Research Paper

The Effect of Three Types of Military Boots Mileage on Knee Muscular Co-contraction During Running

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ABSTRACT

Purpose: Military boots mileage is a main factor that can affect the risk of running injuries. The present study aims to evaluate the effect of three types of military boots mileage on knee muscular co-contraction during running.

Methods: Fifteen healthy males received three pairs of new military boots. Participants wore these boots for more than 6 months. Electromyography activity of lower limb muscles during running at constant speed was recorded during pre- and post-intervention. Then, knee muscular co-contraction was calculated.

Results: Results showed a significant increase during loading response (P=0.030, n^2_p=0.157) and push-off (P=0.008, n^2_p=0.302) phases for general knee co-contraction at post-test compared to the pre-test. Also, directed mediolateral knee co-contraction showed a significant increment during mid-stance (P=0.028, n^2_p=0.040) and push-off (P=0.039, n^2_p=0.115) phases at post-test compared to the pre-test.

Conclusion: It can be concluded that knee joint instability while using polyurethane thermoplastic is more than polyurethane boots. Also, our results demonstrated that maintaining knee stability in the anterior-posterior direction while using polyurethane thermoplastic is better than in polyurethane boots.

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Highlights

• Research utilized biomechanical methodologies through muscle co-contractions to understand the difference between used and new military boots.

• The results showed the type of military boots affects the general and directional co-contraction of the knee joint during running.

• Increased general knee co-contraction may be associated with instability of the joint after fatigue.

Plain Language Summary

During daily activities, soldiers are required to engage in strenuous physical activity. Essentially, this will include walking and running carrying various items of equipment often through rough terrain. Level of fitness increases using running activities. On the other hand, co-contraction increment energy expenditure, leading to a high cost of walking and fatigue. Therefore, this study was conducted to examine the effect of three types of military boots mileage on knee muscular co-contraction during running. Fifteen healthy males received three new and used military boots. They were asked to wear these boots for over 6 months. Participants were recruited in May 2022 from Mohaghegh Ardabili University, Ardabil City, Iran. We used the freeware tool GPower to calculate a one-sided a priori power analysis. A wireless EMG system with eight pairs of bipolar Ag/AgCl surface electrodes was used to record the activity of the tibialis anterior (TA), gastrocnemius medialis (Gas-Med), biceps femoris (BF), semitendinosus (ST), vastus lateralis (VL), vastus medialis (VM), and rectus femoris (RF), and gluteus medius (Glut-Med) muscles of the right leg. Pre and postintervention, EMG testing was conducted and co-contraction of the right leg was recorded during running at 3.6 run speed. Based on the results of this study, and following the use of military boots, the knee general co-contraction was increased. The results demonstrated more directed mediolateral knee co-contraction and greater directed flexion and extension co-contraction in used boots situations. Individuals express a clear need to use military boots using for their soldiers to help cope with challenges associated with the use of military boots and their injuries. Changing boots after 6 months of heavy wearing seems to be suitable for military people.

1. Introduction

During daily activities, soldiers engaged in physical physical activities, including walking and running. These severe physical activities involve potential risks of injury [1]. It has been reported that about 80%–90% of these injuries are associated with training-related activities [1]. These injuries often occur in the knee and spine regions [2]. The risk of injuries in soldiers is 2 to 4 times higher than in the civilian population [3]. It is reported that lower extremity injuries are common in individuals undergoing military training with incidences of 25% and 82% [4, 5]. Overuse lower limb injuries include stress fractures, patella-femoral syndrome, and Achilles tendinopathy. During military training [6], increased running intensity [7], load carrying [8], and wearing military combat boots [9] have all been attributed as causative of different injuries [10].

The shoe mileage affects the lower limb muscular activities in runners [11, 12]. Electromyography (EMG) measurements can help identify the different reasons that increased injury risk. Hinz et al. [13] reported that a softer sole may lead to decreased stress intensity on the metatarsal bones and therefore reduce the possibility of march fractures. Also, EMG activities are associated with running-related injuries [3]. Previous studies have reported that footwear can have a significant effect on running performance, which in turn can lead to injury. However, the effects of footwear on running mechanics received minimal attention in previous studies, especially in soldiers [7, 14].

Co-contraction increases energy expenditure leading to a high cost of walking and finally leads to fatigue [15]. However, insufficient information exists about knee joint muscular contractions when using used and new boots during running. Therefore, this study was conducted to examine the effect of three types of military boots mileage on knee muscular co-contraction during running.

2. Materials and Methods

The type of this study was double-blinded with repeated measures. G*Power software, version 3.1 was used to assess a priori power analysis. The power analysis was performed using the F-test family [16]. This software showed that at least 15 participants per group are required to achieve large-sized interaction effects. Fifteen healthy individuals (age: 22.3[1.7] years; height: 162.3[6.5] cm; mass: 62.4[9.3] kg) volunteered to participate in this study. All participants were right-footed. Participants had previously worn this shoe-type model. The exclusion criteria included a history of surgery or orthopedic disorders.

Experimental procedures

Participants wore new boots during pre-tests and were measured with used boots during post-test. Before and after the 14 months, mechanical boots testing was used to assess boots' stiffness. In addition, running mechanics were assessed while running along an 18-m runway at a constant speed. Before starting the study, all participants received three new pairs of military boots (Arsan Sanat Aghanezhad (private company), rubber and polyurethane, and polyurethane thermoplastic made in Iran-Tabriz). The EVA midsole provides stability to provide cushioning. Six months after pre-test, participants performed post-test. Participants were familiarized with the laboratory environment by running 3 times across the walkway. Participants walked at a constant speed during testing. Three true running trials were recorded at both pre and post-test and used for further data analyses. Finally, muscle-specific-maximum voluntary isometric contraction (MVIC) testing was performed to normalize EMG amplitudes.

Experimental setup and data processing

At pre and post-test stages, all participants were asked to run at a constant speed (3.2 m/s) along an 18-m walkway with new boots (Arsan Sanat Aghanezhad (private company), rubber, polyurethane, and polyurethane thermoplastic made in Iran-Tabriz) during pre-tests and used boots during posttest. A wireless EMG system (Biometrics Ltd., Newport, UK) with 8 pairs of Ag/AgCl electrodes (20 mm center-to-center distance; input impedance of 100 MΩ; and common mode rejection ratio (CMRR) of >110 dB) was used to record EMG data of the tibialis anterior (TA), medial gastrocnemius (Gas Med), biceps femoris (BF), semitendinosus (ST), vastus lateralis (VL), vastus medialis (VM), and rectus femoris (RF), and gluteus medius (Glut-Med) muscles of the dominant limb [17]. The aforementioned muscles were chosen due to their stabilizing role during running [18]. Raw EMG signals were digitized at a sampling rate of 1000 Hz. According to the surface electroMyoGraphy for the non-invasive assessment of muscles (SENIAM), the skin was cleaned with alcohol [17]. Maximum voluntary isometric contraction (MVIC) was recorded for each muscle to normalize EMG amplitude. A bandwidth filter of 10–500 Hz and a notch filter of 50 Hz were applied to filter the EMG waves [19]. The running sub-phases include loading (first 15% of stance), midstance (15%–60% of stance), and late stance (last 40% of stance). Two variables were constructed to calculate knee muscular co-contraction, directed co-contraction ratios (DCCR) of agonists and antagonists, and general co-contraction. directed co-contraction ratios (DCCRs) were measured for medial (semitendinosus (SM), vastus medialis (VM), medial gastrocnemius (MG))/lateral (biceps femoris (BF), vastus lateralis (VL)) muscles directed mediolateral knee co-contraction (MLDCCR), medial (VM)/lateral (VL) quadriceps (VM/VLDCCR), and the knee flexors (SM, BF, MG)/extensors (VL, VM) directed knee flexion and extension co-contraction (FEDCCR) [16]. The DCCRs were measured as follows:

If agonist EMG amplitude>antagonist EMG amplitude;

DCCR=1-antagonist EMG amplitude/agonist EMG amplitude

Else

DCCR=agonist EMG amplitude/antagonist EMG amplitude– 1

Maximum co-contraction is indicated by a DCCR equal to zero, while a minimum co-contraction is indicated by a DCCR of 1 or -1. General co-contraction was measured using the sum of all agonist and antagonist activity.

Statistical analyses

Normal distribution of data was established using the Shapiro-Wilk test. A separate 2 (boots: Rubber vs Polyurethane)×2 (time: Pre vs posttest) analysis of variance (ANOVA) with repeated measures was computed. Effect sizes were determined by partial eta-squared (η^2p). The significance level was set at P<0.05. All analyses were performed using SPSS softwarer, version 23.

3. Results

The results showed no significant main effects of "boot" for general knee co-contraction (P>0.05) during all phases. The results showed a significant main effect of "time" for general knee co-contraction during loading response (P=0.030, n^2_p=0.157). The paired-wise comparison revealed significantly greater general knee co-contraction at the loading response phase in the polyurethane thermoplastic than polyurethane boots. Furthermore, significant boot-by-time interactions were found for general knee co-contraction at push-off phase (P=0.008, n^2_p=0.302) (Table 1).

The results showed no significant main effect of "boot", "time" and boot-by-time for directed vastus lateralis and medialis knee co-contraction knee at all phases (Table 2).

The results demonstrated significant main effects of "boot" for directed knee mediolateral co-contraction (P=0.039, n^2_p=0.115) during the push-off phase. The results showed a significant main effect of "time" for directed knee mediolateral co-contraction at mid-stance phase (P=0.028, n^2_p=0.040). The paired-wise comparison revealed significantly greater directed knee mediolateral co-contraction at the mid-stance phase in the polyurethane thermoplastic than the rubber group. The results showed no significant boot-by-time interactions for directed knee mediolateral co-contraction at all phases (Table 3).

The results showed no significant main effects of "boot" for directed knee flexion and extension co-contraction at all phases (P>0.05). The results showed a significant main effect of "time" for directed knee flexion and extension co-contraction at push-off phase (P=0.017, n^2_p=0.188). The paired-wise comparison revealed significantly greater directed knee flexion and extension co-contraction at the push-off phase in the polyurethane thermoplastic than that polyurethane boots. Furthermore, significant boot-by-time interactions were found for directed knee flexion and extension co-contraction at the loading response phase (P=0.046, n^2_p=0.308) (Table 4).

4. Discussion

This study was conducted to examine the effect of three types of military boots mileage on knee muscular co-contraction during running.

The results revealed significantly greater general knee co-contraction at the loading response phase in the polyurethane thermoplastic than in polyurethane boots. Previous studies have shown that knee joint instability is

Table 1. General knee co-contraction

Co-contraction Variables	Mean±SD						Sig. (Effect Size)		
	Rubber		Polyurethane		Polyurethane Thermo-plastic		Main Effect Boot	Main Effect Time	Interaction: Boot×Time
	New	Used	New	Used	New	Used			
Loading response	71.13±11.43	73.38±9.31	70.15±11.01	80.40±15.88	70.43±7.78	82.15±17.85	0.419(0.062)	0.030(0.157)*	0.265(0.094)
Mid stance	79.12±36.75	73.65±9.96	74.63±11.74	80.75±18.09	71.02±7.31	77.96±25.08	0.729(0.023)	0.592(0.010)	0.530(0.041)
Push-off	80.06±25.15	71.01±11.17	73.94± .09	74.30±12.15	70.23±10.09	83.39±14.07	0.487(0.052)	0.678(0.006)	0.008(0.302)*

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Table 2. Directed vastus lateralis and medialis knee co-contraction

Co-contraction Variables	Mean±SD						Sig. (Effect Size)		
	Rubber		Polyurethane		Polyurethane Thermoplastic		Main Effect Boot	Main Effect Time	Interaction: Boot×Time
	New	Used	New	Used	New	Used			
Loading response	0.97±0.64	0.86±0.72	0.74±0.81	0.81±0.64	0.65±0.83	0.10±3.08	0.385(0.073)	0.382(0.027)	0.592(0.038)
Mid stance	0.13±0.45	0.69±0.48	0.53±1.09	0.66±0.95	0.69±0.58	0.26±2.97	0.121(0.145)	0.333(0.033)	0.197(0.113)
Push-off	0.87±0.71	0.94±0.39	0.74±0.66	0.85±0.94	0.75±0.82	0.27±2.22	0.407(0.064)	0.685(0.006)	0.671(0.029)

*P<0.05

PHYSICAL TREATMENTS

Table 3. Directed mediolateral knee co-contraction

Co-contraction Variables	Mean±SD						Sig. (Effect Size)		
	Rubber		Polyurethane		Polyurethane Thermoplastic		Main Effect Boot	Main Effect Time	Interaction: Boot×Time
	New	Used	New	Used	New	Used			
Loading response	124.51±35.79	122.27±43.15	115.94±27.22	128.12±61.79	127.87±44.31	124.51±35.79	0.174(0.122)	0.466(0.019)	0.737(0.022)
Mid stance	114.11±37.70	124.19±34.64	137.84±53.82	145.90±108.29	127.01±33.12	176.05±146.55	0.253(0.097)	0.028(0.040)*	0.546(0.034)
Push off	125.04±40.34	111.71±30.72	125.08±27.73	122.81±25.99	131.24±37.93	161.56±97.33	0.039(0.115)*	0.652(0.007)	0.342(0.076)

*P<0.05

PHYSICAL TREATMENTS

Table 4. Directed knee flexion and extension co-contraction

Co-contraction Variables	Mean±SD						Sig. (Effect Size)		
	Rubber		Polyurethane		Polyurethane Thermoplastic		Main Effect Boot	Main Effect Time	Interaction: Boot×Time
	New	Used	New	Used	New	Used			
Loading response	172.92±82.33	151.83±43.35	148.53±63.14	183.96± 5.58	153.10±60.13	203.01±79.30	0.661(0.030)	0.201(0.058)	0.046(0.308)*
Mid stance	171.11±84.41	172.01±74.79	146.05±46.40	177.61±46.46	157.15±66.57	209.98±70.42	0.167(0.124)	0.117(0.085)	0.292(0.087)
Push-off	151.98±53.01	182.34±121.72	145.85±41.95	184.44±59.29	154.10±55.01	188.11±70.75	0.923(0.006)	0.017(0.188)*	0.976(0.002)

*P<0.05

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one of the risk factors for falls [20]. Increased general knee co-contraction may be associated with instability of the joint after fatigue [21]. By our results, it can be concluded that knee joint instability while using polyurethane thermoplastic is more than in polyurethane boots.

The results showed no significant group-by-time interactions for directed knee mediolateral co-contraction at all phases. Furthermore, the results revealed significantly greater directed knee flexion and extension co-contraction at the push-off phase in the polyurethane thermoplastic than in polyurethane boots. Hirokawa et al. [22] reported that hamstring co-contraction has a significant effect on maintaining knee stability, providing synergistic action to the anterior cruciate ligament by preventing excessive anterior displacement and internal rotation of the tibia. Based on our results, it can be concluded that maintaining knee stability in the anterior-posterior direction while using polyurethane thermoplastic is better than in polyurethane boots.

This study has some limitations that should be regarded. Firstly, we did not evaluate the kinematic data. Secondly, we did not evaluate kinetic data, such as ground reaction forces and joint moments. Future studies should assess both kinematic and kinetic data to better establish the effect of military boots mileage on running mechanics.

5. Conclusion

It can be concluded that knee joint instability while using polyurethane thermoplastic is more than using polyurethane boots. Also, our results demonstrated that maintaining knee stability in the anterior-posterior direction while using polyurethane thermoplastic is better than polyurethane boots.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of the Mohaghegh Ardabili University (Code: IR.UMA.REC.1401.026) and was registered at IRCT (IRCT20220714055469N1). All participants signed their written informed consent to participate in the present study.

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Authors' contributions

Conceptualization and writing the original draft: Milad Piran Hamlabadi; Methodology: Milad Piran Hamlabadi and AmirAli Jafarnezhadgero; Investigation: Milad Piran Hamlabadi; Writing–review and editing: Milad Piran Hamlabadi and AmirAli Jafarnezhadgero; Funding acquisition: Iman Bakhshodeh Nia and Hamid Hassannejad; Resources: Iman Bakhshodeh Nia and Hamid Hassannejad; Supervision: Amir Ali Jafarnezhadgero.

Conflict of interest

The authors declared no conflict of interest.

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