Applied Ergonomics 60 (2017) 146–153

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Effect of work boot type on work footwear habits, lower limb pain and perceptions of work boot fit and comfort in underground coal miners

Jessica A. Dobson*, Diane L. Riddiford-Harland, Alison F. Bell, Julie R. Steele

Biomechanics Research Laboratory, School of Medicine, Faculty of Science, Medicine & Health, University of Wollongong, Wollongong, Australia

ARTICLE INFO

Article history:
Received 29 June 2016
Received in revised form
11 November 2016
Accepted 14 November 2016

Keywords:
Boots
Mining
Fit
Comfort
Pain

ABSTRACT

Lower limb injuries are highly prevalent in underground coal mining. Wearing gumboots with inadequate ankle support was thought to contribute to these injuries. Despite the uptake of leather lace-up boots, which provide more ankle support, no recent research could be found investigating the effect of this alternative work boot in underground coal mining. Consequently, this study aimed to determine whether boot type (gumboot, leather lace-up boot) influenced work footwear habits, foot problems, lower limb pain, lower back pain, or perceptions of work boot fit and comfort in underground coal miners. Chi-squared tests were applied to 358 surveys completed by underground coal miners to determine whether responses differed significantly ($p < 0.05$) according to boot-type. There were no significant between-boot differences in regards to the presence of foot problems, lower limb pain or lower back pain. However, the types of foot problems and locations of foot pain differed according to boot type. Gumboot wearers were also more likely to state that their work boot comfort was either 'uncomfortable' or 'indifferent', their work boot fit was 'poor' and their current boot did not provide enough support. The introduction of more structured leather lace-up boots appears to have positively influenced the support and fit provided by mining work boots, although foot problems, lower limb pain and lower back pain continue to be reported. Further investigation is recommended to identify which specific boot design features caused these observed differences in work boot fit, comfort and locations of foot pain and how these design features can be manipulated to create an underground coal mining work boot that is comfortable and reduces the high incidence of foot problems and lower limb pain suffered by underground coal miners.

1. Introduction

During a typical 8 h shift, underground coal miners spend most of their time standing and walking on challenging surfaces that are uneven, wet and unstable (Dobson et al., 2016; Marr, 1999). As a result, lower limb injuries are highly prevalent with sprains and strains accounting for over half of all WorkCover claims annually (WorkCoverNew South Wales, 2010). Of these sprain/strain related lower limb injuries, 49.2% occur at the knee and 36.5% occur at the ankle (Smith et al., 1999). An unstructured gumboot that lacked ankle support and allowed too much foot movement within the boot was thought to explain this high lower limb injury incidence in the coal mining industry (Marr, 1999; Smith et al., 1999). Indeed, a report to the Joint Coal Board Health and Safety Trust (Smith et al., 1999) revealed that almost 40% of miners who sustained lower limb injuries identified their mining work boots as the main contributing factor to these injuries.

Underground coal miners (n = 400, aged 20–70 years) who habitually wore gumboots reported excessive foot movement within their work boot and a lack of ankle support (Marr, 1999). Of the miners surveyed, 41% reported their feet slid within their work boot, 46% stated that their ankle did not feel stable and 35.5% felt unstable when walking on uneven ground. Marr (1999) suggested the inability of gumboots to stabilise the foot within the boot also contributed to the high incidence of calluses (48%) and lower back stiffness (34%) reported by coal miners. These findings are consistent with the results of a survey of 589 miners in which insufficient ankle support (63.5%) and inadequate boot fit (52.1%) were cited as the two main reasons miners thought their gumboots contributed to their lower limb injuries (Smith et al., 1999). Consequently, 71.4%

* Corresponding author. Biomechanics Research Laboratory, School of Medicine, Faculty of Science, Medicine & Health, University of Wollongong, Wollongong, NSW, 2522 Australia.
E-mail address: jd225@uowmail.edu.au (J.A. Dobson).

http://dx.doi.org/10.1016/j.apergo.2016.11.008
0003-6870/

of the miners wanted their work boots changed (Smith et al., 1999).

Based on this previous research (Smith et al., 1999; Marr, 1999), leather lace-up boots were introduced as a work boot option for underground coal miners, providing them with an alternative that delivered a tighter fit and more ankle support than gumboots. Due to variations in the materials that a gumboot and leather lace-up boot are made out of, they substantially differ structurally, particularly in regards to shaft stiffness (upper part of the boot; see Fig. 1 and Table 1). It was hypothesised that introducing a mining work boot with a stiffer shaft that provided a tighter fit and more support around the ankle/shank would improve the miners' perceptions of comfort and stability while minimising lost time at work due to injury (including lower back, hip, knee, ankle and foot injury; Marr, 1999). Previous research has shown that increased proprioception acuity and trends towards more active ankle stiffness have resulted when circumferential ankle pressure was applied to the ankle, although this was applied using a blood pressure cuff and it is unknown whether a boot shaft pressing against the shank would yield the same result (You et al., 2004). Nevertheless, differences in boot shaft design have been shown to limit lower limb motion and, consequently, lower limb pain (Böhm and Hösl, 2010; Jefferson, 2013; Dobson et al., 2015). The literature, however, is inconclusive and it is unknown whether a tighter fit due to a stiffer shaft is in fact beneficial in regards to reducing lower limb pain occurrence.

Manipulation of shaft stiffness in hiking boots (Böhm and Hösl, 2010; Cikajlo and Matjacić, 2007), military boots (Hamill and Bensel, 1996), work boots (Simeonov et al., 2008), basketball boots (Robinson et al., 1986), ski boots (Noé et al., 2009) and snowboarding boots (Delorme, 2004) has been found to significantly alter ankle range of motion. That is, a more flexible shaft has been shown to increase ankle range of motion during walking and a stiffer shaft can reduce it. The amount of ankle range of motion allowed by a boot shaft appears crucial to both efficient walking biomechanics, as well as reducing lower limb injury occurrence. Although adequate ankle range of motion is vital to efficient gait, excessive ankle motion is problematic because it causes the joint to rely on secondary anatomical structures, such as the muscles and ligaments, for support (Böhm and Hösl, 2010; Hamill and Bensel, 1996), increasing the risk of lower limb sprain/strain injuries (Neely, 1998). Conversely, there is relatively strong evidence suggesting that restricted ankle joint motion during walking can have negative implications for the more proximal joints of the lower limb, such as the knee or hip (Böhm and Hösl, 2010; Horak and Nashner, 1986). For example, a lace-up hiking boot, with 50% less passive shaft stiffness, decreased eccentric energy absorption at the ankle joint while simultaneously increasing eccentric energy absorption at the knee joint, indicating that when the ankle joint's ability to absorb the ground reaction force is impaired, the knee joint has to compensate (Böhm and Hösl, 2010). Therefore, although the leather lace-up boot with its stiffer shaft might positively impact the ankle by providing more support, it could potentially have negative implications for the knee and more proximal joints by restricting normal ankle motion and causing compensations further up the lower limb chain.

Despite the introduction of a leather lace-up boot for coal miners over a decade ago, no research could be found investigating whether this more fitted and supportive work boot affected their lower limb pain or their perceptions of fit and comfort. Given the gap in the current literature, the aim of this study was to determine whether boot type (gumboot versus leather lace-up boot) influenced self-reported work footwear habits, lower limb pain, lower back pain, or perceptions of fit and comfort in underground coal miners. It was hypothesised that miners who wore leather lace-up boots would report more ankle support, fewer foot problems, less pain, and improved comfort and fit ratings when compared to gumboot wearers. However, due to restricted ankle motion, leather lace-up boot wearers would report more knee and hip pain compared to gumboot wearers.

2. Methods

2.1. Participants and survey implementation

Three hundred and fifty eight underground coal miners (n = 355 men and 3 women; age = 39.1 ± 10.7 years; height = 1.78 ± 0.31 m; mass = 92.1 ± 13.7 kg) employed by Illawarra Coal at the Dendrobium and West Cliff sites (NSW, Australia) volunteered to complete a survey which collected job details, work boot habits, foot problems and lower limb pain history, boot likes/dislikes and ideal boot preferences. Underground coal mining remains a male dominated occupation with workers generally being middle aged (personal communication with industry, March 2016). Over half of the participants had worked underground (54.8%), and performed their current working role (52.6%), between 3 and 10 years. Nearly a fifth had worked underground for over 16 years (18.8%). The most common mining work boot sizes worn were sizes 8–12 with 90% of participants falling within this size range. Surveys were handed out to the participants at scheduled work health and safety meetings and training days or immediately prior to commencing a shift at the mines. The participants completed the survey under the guidance of the research team, who clarified any questions the participants had and ensured all questions were completed. All 358 participants who volunteered to fill out the survey completed it.

Participants were divided into two groups for analysis based on whether they chose to wear the employer-provided gumboot (n = 219 men and 3 women; age = 38 ± 9.8 years; height = 1.77 ± 0.67 m; mass = 91.6 ± 13.8 kg) or the other mandatory boot option of the leather lace-up boot (n = 109 men; age = 37.8 ± 10.1 years; height = 1.78 ± 0.63 m; mass = 92.6 ± 14.9 kg; see Fig. 1 and Table 1). Those who did not answer the question or selected wearing both boots were not included for analysis.

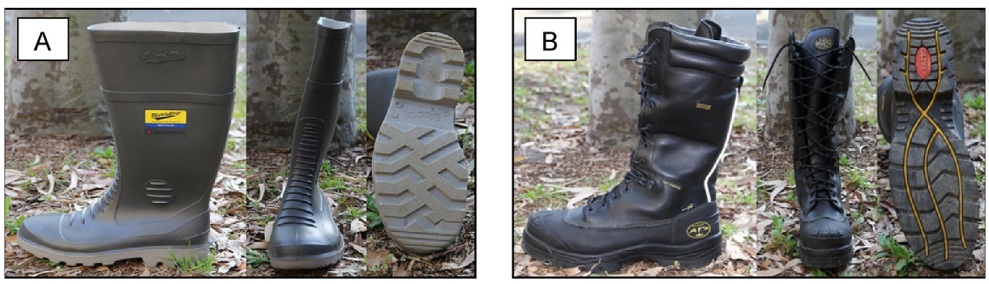

Fig. 1. The two different underground coal mining work boots provided by Illawarra Coal (NSW, Australia) at the time of the study. A: Gumboot (Blundstone®, Australia) and B: Leather lace-up boot (Oliver, Australia).