0.826 (0.002)	0.904 (0.001)
BF	64.78±14.10	67.65±28.47	64.66±20.14	74.86±68.16	0.611 (0.013)	0.556 (0.018)	0.702 (0.008)
ST	125.03±185.46	71.30±24.27	67.56±19.26	68.15±16.12	0.309 (0.052)	0.345 (0.045)	0.365 (0.041)
Glut-M	92.16±49.22	133.64±142.56	106.11±36.63	127.36±56.36	0.920 (0.001)	0.195 (0.082)	0.720 (0.007)

PHYSICAL TREATMENTS

Abbreviations: TA: Tibialis anticus; Gas-M: Medial gastrocnemius; BF: Biceps femoris; ST: Semitendinosus; VL: Vastus lateralis; VM: Vastus medialis; RF: Rectus femoris; Glut-M: Gluteus medius; MVIC: Maximum voluntary isometric contraction.

studies. Secondly, we only record EMG data. Therefore, future studies should investigate ground reaction forces in future studies. Thirdly, our comparison of muscle activity while walking in rubber boots is limited to active men with pronated feet. Therefore, our results cannot be extrapolated to working women. Consequently, future studies are needed to determine the complete range of physiological and biomechanical benefits offered by boots. Because of the low number of samples and the above reasons, it is essential to exercise caution when making generalizations given the aforementioned reasons.

Conclusion

Rubber's military boots mileage affects selected muscle activities in men with and without pronated feet. The results showed that the use of rubber military boots can increase the possibility of injury to pronated feet.

Ethical Considerations

Compliance with ethical guidelines

The protocol of this study was confirmed by the Ethical Committee of the Mohaghegh Ardabili University (Code: IR.UMA.REC.1401.026). All subjects gave their consent to participate in the present research.

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Authors' contributions

The study design and writing: All authors; Laboratory works and data analysis: Kimia Hoseinpour.

Conflict of interest

The authors declared no conflict of interest.

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