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Are underground coal miners satisfied with their work boots?

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Abstract
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Running Head: Underground Coal Mining 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 ± 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.

Keywords:

Boots, mining, pain

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 Figure 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).

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

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 ± 10.7 years; height =1.78 ± 0.31 m; mass = 92.1 ± 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 in current working role, type of surface worked on (muddy, uneven, slippery/wet), and hours spent walking, standing and sitting during a typical shift.

2.3.2 Work footwear habits

Open-ended questions asked 'what is your current mining footwear' and 'what don't you like about your current work footwear'. Whether the work boots were provided by their employer (Illawarra Coal), why this footwear was preferred and the miner's preferred fastening method were determined with closed-ended questions.

2.3.3 Orthotics

Within this section, underground coal miners answered the close-ended questions of whether they were ever prescribed orthotics and, if so, do they currently wear them.

2.3.4 Foot Problems and Lower Limb and Lower Back Pain History

Foot problems were defined by a closed-ended question where participants circled the current foot problems they had or they circled 'no' if they did not have any current foot problems. This style of question was repeated for foot and ankle pain. Those participants who circled

having foot and/or ankle pain were asked to elaborate with close-ended questions regarding frequency of pain on a 5 point Likert scale (1 ‘rarely’ to 5 ‘always’), marking on a picture of the foot where the pain was located and circling ‘yes’ or ‘no’ as to whether they believed this pain was related to their work footwear. Finally, participants were asked a closed-ended question where they circled any other lower limb pain they had (knee and/or hip), if they had lower back pain or circled ‘no’.

2.3.5 Work Footwear Fit and Comfort

Participants were asked two closed-ended questions about fit and comfort. One question required participants to rate their overall work footwear fit (1 ‘very poor’ to 5 ‘very good’) and the second question was to rate their work footwear comfort (1 ‘very uncomfortable’ to 5 ‘very comfortable’). The participants were also asked a closed-ended question to rank, from 1 to 11 (1 being most important), which design features would make their ideal work footwear more comfortable.

2.4 Survey Analysis

2.4.1 Descriptive analysis

Responses to the closed-ended items were coded and counted to determine the frequency of responses for each item, before calculating descriptive statistics. A thematic analysis was conducted on the answers to the open-ended questions to determine response frequencies. The number of responses for each question varied due to non-responses, multiple answer selection or when questions did not require an answer from all participants. Data were analysed only on the miners who provided a response to that question.

2.4.2 Relationship analysis

To assess current mining work boot design in relation to the work-related requirements and miner satisfaction with their current mining work boots, Chi-squared tests were applied to the data pertaining to work footwear habits, foot problems and lower limb and lower back pain

history. This determined whether the frequency of responses differed significantly ($p < 0.05$) based on job details or work footwear fit and comfort (SPSS Version 21, USA).

3. Results

3.1 Job Details

The main working roles reported by the participants were machine operation and heavy lifting (Figure 2). It is noted that whereas some participants described their job title (e.g. electrician), others described the activity they most commonly performed (e.g. walking). Muddy (86.1%), uneven (88.3%) and slippery/wet (72.4%) surfaces were the most common ground-surface conditions worked on.

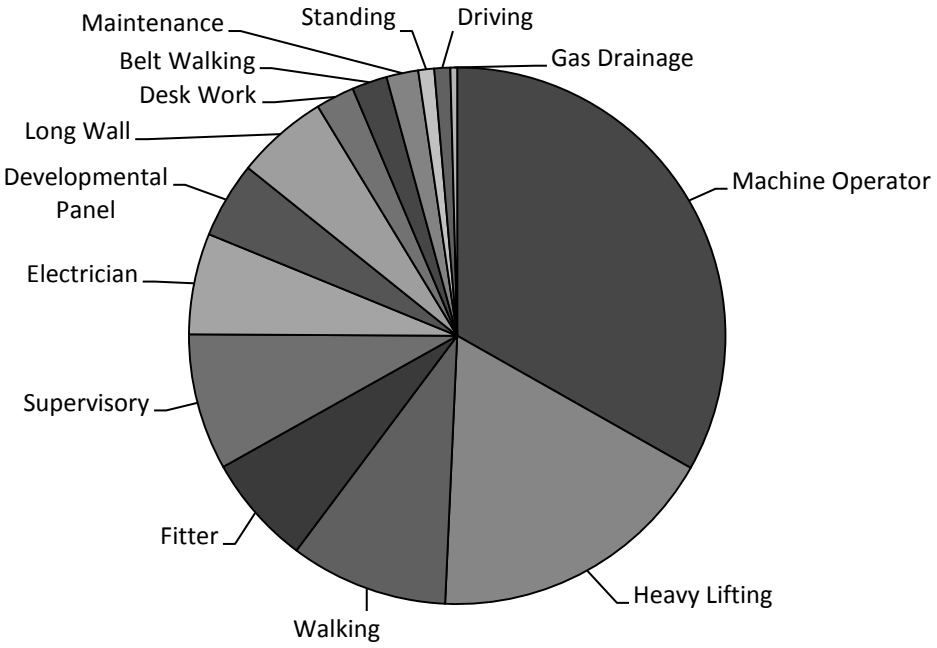

Figure 2: Current main working roles or tasks reported to be undertaken by the participants (n = 349).

During a typical 8-12 hour shift, the participants spent the most time walking and minimal time sitting (see Figure 3).

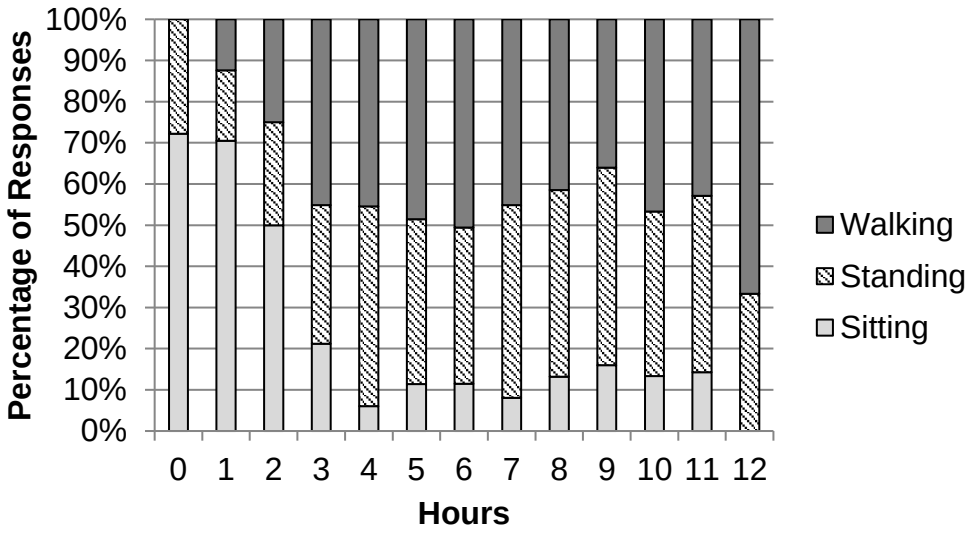

Figure 3: Amount of hours participants spend walking, standing and sitting during a typical 8-12 hour shift (n = 288).

3.2 Foot Problems, Lower Limb and Lower Back Pain History and Orthotic Use

Foot problems were reported by 55.3% of the participants, with calluses (33.1 %), dry skin (30.2%) and tinea (12.8%) being the most common complaints. Most miners reported similar levels of foot pain and lower back pain (Figure 4). Almost half of the miners who answered this question had lower back pain (44.5%) and foot pain (42.3%), and almost a quarter had knee pain (21.5%) and ankle pain (24.9%). Of the miners who reported having foot pain, over half said the foot pain occurred 'occasionally' to 'often' (68.8%). This was similar to ankle pain where 57.9% of miners who had ankle pain said it occurred 'occasionally' to 'often'. Of those who listed foot and/or ankle pain, over half (62.3%) believed the pain was related to their mining work boots. The most common locations on the foot indicated as causing pain are presented in Figure 5. Although 17.3% of participants had previously been prescribed orthotics by a health professional, only 6.7% currently wore orthotic devices.

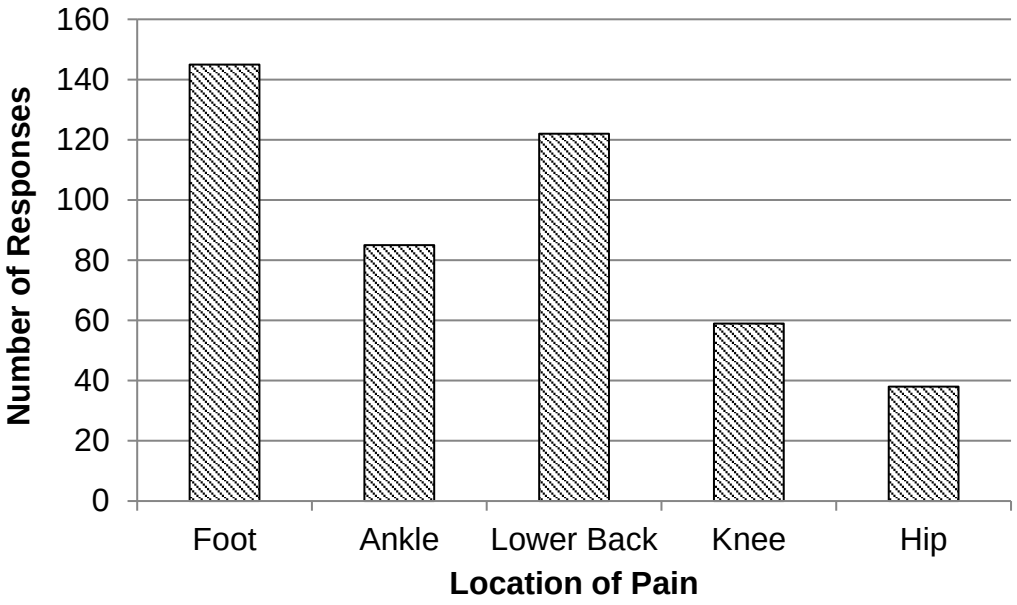

Figure 4: Number of participants who reported having lower limb or back pain (n = 343 for foot and ankle, n = 274 for lower back, knee and hip).

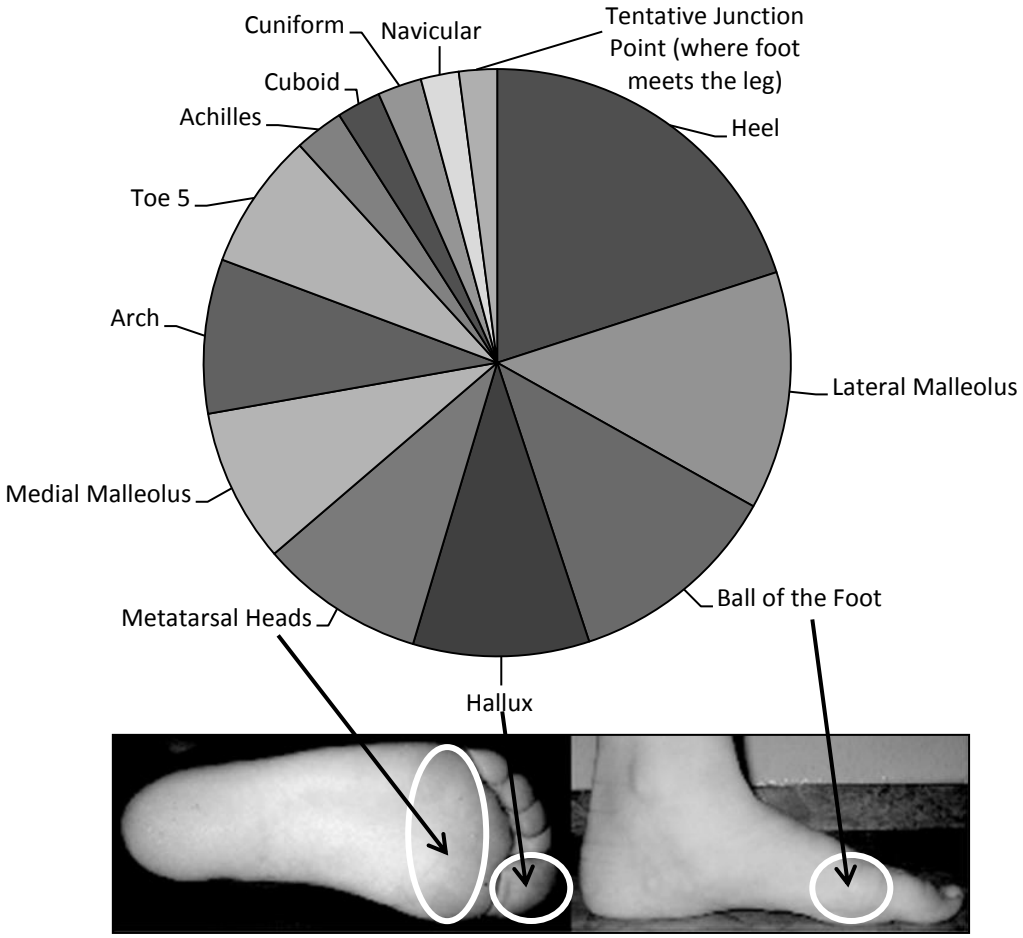

Figure 5: Specific locations of pain marked on a foot picture by the participants who reported having foot pain (n = 182).

3.2.1 Foot Problems and Lower Limb Pain Related to Job Details

Significant associations ($p < 0.05$) were found between the occurrence of foot problems and lower limb pain and the main surface type the miners worked on (see Table 1) and the main working role a miner performed (see Table 2).

Table 1: Significant associations between specific surfaces and foot problems and lower limb pain (Chi-squared result).

Surface	Foot Problems and Lower Limb Pain
Hard	More likely dry skin ($\chi^2 = 4.9$, $p < 0.05$) and heel pain ($\chi^2 = 4.1$, $p < 0.05$)
Wet/slippery	More likely ball of foot pain ($\chi^2 = 3.2$, $p < 0.05$)
Muddy	More likely foot pain ($\chi^2 = 6.9$, $p < 0.05$)
Dirt	More likely foot pain ($\chi^2 = 4.3$, $p < 0.05$) and hip pain ($\chi^2 = 3.8$, $p < 0.05$)
Flat	Less likely knee pain ($\chi^2 = 4.6$, $p < 0.05$)
Dry	Less likely knee pain ($\chi^2 = 3.7$, $p < 0.05$)

Table 2: Significant associations between specific working roles and foot problems and lower limb pain (Chi-squared result).

Working Role	Foot Problems and Lower Limb Pain
Belt Walker	More likely foot problems ($\chi^2 = 4.9$, $p < 0.05$)
Desk Work	Less likely foot problems ($\chi^2 = 7.1$, $p < 0.05$)
Walking	More likely calluses ($\chi^2 = 4.3$, $p < 0.05$), hammer toes ($\chi^2 = 6.1$, $p < 0.05$) and Achilles pain ($\chi^2 = 6.8$, $p < 0.05$)
Standing	More likely to have pain where the foot meets the leg ($\chi^2 = 40$, $p < 0.05$)
Supervisor	More likely to have rashes ($\chi^2 = 7.3$, $p < 0.05$), spurs ($\chi^2 = 7.3$, $p < 0.05$) and knee pain ($\chi^2 = 5.8$, $p < 0.05$)
Electrician	More likely to have blisters ($\chi^2 = 5.6$, $p < 0.05$) and arch pain ($\chi^2 = 4.5$, $p < 0.05$)
Gas Drainer	More likely to have cuboid ($\chi^2 = 21.5$, $p < 0.05$) and navicular pain ($\chi^2 = 24.7$, $p < 0.05$)
Heavy Lifting	More likely foot pain ($\chi^2 = 7.9$, $p = <0.05$)

3.3 Work Footwear Habits and Work Footwear Fit and Comfort

The gumboot was the most popular boot worn by the participants (66.3%), followed by the leather lace-up boot (32.5%). A small percentage of participants purchased their own work boots but their employer provided most (83.8%) of the work boots. More than three-quarters of the participants (82.4%) indicated a mining work boot fit rating of 'reasonable' to 'good'. The ratings of comfort, however, were not as clustered with 18.1% of the participants rating their mining work boots as 'uncomfortable', 38.5% as 'indifferent' and 37.7% as 'comfortable'. The main features participants did not like about their current mining work boots are displayed in Figure 6. The preferred fastening method of an ideal underground coal mining work boot was non-fastening (i.e. slip-on; 62.9%) or zipper (31.1%) and the boot features that the participants reported would make an ideal work boot more comfortable are displayed in Figure 7.

3.3.1 Work Footwear Habits and Work Footwear Fit and Comfort Related to Foot Problems, Lower Limb Pain History and Job Details

Participants who had hip pain were more likely to rate their work boot fit as 'very poor', 'poor' and 'reasonable' ($\chi^2 = 11.9$, $p < 0.05$) whereas those with foot pain were more likely to rate comfort as 'uncomfortable' to 'indifferent' ($\chi^2 = 18.4$, $p < 0.001$). The presence of calluses made fit ratings of 'poor' to 'reasonable' more likely ($\chi^2 = 11.4$, $p < 0.05$) and ratings of comfort more likely to be 'uncomfortable' to 'indifferent' ($\chi^2 = 11$, $p < 0.05$). Participants with swollen feet were more likely to rate their boot fit as 'poor' ($\chi^2 = 11.4$, $p < 0.05$) and their boot comfort as 'uncomfortable' ($\chi^2 = 9.9$, $p < 0.05$).

Irrespective of mine site (Dendrobium or West Cliff) the top listed mining work boot features required for an ideal boot remained the same; waterproof (40%, 33.8%, respectively) and provide ankle support (18.9%, 16.9%; $\chi^2 = 12.1$, $p = 0.28$). This finding was despite environmental differences between the two mines, with Dendrobium workers more likely to

list working on muddy ($\chi^2 = 12.4$, $p < 0.001$) and uneven ($\chi^2 = 7.6$, $p < 0.05$) surfaces and West Cliff miners more likely to work on dry ($\chi^2 = 14.6$, $p < 0.001$), hard ($\chi^2 = 5$, $p < 0.05$) and flat ($\chi^2 = 4.1$, $p < 0.05$) surfaces.

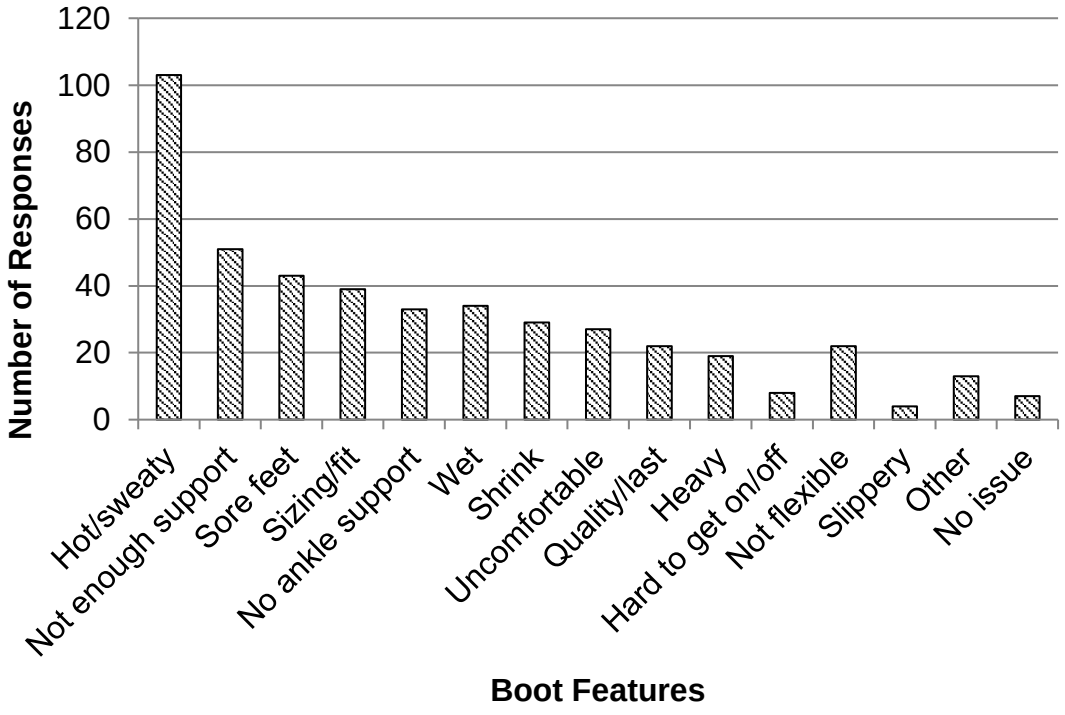

Figure 6: Features participants did not like about their current mining work boots (n = 380).

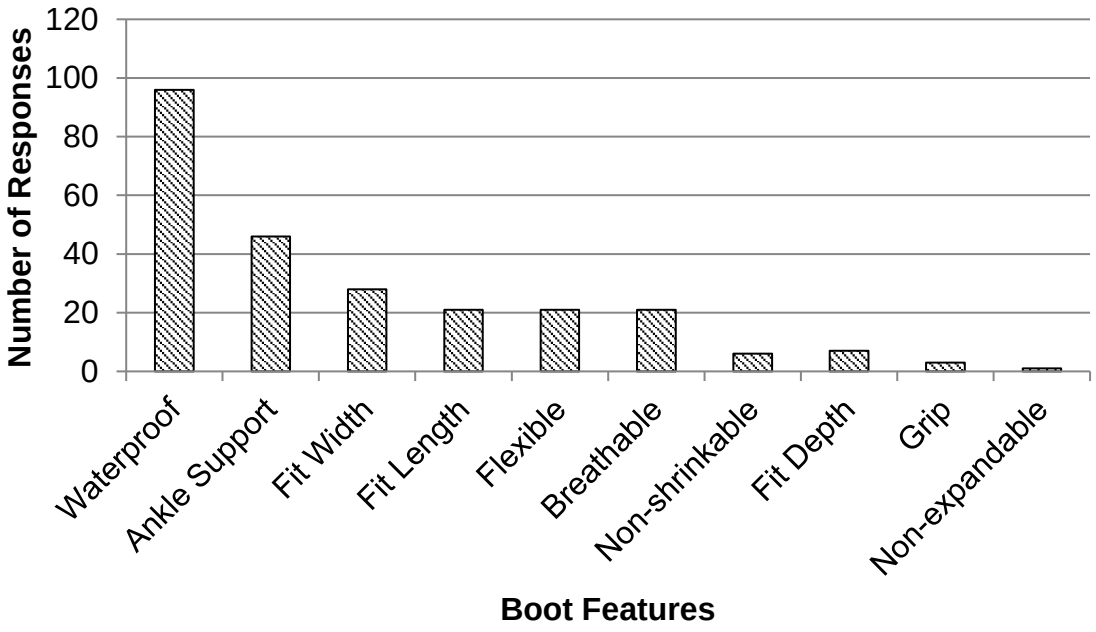

Figure 7: Participants preferred design features to make an ideal boot more comfortable (n = 359).

4. Discussion

Foot problems, lower limb and lower back pain and boot discomfort previously reported by underground coal miners suggest that, historically, mining work boots were not meeting the demands of the job or the satisfaction of coal miners. As previous studies examining underground coal mining work boots were conducted more than a decade ago, it remained unknown whether work tasks, environmental demands or work boots had improved during that time period. This study therefore explored whether current mining work boots were meeting the work-related requirements of underground coal mining. The findings of the present study demonstrate that underground coal miners still report a multitude of foot problems and lower limb and lower back pain, indicating that their work boots continue to be problematic. The implications of these results are discussed below.

Underground coal miners are required to remain on their feet for most of their shift, whether this is standing or walking, and they work on surfaces that are uneven, wet and muddy (Marr, 1999). Despite the introduction of more advanced mining equipment (personal

communication with industry, March 2016), the findings of this study reveal that the working roles and environmental conditions in underground coal mining have remained virtually unchanged since the last underground coal mining surveys (Marr, 1999; Smith et al., 1999). Lower back pain was still the highest rated pain experienced in this present study with almost half the miners reporting this pain (44.5%); an increased incidence of 10% compared to the 34% of participants who reported lower back stiffness in Marr's (1999) study.

Different surfaces and working roles are associated with different risk factors for foot problems and lower limb pain. For example, working on muddy and dirt surfaces increased a miner's likelihood of reporting foot pain and hip pain, whereas dry skin and heel pain were more likely to be reported by participants who worked on hard ground and ball of foot pain more likely when working on slippery/wet surfaces. Although working on dry and flat surfaces decreased a miner's likelihood of developing foot problems and knee pain, realistically underground coal mining work cannot be limited to dry and flat surfaces. Similarly, foot pain was more common if a miner performed heavy lifting as a main working role and pain where the foot meets the leg was associated with standing. Belt walkers, a job requiring continuous walking, were more likely to have foot problems, whereas desk workers, who are predominantly sitting, were less likely to have foot problems. As underground coal mining is an occupation that predominantly requires workers to perform physically demanding tasks while standing or walking, further research is needed to investigate ways to minimise foot problems and lower limb pain under specific working conditions.

Work boots have the potential to alter foot movement and therefore affect the occurrence of foot problems and lower limb pain (Böhm and Hösl, 2010, Smith et al., 1999, Neely, 1998 Hamill and Bensel, 1996). However, underground coal miners still believe their mining work boots are not meeting the physical demands placed on their feet/ankles while

working, leading to pain. Previously, 56.5% of injured workers were not satisfied with their mining work boots and 53.4% thought their boots contributed to their lower limb injuries (Smith et al., 1999). Over half (56.7%) of the underground miners in the current study who reported foot and/or ankle pain believed this pain was related to their mining work boots, a figure that has not improved since the last surveys conducted in 1999 (Marr, 1999; Smith et al., 1999). Furthermore, working roles that require continuous walking combined with crouching down to examine and/or adjust machinery (e.g. supervisor, gas drainer and electrician) were also associated with specific foot problems. Problems such as rashes, spurs, blisters and cuboid, navicular and arch pain indicate current work boots are not correctly supporting the feet of the miners and not fitting the shape of their feet.

Previously, 46.3% of underground coal miners listed poor support as a limitation of their mining work boots (Marr, 1999) and a further 65.3% specifically listed inadequate ankle support (Smith et al., 1999). Participants in the current study were still dissatisfied with the amount of support provided by their mining work boots, with not enough support identified as the second most common disliked design feature. A work boot that does not provide adequate ankle support, and limits inversion and rotation of the ankle, is likely to increase the risk of ankle sprain (Barrett and Bilisko, 1995). Furthermore, abnormal rotation at the ankle can also increase injury risk at more proximal joints of the lower limb (Neely, 1998). In the current study the high incidence of ankle, knee and hip pain confirms current underground coal mining work boots are not providing sufficient support to the lower limb while underground coal miners are working and, as a consequence, resulting in lower limb pain.

In addition to lack of ankle support, over half (52.1%) of the 1999 cohort reported their underground coal mining work boots did not fit properly, particularly in regards to width and length (Marr, 1999; Smith et al., 1999). Furthermore, 41.3% said their feet slid inside their boots (Marr, 1999; Smith et al., 1999). Results of the current study indicate an

improvement in fit has occurred with 83.8% of underground coal miners now rating their mining work boot fit as 'reasonable' to 'good'. The introduction of a leather lace-up boot (hypothesised to provide a better fitting underground coal mining work boot compared to a gumboot) was the main difference in footwear between the current study and previous studies (Marr, 1999; Smith et al., 1999). Improvements in boot fit ratings compared to 1999 appear to be due to the option for underground coal miners to now wear leather lace-up boots (Dobson et al., 2017). The same explanation seems to underpin the variation in comfort ratings observed between the current study and previous research (Dobson et al., 2017). For example, ankle support was rated as the second priority in an ideal boot by the miners, hence it is expected a boot that provides more ankle support would improve comfort ratings. In 1999, 56.5% of underground coal miners were dissatisifed with their current mining boots, over two thirds (71.4%) wanted them changed and 38% found them uncomfortable (Marr, 1999; Smith et al., 1999). Now, only 18.1% of underground coal miners considered their work boots 'uncomfortable' and in fact, 37.7% rated their boots as 'comfortable'. This notion of comparing gumboot wearers to leather lace-up boot wearers to conclude whether the introduction of the leather lace-up boot has indeed caused these observed improvements in ratings of fit and comfort is explored in more detail by Dobson et al. (2017).

Ahead of ankle support, waterproofing was the main design feature participants in the present study listed as first priority in an ideal boot. In contrast, hot/sweaty was the main dislike participants had with their current work boots. These results were regardless of whether miners worked in a 'wet mine' (i.e. Dendrobium) or a 'dry' mine (i.e. West Cliff). Tinea growth and dry skin, two of the most common foot problems reported in the present study, are caused by constant exposure to moisture (Habif, 2011), indicating that excess moisture within work boots is an issue faced in both mines. The similarity in these results reported by participants from both Dendrobium and West Cliff miners indicate contact with

water is not the sole explanation for the issue of excess moisture within the work boots. Overheating and poor ventilation also appeared to be playing a role in excess moisture inside the boot. Ensuring a work boot is waterproof but still allows ventilation without resulting in overheating is a difficult task. Nevertheless, recent advancements in materials should be considered in future boot designs to cater for moisture management. Participants also specified they would prefer a slip-on mining work boot. This means boot fastening designs other than laces should also be investigated as a way to create a mining work boot that is tight enough to prevent water entry into the boot and provide adequate ankle support, but can be easily put on and taken off the foot.

Overall, in support of our hypothesis, underground coal miners still have a high incidence of foot problems and lower limb pain, and still believe their work boots do not provide enough support and contribute to their lower limb pain. Contrary to our hypothesis, however, the underground coal miners were satisfied with the fit of their boots and comfort ratings have improved. 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 miners. Future research is therefore needed to investigate the interaction of a variety of boot designs across the different underground mine surfaces and the different tasks miners perform. Such an investigation could identify key boot design features that are likely to minimise foot problems and lower limb pain under specific conditions. This, in turn, will allow a series of boots to be made that cater for the variety of different work-related requirements of underground coal miners and improve worker comfort and satisfaction.

4.1 Limitations

As with any survey, there are limitations of the current study that should be acknowledged. The accuracy of self-reported measures, presence of the research team, errors due to non-

responses and validity differences between open and closed questions were all limitations to the current survey. Given this study was compared to similar surveys conducted on the same demographics under similar conditions we believe the impact of these limitations on the study findings was minimal. The open-ended question asking a miner to describe their current main working role also provided a mix of specific job titles and actions performed as responses. This created substantial overlap; for example a fitter can do heavy lifting, machine operation and walking. Therefore, it was not possible to determine whether specific working roles had higher risks for specific foot problems and lower limb pain.

5. Conclusions

Underground coal miners are required to remain on their feet for long periods of time, perform tasks of a physical nature and work on challenging surfaces that are muddy, uneven and slippery/wet. Current mining work boots do not appear to be meeting the requirements of the underground coal miners who work in this challenging environment. This is evident in the high incidence of foot problems and lower limb and lower back pain reported by the underground coal miners surveyed in this study. More importantly, the miners believe their work boots are contributing to the pain they experience. Further investigation into the influence that different boot designs have on how underground coal miners perform typical working tasks is paramount to be able to design work boots that can reduce this high incidence of foot problems and lower limb pain experienced, as well as providing boots that the miners find comfortable.

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Conflict of interest

None

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