

Pages: 18

Words: 3,552

Tables: 2

Figures: 5

References: 18

Contact: Stewart Birrell

Email: Stewart.Birrell@Brunel.ac.uk

Guarantor: Stewart Birrell

# Subjective Skeletal Discomfort Measured Using a Comfort Questionnaire Following a Load Carriage Exercise

Stewart A Birrell, PhD *

Roger A Haslam, PhD **

* Ergonomics Research Group

School of Engineering and Design

Brunel University

Uxbridge

Middlesex

UB8 3PH, UK

** Department of Human Sciences

Loughborough University

Leicestershire

LE11 3TU, UK

KEYWORDS

Load Carriage, Discomfort, Injury, Marching

**Abstract**

*Objective:* Limited research has been conducted into the effect of load carriage on discomfort and injuries. This study aimed to determine the skeletal discomfort for part-time soldiers who completed a 1-hour field march carrying 24 kg.

*Methods:* A post-march comfort questionnaire was completed by 127 participants, with exercise withdrawals and post-march injuries also recorded.

*Results:* The foot was subjectively rated as the most uncomfortable skeletal region. Females reported hip discomfort to be significantly greater than males. The military experience of participants had no difference on the mean perceived comfort ratings of any of the measured regions. Finally, only one participant withdrew from the exercise with no participants reporting a load carriage injury in the 2-3 days proceeding the exercise.

*Conclusions:* This study concludes that although a 1-hour period of load carriage causes noteworthy discomfort it is not sufficient to result in non-completion of a military exercise or cause injury.

## Introduction

Research into the specific effects of load carriage (aka load carrying or bearing) on injury rates within the military seems to be lacking in the published literature. Reasons for this may be that load carriage is often viewed as being a non-modifiable, extrinsic risk factor for injury. It is the authors' opinion that many of the most detailed literature reviews and epidemiological studies fail to include any load carriage variables as risk factors for injuries. The importance for understanding typical discomforts and injuries during load carriage lies in the preparation and knowledge for medical units. Armed with this information they will be more adequately prepared to recognize, treat and even prevent such problems before they seriously affect combat readiness[1].

Female military trainees have been shown to be approximately twice as likely as males to sustain an injury during basic training[2,3,4]. Stress fractures, especially to the hip, have been identified as a specific issue[5]. In addition to gender, the age of trainees has been identified as an intrinsic risk factor for injury. Research suggests that older trainees and younger soldiers are at an increased risk of sustaining any injury[2,6]. Numerous high-quality studies have been conducted to assess injury rates during marching[1,7,8,9]. However, these have not distinguished between load carriage and marching related injuries. Previous research conducted by the authors has concluded that the upper limb is susceptible to short-term injuries such as soft tissue damage and trapped nerves or blood supplies. Also, that early development of shoulder pain or blisters may be a risk factor for severe pain or non-completion of a period of prolonged load carriage[10].

The primary aim of this study was to determine the skeletal comfort of key regions of the body that are at risk of injury following a 1-hour load carriage field exercise. The discomfort data were collected via subjective comfort questionnaire completed immediately following the march. Secondary aims were to assess the impact of load carriage on dropout rates and injuries which may be sustained.

## Methods

### *Participants*

One-hundred and twenty seven participants from the UK East Midlands Universities Officer Training Corps (OTC) were involved in the study (table 1). These participants were not full-time soldiers, but studying for undergraduate degrees. Once their studies were completed they entered the armed forces for a period of service, many would subsequently train as Officers. No inclusion or exclusion criteria for participation were set, as the field march was a predetermined exercise completed by all OTC members. The participants were split into two categories depending on their year of study, and therefore progression through the OTC. 'A' Company were termed the advanced group with students in their 2$^{nd}$, 3$^{rd}$ or final year of their degree. 'B' Company or the basic group were students in their 1$^{st}$ or foundation years. Both males and females were involved in the study. Ethical approval was granted by the Loughborough University Ethical Advisory Committee (G03/P18) and permission was sought from OTC Commanding Officers. No sensitive private health information was collected or participants  medical records interrogated, only subjective measures were recorded.

Insert Table 1 Here

*Protocol*

The exercise conducted by the participants was the Territorial Army Combat Fitness Test (TACFT). This involved completing a 4-mile (6.4 km) field march with load in a maximum time of 1 hour, but no less than 57 minutes 30 seconds. The load carried was between 20 and 25 kg depending on the participant's regiment. This load was inclusive of weapon and ancillary items (such as helmet, boots, body armor etc); the mean load carried was 23.26 kg (± 3.0). The load was distributed between the webbing and backpack, with each participant packing their own equipment. The exercise was conducted on mud-tracks and tarmac paths, over relatively flat terrain. After the formalities of the exercise were complete the participants were given a brief overview of the research objectives and then the comfort questionnaires were distributed and completed. The protocol was identical for both companies who completed the exercise 5 days apart, with weather conditions similar for both companies.

Participants who withdrew from the exercise for whatever reason were picked up by a Land Rover and brought back to the start/end point. Here they completed the same comfort questionnaire and were asked some additional questions. The on-site medical facility was open from 0800 until 1800 hrs, here participants could receive medical attention from a military doctor for any ailment. Before the exercise was undertaken the doctor was briefed as to the aims of the research and data to be collected. The doctor agreed to record all visits that in his professional opinion were caused or aggravated by carrying loads.

*Methods of Data Collection*

A comfort questionnaire was distributed to all participants following the completion of the exercise. This involved rating regions of the body in terms of perceived comfort; ratings were given out of 5, with 1 being comfortable and 5 extremely uncomfortable (figure 1). This comfort rating scale has been validated extensively for military in-field testing[10,11]. Any participants who withdrew from the exercise before the designated end point still completed the comfort questionnaire and additional questions were asked in an effort to determine precise reasons for their withdrawal. In addition, instructions were left with the doctor to collect and record any visit to the clinic in the 2 to 3 days following both the A and B Company exercises. The doctor was asked to record on a standard collection sheet the date, type, cause and treatment of any potential injury as well as asking the participants other load carriage related questions.

*Statistical Analysis*

All 127 participants completed the comfort questionnaire. Sub-groups were identified allowing between subject comparisons to be made, these being gender and company. For the purpose of this study the 'company' of which the participant is designated will be used to determine his or her military experience. Table 1 shows the number of participants assigned to each sub-group. As the data collected were ordinal, non-parametric statistical tests were conducted. To evaluate potential differences between the subgroups a Kruskal-Wallis test was used. Significance within the group (or subgroups) was determined by performing a Friedman test, if this showed significance then a Wilcoxon signed-rank test was conducted to determine where the

significant difference lay. All statistical tests were run using SPSS 12.0 and completed by the authors, significance between the mean scores was taken at the $p<0.05$ level.

Insert Figure 1 Here

**Results**

The overall effect of a 4-mile field march carrying approximately 24 kg was to increase whole body skeletal discomfort (a mean rating for all five regions of the body) within this group of participants to 1.62 (table 2). Results also showed that for the entire group combined (males and females, A and B company) the hip was rated as significantly the least uncomfortable (or most comfortable) region of the body measured at the end of the exercise ($p=0.006$). The most uncomfortable region measured was the foot ($p=0.001$).

Insert Table 2 Here

Interpreting results from table 2 shows that females rated both the regions of the foot ($p=0.031$) and hip ($p=0.030$) as significantly more uncomfortable at the end of the march compared to their male counterparts. There were also trends for greater discomfort in the lower back and knee. There were no differences in comfort ratings given between A and B Company. As well as the actual mean scores reported, the number of participants giving a specific comfort rating was also assessed. Put simply, this is the number of participants who gave either 1, 2, 3, 4 or 5 on the comfort rating

scale for each body zone. Frequency analysis showed that the most commonly cited comfort rating was 1 (or comfortable) with 57% of responses given this rating.

In addition to the comfort questionnaire the study aimed to gain additional data from those participants who withdrew from the TACFT, and also from the onsite medical professional in the 2-3 days following the load carrying exercise. Only one person withdrew from the exercise before its completion, and is reviewed as a case study in the discussion. In the days following the TACFT, the on-site doctor recorded no injuries that were a direct result of the load carriage exercise.

## Discussion

The current study distinguished itself clearly from other pertinent research by examining skeletal discomfort and not general fatigue, muscle soreness or blisters. The aim was to distinguish between superficial discomforts, such as muscle or skin soreness due to contact from the load carriage system, and actual skeletal discomfort which may have been caused by forced postures and repetitive loading of the joints. The current study evaluates the effects a single bout, 1-hour period of load carriage has on skeletal discomfort, while also determining sub-populations and regions of the body that may be at an increased risk of discomfort.

### *The Group as a Whole*

As indicated in the results the overall effect of a 4-mile march with load was to increase whole body skeletal discomfort to 1.62 (± 0.91), this equates to just below slightly uncomfortable. Taken individually this may not represent a substantial issue

as load carriage will cause inevitable discomfort. The key factors for military researchers are whether the discomfort is manageable, and also to determine which populations are at risk from developing more severe discomfort. This discomfort can lead to injury, either in the short or long term, or the non-completion of a set task.

Figure 2 shows the mean comfort ratings for all participants at each body region on the comfort questionnaire. The results show that the hip region was rated significantly ($p<0.05$) more comfortable (or less uncomfortable on the comfort rating scale) than any other regions. Also highlighted was that the foot was rated significantly more uncomfortable than the other region. This suggests that the foot is an area of increased concern. With the addition of blisters to this skeletal discomfort and a soldier's preference for their own civilian boots[10], all factors equate to a point for concern for the Armed Forces. Reynolds and colleagues[9] investigated injuries and risk factors in a 100-mile infantry road march (5 consecutive days of 20-miles) while carrying 47 kg in an US ALICE pack and webbing. At the end of the 5 days foot pain was the second most frequent injury sustained, behind blisters, with 8% of the participants sustaining a foot injury. Foot pain was also the largest single cause of limited duty days, with 22 days of limited duty after the march[9]. The current study is in agreement with this suggesting that after a 1-hour march carrying around 24 kg the foot was the most uncomfortable skeletal region. Knapik and colleagues[1] reported a 3.3% incidence of metatarsalgia after a single strenuous 20 km road march.

Insert Figure 2 Here

A more surprising result was that the lower back was not rated as more uncomfortable, this is despite it being rated as the second most uncomfortable region

behind the foot (figure 2). This was unexpected as previous work has shown that during a 20 km road march carrying 45 kg, 50% of soldiers who were unable to complete the march reported problems associated with the lower back[1]. Potential reasons for the lower back results observed with this study were that the period of load carriage may not have been long enough, or loads not substantial enough to cause significant discomfort. Another factor could be that the lower back may be more susceptible to successive periods of load carriage and not just a single bout. Finally, lower back discomfort or injury may become of increased importance with the older age, or greater experience, of a soldier. Ten to fifteen years of load carriage will inevitably place continual stress on the musculature and skeletal system of the lower back, thus potentially leading to gradual failure or chronic pain. This is supported by Songer and LaPorte[12] who state that lower back pain is one of the leading causes of life-time compensation within the military. Participants who completed this study were of relatively young age, between 18 and 23, therefore may not experience the same persistent problems with lower back discomfort.

Further analysis of the data shows that the most frequent response given by the participants for all body regions was 1, or comfortable. This is not surprising given the relatively short period of load carriage. More interesting maybe the number of participants that rated a particular body zone as 3 (uncomfortable) or above. This will give an insight into which of the regions of the body experience the worst discomfort, and highlight the areas that are most at risk of injury during load carriage. Figure 3 shows the percentage of participants from the entire group that rated each of the regions of the body enquired about in the comfort questionnaire as uncomfortable, very uncomfortable or extremely uncomfortable (3, 4 or 5 out of 5 on the comfort rating respectively). As can be seen the hip follows the same trend as shown in figure

2 and exhibits the least number of responses of uncomfortable or greater. The foot received the greatest number of 3 or over comfort ratings, with 26.6% of participants rating the foot as uncomfortable or greater. The percentage of participants who rated the body regions at very or extremely uncomfortable remains relatively even across the zones with the exception of the foot which received three times the number of responses than any other region. This again is reflected in the fact that the foot received the highest discomfort score compared to any of the other regions in question.

Insert Figure 3 Here

*Male verses Female*

A total of 29 females and 98 males from both A and B Company took part in the study, no difference in age or relative experience was present between genders (table 1). This study enabled the comparison of the skeletal discomfort experienced between genders following a 1-hour period of load carriage to be examined. Results showed that females experienced statistically significantly greater discomfort in the hip and the feet compared to males. They also showed a trend for increased discomfort in the lower back and knee regions (figure 4). The reasons for these differences may be a result of physiological or biomechanical differences which are causing these heightened feelings of discomfort. When reviewing the group as a whole the hip was rated as significantly less uncomfortable than any other region. However, when analyzing the females on their own this was not the case and the hip was only significantly more comfortable than the foot (as were all the regions).

Insert Figure 4 Here

Studies have shown females to be at an increased risk of injury during basic military training compared to males; this increase in risk has been shown to be around two times greater in females[2,3,4]. A review by Deuster and colleagues[5] highlighted that stress fracture rates were higher in females and these also represented a larger percentage of the musculoskeletal injuries being sustained. More specifically pelvic stress fractures are a particular problem concerning females in the military. Pelvic stress fractures can occur when increased shear forces are exerted on the pubic rami by the hip abductors and the hamstrings[13]. In addition, females have lower bone densities and consequently are less able to resist stress and their muscle mass is physiologically weaker and more readily fatigued[14]. Significant problems are also associated with marching. Marching pace is usually set by the males. This puts females at an added disadvantage due to their generally shorter leg lengths, and therefore reduced preferred stride length. In order to maintain pace with the group females will either increase their stride length or stride frequency, this increases risk of pelvic stress fractures[13,15]. A study by Martin and Nelson[16] showed that at a fixed walking speed females have significantly shorter stride lengths and increased stride frequencies compared to males when carrying loads ranging from 0 to 36 kg. In this current study female participants experienced greater hip discomfort compared to the males questioned. This would support the notion that females are at greater risk of pelvic stress fractures, which are most likely caused by the discrepancy in stride parameters between genders.

In addition to the difference in hip comfort females also reported significantly ($p<0.05$) greater foot discomfort compared to males. This again may be linked to the

discrepancy in stride parameters when marching. Research has shown that walking with heavy loads may constitute a predisposition for the development of foot pain as load carriage causes the foot to rotate around the distal ends of metatarsals, exposing them to greater mechanical stress for prolonged periods of time[17]. This occurs at every stride taken, therefore the greater the number of strides taken by females leads to greater mechanical stress placed on the foot. It is also suggested that a greater maximum braking force (GRF in the anteroposterior direction) increases the movement of the foot inside the boot, thus increasing the shear forces produced[8]. This was originally thought to have an impact on blisters; however, this study proposes that it may be just as relevant when considering metatarsalgia. An increase in maximum braking force has again been seen with forced increases with stride length[18], again placing females at an increased risk of developing foot injuries. The above factors are potential biomechanical reasons why females in this current study experienced significantly greater foot discomfort compared to males.

*A verses B Company*

As stated previously the OTC were split into two companies A and B. A Company was deemed to have more military exercise experience, including marching, load carriage and other essential military skills, than their B Company counterparts. Sampled during this study were 79 participants from B Company and 48 from A. Results from the study revealed no differences in skeletal comfort between the two companies for any region of the body measured (figure 5). Despite this lack of difference between the sub-groups, both companies followed the same trends as shown in figure 2 (namely the hip receiving the lowest comfort rating and the foot the highest).

Insert Figure 5 Here

Previous research has suggested that age is a risk factor for the development of injuries; this is older age in trainees and younger age in soldiers[2,6]. The age of trainees utilized for this current study as determined by company was 21.4 (± 3.7) and 20.2 (± 1.4) years, for A and B Company respectively. As mentioned above no differences in the comfort ratings were found between A and B Company, and therefore with age. This suggests that an average age difference of only 1.2 years is not sufficient to support the theory that higher age is a risk factor for injury in trainees. Difference may however exist when comparing 18-21 year old trainees to the 30 and over.

*Non Comfort Questionnaire Results*

As stated in the results section only one participant could not complete the load carriage exercise, this was a 20 year old female from A Company. The main reason given for their withdrawal from the exercise was general fatigue, dehydration and sleep deprivation. This was as a direct result of the participant having completed three consecutive days of strenuous walking, just two days prior to the TACFT. The participant felt that load carriage increased their feelings of discomfort; most significant were shoulder and neck discomfort. Finally, the participant did not feel that they would have been able to complete the task if they were not carrying load. Although no conclusions can be draw from one persons experience it does highlight the effect that repeated bouts of strenuous activities, which may include load carriage,

has on task completion. This includes impeding the performance of soldiers during exercises, causing non-completion of tasks or increasing the feelings of discomfort.

No load carriage related injuries were reported by the on-site medical professional in the 2 to 3 days proceeding the exercise. When the doctor was originally consulted regarding recording this data he was very receptive to the research being conducted, and stated he would record any injuries that in his opinion were as a result of carrying loads. Therefore it can only assume that no participants reported any such injuries.

## Conclusions

This study concludes that although a 1-hour period of load carriage causes significant discomfort it is not sufficient to result in non-completion of the task or cause injury. In addition females reported subjective skeletal discomfort to be greater than their male counterparts; this difference was significant when considering the hip.

## Limitations

Due to the nature of the field task only limited participant characteristics could be gained. Information such body mass index (BMI) and body composition data may have added extra depth to the analysis. Load carriage experience was assumed only by the company in which the participant was in, a formal measure of load carriage experience may have proved useful. The final limitations of the study are also inherently its main conclusions. Young part-time military trainees were the population in question for this study and not a range full-time soldiers. However, with high drop

out rates of trainees from basic training and retention issues with young soldiers, the analysis of injuries and discomforts to these participants is of obvious importance. Finally, a 1-hour period of load carriage was not sufficient to cause injury or non-completion of a task. For a more detailed analysis of injury prolonged periods or successive bouts of load carriage are needed.

**Acknowledgements**

I extend my thanks to Dr Robin Hooper who was the supervisor for the initial part of my PhD. His help and guidance were a major contribution to this study. Also thanks to my colleagues who assisted with this study, and participants who took part.

**References**

1. Knapik JJ, Reynolds K, Staab J, Vogel J, Jones BH: Injuries associated with strenuous road marching, Military Medicine 1992; 157: 64-67.

2. Jones BH, Knapik JJ: Physical training and exercise-related injuries: Surveillance, research and injury prevention in military populations, Sports Medicine 1999; 27: 111-125.

3. Bell NS., Mangione TW, Hemenway D, Amoroso PJ, Jones BH: High injury rates among female Army trainees: A function of gender? American Journal of Preventive Medicine 2000; 18: 141-146.

4. Knapik JJ, Sharp MA, Canham-Chervak M, Hauret K, Patton JF, Jones BH: Risk factors for training-related injuries among men and women in basic combat training, Medicine and Science in Sports and Exercise 2001; 33: 946-954.

5. Deuster P, Jones B, Moore J: Patterns and risk factors for exercise-related injuries in women: A military perspective, Military Medicine 1997; 162: 649-655.

6. Jones BH, Cowan DN, Tomlinson JP, Robinson JR, Polly DW: Epidemiology of injuries associated with physical training among young men in the army, Medicine and science in sports and exercise 1993; 25: 197-203.

7. Knapik JJ, Ang P, Meiselman H, Johnson W, Kirk J, Bensel C, Hanlon W: Soldier performance and strenuous road marching: Influence of load mass and load distribution, Military Medicine 1997; 162: 62-67.

8. Knapik J, Reynolds K, Barson J: The Influence of Antiperspirants on Foot Blister Incidence Following Road Marching. Natick, MA, U.S. Army Research Institute of Environmental Medicine 1997.

9. Reynolds K, White J, Knapik J, Witt C, Amoroso P: Injuries and Risk Factors in a 100-Mile (161-km) Infantry Road March, Preventive Medicine 1999; 28: 167-173.

10. Birrell SA, Hooper, RH: Initial subjective load carriage injury data collected by interviews and questionnaires, Military Medicine 2007; 172: 306-311.

11. Martin, JL: Military load carriage: an innovative method of interface pressure measurement and evaluation of novel load carriage designs. Doctoral Thesis, Loughborough University, UK 2002.

12. Songer TJ, LaPorte RE: Disabilities due to injury in the military, American Journal of Preventive Medicine 2000; 18: 33-40.

13. Kelly E, Jonson S, Cohen M, Shaffer R: Stress fractures of the pelvis in female navy recruits: an analysis of possible mechanisms of injury, Military Medicine 2000; 165: 142-146.

14. Jones BH, Cowan DN, Knapik JJ: Exercise, Training and Injuries. Sports medicine 1994; 18: 202-214.

15. Pope R: Prevention of pelvic stress fractures in female army recruits, Military Medicine 1999; 164: 370-373.

16. Martin PE, Nelson RC: The effect of carried loads on the walking patterns of men and women, Ergonomics 1986; 29: 1191-1202.

17. Kinoshita H: Effects of different loads and carrying systems on selected biomechanical parameters describing walking gait, Ergonomics 1985; 28: 1347-1362.

18. Martin PE, Marsh A: Step length and frequency effects on ground reaction forces during walking, Journal of Biomechanics 1992; 25: 1237-1239.

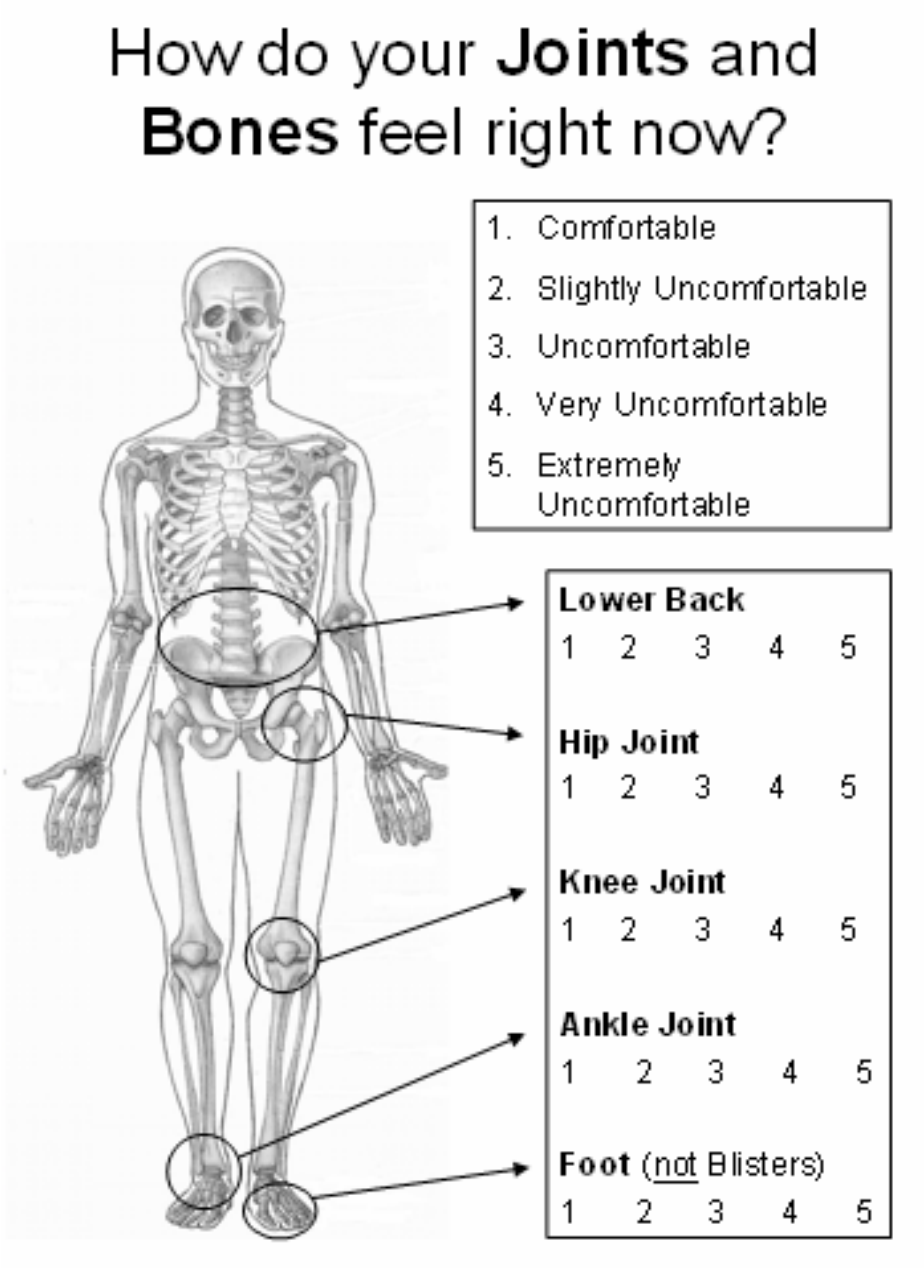


**Figure 1:** Questionnaire section used to rate skeletal discomfort.

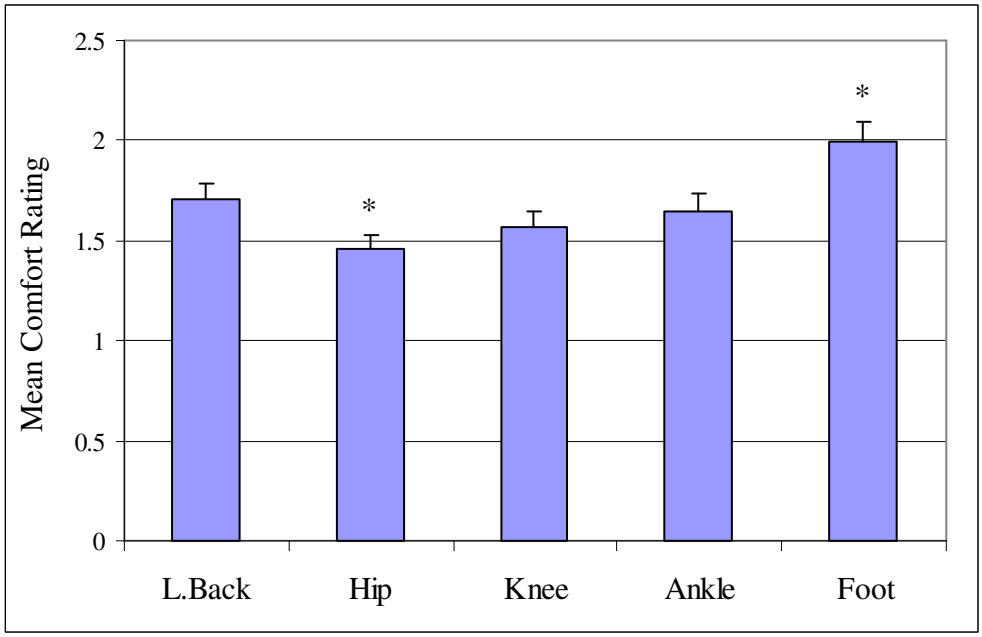


**Figure 2:** Combined mean comfort ratings for each body region, error bars represent the standard error of the data. * indicates significance ($p<0.05$).

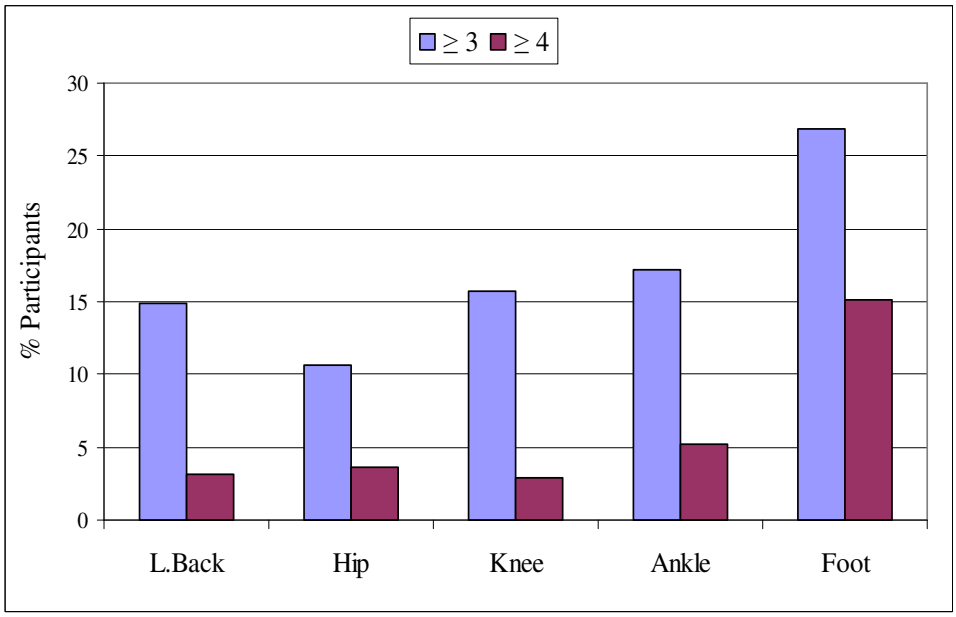


**Figure 3:** Percentage of participants that rated each region of the body at either uncomfortable (3) or very uncomfortable (4) or above.

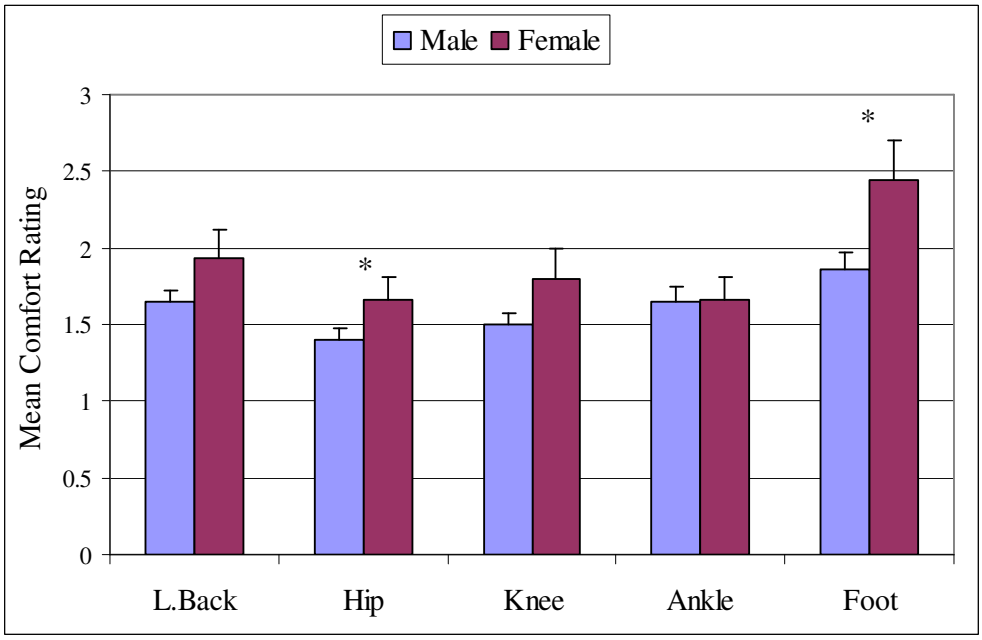


**Figure 4:** Combined mean comfort ratings for each body region as given by males and females, error bars represent the standard error. * indicates significance ($p<0.05$).

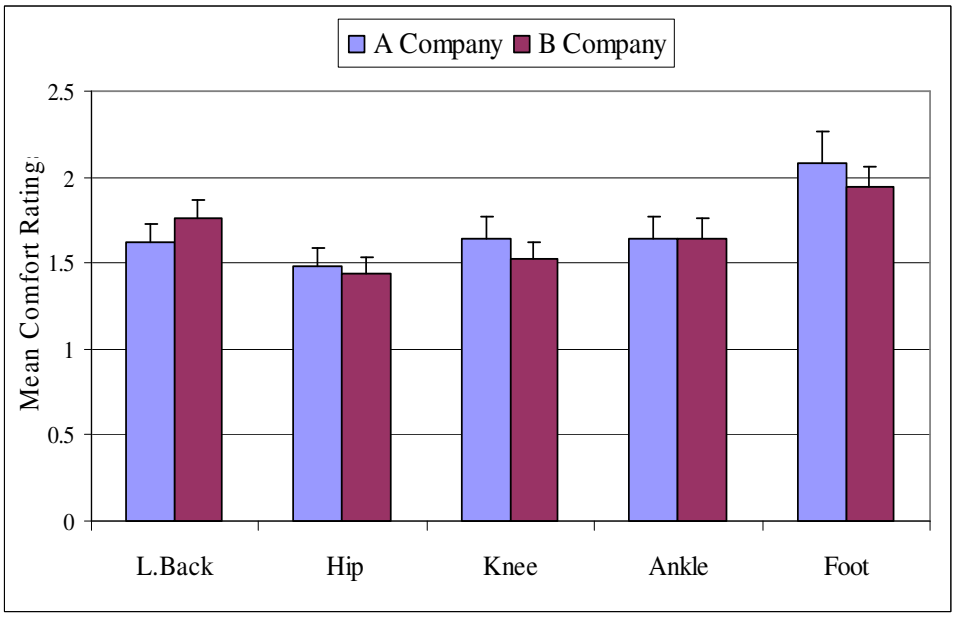


**Figure 5:** Combined mean comfort ratings for each body region as given by A and B Company, error bars represent standard error of the data.

**Table 1:** Participant characteristics, mean value standard deviation in parentheses.

| | Age (years) | Male / Females | n |
|---|---|---|---|
| **Combined** | 20.61 (2.55) | 98 / 29 | 127 |
| **A** | 21.38 (3.66) | 38 / 10 | 48 |
| **B** | 20.16 (1.40) | 60 / 19 | 79 |
| **Male** | 20.67 (2.83) | - | 98 |
| **Female** | 20.41 (1.15) | - | 29 |

**Table 2:** Mean subjective skeletal comfort data, standard deviations in parentheses. Ratings represent comfort as assessed using figure 10.1.

| | **Combined** | **A Com** | **B Com** | **Male** | **Female** |
|---|---|---|---|---|---|
| **L. Back** | 1.71 (0.88) | 1.63 (0.73) | 1.76 (0.95) | 1.64 (0.83) | 1.93 (1.00) |
| **Hip** | 1.46 (0.81) | 1.48 (0.77) | 1.44 (0.84) | 1.40 (0.81) | 1.66 (0.81) |
| **Knee** | 1.57 (0.85) | 1.65 (0.84) | 1.52 (0.86) | 1.50 (0.76) | 1.79 (1.08) |
| **Ankle** | 1.65 (0.98) | 1.65 (0.86) | 1.65 (1.04) | 1.64 (1.01) | 1.66 (0.86) |
| **Foot** | 1.99 (1.19) | 2.08 (1.27) | 1.94 (1.14) | 1.86 (1.10) | 2.45 (1.35) |
| **Body** | 1.62 (0.91) | 1.75 (0.86) | 1.66 (0.98) | 1.57 (0.88) | 1.80 (1.01) |