



## Are underground coal miners satisfied with their work boots?

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### ABSTRACT

Dissatisfaction with work boot design is common in the mining industry. Many underground coal miners believe their work boots contribute to the high incidence of lower limb injuries they experience. Despite this, the most recent research to examine underground coal mining work boot satisfaction was conducted over a decade ago. This present study aimed to address this gap in the literature by assessing current mining work boot satisfaction in relation to the work-related requirements for underground coal mining. 358 underground coal miners (355 men; mean age =  $39.1 \pm 10.7$  years) completed a 54-question survey regarding their job details, work footwear habits, foot problems, lower limb and lower back pain history, and work footwear fit and comfort. Results revealed that underground coal miners were not satisfied with their current mining work boots. This was evident in the high incidence of reported foot problems (55.3%), lower back pain (44.5%), knee pain (21.5%), ankle pain (24.9%) and foot pain (42.3%). Over half of the underground coal miners surveyed believed their work boots contributed to their lower limb pain and reported their work boots were uncomfortable. Different working roles and environments resulted in differences in the incidence of foot problems, lower limb pain and comfort scores, confirming that one boot design cannot meet all the work-related requirements of underground coal mining. Further research examining the interaction of a variety of boot designs across the different underground surfaces and the different tasks miners perform is paramount to identify key boot design features that affect the way underground coal miners perform. Enhanced work boot design could improve worker comfort and productivity by reducing the high rates of reported foot problems and pain amongst underground coal miners.

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### 1. Introduction

The prevalence of workplace injuries in the mining industry is high and, in the Australian context, occurs most often in underground coal mines (Smith et al., 1999; Government of Western Australia, 2011; Leigh et al., 1990). The most common underground mining injuries are to the lower limb, contributing to approximately 18,900 lost working days and incurring \$28 million in compensation claims annually (Armour, 2003; Government of Western Australia, 2011). As the foot is the most distal segment of the lower limb, any abnormal loading or erroneous movement of this segment could explain this high incidence of lower limb injuries, particularly as foot biomechanics can influence proximal joints such as the ankle, knee, hip and lower back (Böhm and Hösl,

2010; Horak and Nashner, 1986; Liu et al., 2012; Neely, 1998). A primary factor that alters loading and movement of the foot is footwear. Consequently, underground coal mining work boots that are uncomfortable, restrict movement or provide inadequate ankle support can lead to incorrect foot placement when walking and, in turn, influence proximal joints of the lower limb (Redfern et al., 2001; Böhm and Hösl, 2010; Smith et al., 1999; Neely, 1998 Hamill and Bensel, 1996). This perhaps explains why 49.2% of the lower limb injuries reported by Australian underground coal miners occur at the knee and 36.5% at the ankle (Neely, 1998; Smith et al., 1999).

Underground coal miners are required to wear steel-capped work boots with a high shaft (upper part of the boot that covers the shank) to satisfy personal protective equipment minimum standards (Marr and Quine, 1993; Australia/New Zealand Standard, 2010). The type of steel-capped work boots worn by underground coal miners is generally restricted to those provided by their employer. These work boots traditionally come in two main styles (slip on or lace-up), being made of either rubber or leather (see

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**Fig. 1.** Underground coal mining work boots. A: Gumboot and B: Leather Lace-up Boot.

**Fig. 1; Dobson et al., 2015**). Despite the importance of footwear in the coal mining industry, there is a large gap in the scientific literature examining the work boots worn by underground coal miners. In fact, the main research investigating underground coal mining work boot satisfaction was conducted over a decade ago (Marr, 1999; Smith et al., 1999). These older studies indicated that underground coal mining work boots were not meeting the work-related requirements of the miners, particularly in regards to comfort and lower limb pain (Marr, 1999; Smith et al., 1999).

As an item of personal protective equipment, work boots should be designed to minimise potential injury while allowing the wearer to walk proficiently, in comfort and without pain (Harman et al., 1999). In the mining industry, however, previous studies have revealed that dissatisfaction with work boot design was high with many miners reporting their work boots to be hot/sweaty (77.4%), uncomfortable (38%), unstable on walking surfaces (24.7%) and inflexible (27.4%, Marr, 1999). This mismatch between work boot fit and comfort was further illustrated by a survey of lower limb injuries incurred by miners, which found that over one third (37.4%) of the miners attributed their injuries to their work boots (Smith et al., 1999).

Since the late 1990's there have been numerous technological advancements in the design and methods used to manufacture underground coal mining footwear (Oliver, 2013; Mack Boots, 2015; Blundstone, 2016). This has included the introduction of features such as wide fit footwear models, cushioned arch supporting insoles, soles shaped to adapt to uneven surfaces and the use of lighter polyurethane materials (Oliver, 2013; Mack Boots, 2015; Blundstone, 2016). There have also been changes in the tasks performed by coal miners, often as a result of new machinery used in underground coal mines (personal communication with industry, March 2016). Given these changes, it is possible that, compared to 1999, the work boots coal miners wear might have changed sufficiently to enhance miner comfort and reduce lower limb pain when performing their work tasks. Indeed, Dobson et al. (2015) reported that participants displayed differences in how they used their muscles while walking when wearing gumboots compared to leather lace up boots on changing surface conditions. However, although boot design has the potential to alter lower limb function when performing work-related tasks, no research has examined whether modifications to boot design have influenced miner comfort or lower limb pain incidence.

Given the lack of recent research, it is also unknown whether the work boots currently worn by underground coal miners are compatible with their work tasks. Therefore, the aim of this study was to assess whether current mining work boots meet current work-related requirements for underground coal mining and whether the miners are satisfied with their mining work boots. To achieve this aim, the requirements of underground coal mining were characterised by documenting the miner's job details

(including working tasks, environment and work footwear habits), tabulating the miner's foot problems and lower limb and lower back pain history and taking measures of their work footwear fit and comfort. Relationships between work footwear habits, foot problems and lower limb pain history were then investigated to determine whether these responses differed significantly based on job details and work footwear fit and comfort. Based on past research, it was hypothesised that the underground coal miners would report a high incidence of foot problems and lower limb pain and be dissatisfied with the fit and comfort of their work boots. It was further hypothesised that different working environments and roles would be associated with differences in the incidence of foot problems, lower limb pain and comfort scores reported by the miners.

## 2. Methods

### 2.1. Participants and survey implementation

Underground coal miners ( $n = 355$  men and 3 women; age =  $39.1 \pm 10.7$  years; height =  $1.78 \pm 0.31$  m; mass =  $92.1 \pm 13.7$  kg) employed by Illawarra Coal, at Dendrobium and West Cliff sites (NSW, Australia), volunteered to complete a survey. The survey recorded their job details, work boot habits, foot problems, lower limb and lower back pain history, boot likes/dislikes and ideal boot preferences. Underground coal mining remains a male dominated occupation with workers generally being middle aged (Marr, 1999; Smith et al., 1999). Over half of the participants had worked underground (54.8%), and performed their current working role between 3 and 10 years (52.6%). 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.

### 2.2. Survey design and development

The design of the survey was based on previously validated surveys that had investigated underground coal mining work boots (Marr and Quine, 1993; Marr, 1999; Smith et al., 1999), and modified after discussions with coal mining industry representatives. The survey was trialled by 15 participants (age = 18–40 years) to ensure questions were readily understood.

The final survey instrument included 54 items (15 closed-ended and 39 open-ended items), divided into six sections that sought information pertaining to the underground coal miners' job details; work footwear habits; foot problems and lower limb and lower back pain history; orthotic use, work footwear fit and comfort; and foot and footwear knowledge. The variables used for analysis in this current study are discussed in more detail below. The University of Wollongong Human Research Ethics Committee (HE11/198) provided approval of the survey content and administration procedures.

### 2.3. Survey items

#### 2.3.1. Job details

Underground coal miner's job details were determined via the open-ended question 'describe your current main working role' and close-ended questions relating to years worked underground, years

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