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Relationship between skin abrasion injuries and clothing material characteristics in motorcycle crashes

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ABSTRACT

In recent years, increases in motorcycle registrations have led to increases in the numbers of motorcycle casualties. Abrasion injuries are the most common injury to crashed motorcyclists and can still occur when the skin is fully protected by motorcycle specific clothing. This study investigated abrasion injuries and whether the type of material and the dynamic coefficient of friction (COF) of that material against skin could predict injury. This investigation was performed on a sample of riders who were involved in crashes (n = 92). The dynamic COF of the materials worn by the riders against an artificial skin substitute, Lorica® Soft, was determined using a biaxial materials testing machine. The occurrence of abrasion injuries for each of the riders was recorded and the injury outcome was compared to the type of material and the COF of these materials. Riders wearing heavy cotton and fleecy cotton knit sustained significantly more abrasion injuries than riders who wore other materials. No relationship was found between the dynamic COF of the materials and the likelihood of abrasion injuries to crashed motorcyclists. These results suggest that some materials are associated with higher levels of abrasion injuries, yet the COF may not be used to predict abrasion injury.

1. Introduction

Research into motorcycle crashes is becoming increasingly important with increasing motorcycle usage and a corresponding increase in motorcycle casualties [1]. Motorcycle crashes are over-represented in crash statistics and little progress has been made in recent years in protecting motorcycle riders from injury [2].

The most common forms of injuries to motorcycle riders involved in crashes are soft tissue injuries such as skin abrasions, contusions and lacerations [3–5]. These soft tissue injuries are primarily due to contact with the roadway [3]. Protective clothing for motorcycle riders has been developed, and can reduce the risk of injury if it provides an effective barrier between the skin and the road surface [4].

A recent in-depth investigation of motorcycle crashes in Sydney, NSW, has highlighted that skin abrasion injuries can still occur when motorcycle clothing does not completely abrade through and the skin does not come into direct contact with the road surface (Brown and Meredith, unpublished data). This raises the question as to whether the material itself is causing abrasion injuries and whether this is due to the frictional properties of the materials worn against the skin. While not necessarily a serious injury, these injuries appear to be frequently occurring in motorcycle crashes and it may be possible that they are preventable through the use of appropriate lining materials.

There does not appear to be any research into the frictional properties of textiles specifically for use while riding a motorcycle; however, the frictional properties of clothing materials have commonly been researched with the aim of minimising friction blisters for applications including military use and sports injury prevention [6–15]. An early study by Naylor [15], investigated how the coefficient of friction between skin and polyethylene varied during blister formation on feet when applying a continuous rubbing motion with one cycle taking 3 s at a constant vertical force of 5.2 N to skin in vivo. They found that the coefficient of friction increased with a linear relationship to the number of rubs performed, and the average frictional force required to produce a blister varied between 1.9 and 3.4 N. This variation could be attributed to levels of skin moisture and oil levels. A more recent study by Dai et al. [7] used a 3-D finite element model to investigate the biomechanical effects of wearing socks with different frictional properties and was investigated under three different conditions. A relationship was observed between a material with low friction and a reduction in the occurrence of friction blisters on the foot due to the decreased shear-forces associated with low-frictional materials. Frictional properties have also been investigated for product design and comfort evaluation ranging from hospital materials, clothing comfort and diaper wearing

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[16–21]. In particular, the coefficient of friction has been investigated for skin against hospital bed sheets in order to minimise the occurrence of decubitus and superficial abrasions [16,22]. For these studies, the dynamic coefficient of friction was measured in vivo, with the participant rubbing their forearm on a tri-axial quartz force plate in order to investigate the influence of age and epidermal hydration on the coefficient of friction. The results found that the coefficient of friction increased typically by 43% for women and 26% for men when skin hydration varied between very dry and normally moist skin. However, they did not find any difference in the coefficient of friction between age groups, indicating that in this circumstance, the coefficient of friction did not contribute to the increased levels of decubitus in aged persons.

An artificial skin substitute, Lorica® Soft, has also been used to provide a measure of the coefficient of friction of skin against textiles. Derler et al. [23] validated Lorica® Soft as a suitable substitute for skin by measuring the coefficient of friction of Lorica® Soft against a variety of textiles using a tri-axial quartz force plate. They found that Lorica® Soft was the artificial skin substitute which matched dry skin most closely for normal forces of up to 10 N. There has been a wide variety of methods used to investigate frictional properties of textiles against skin or skin surrogates in the past to investigate skin injury, however none have previously investigated this in the context of motorcycle injuries, despite skin abrasion being very common.

This study used the sample of real world crashes from the recent in-depth crash investigation [24] which occurred in Sydney, Australia, in order to investigate abrasion injuries which are occurring in crashed motorcyclists due to contact with the clothing they were wearing at the time of the crash. This study aimed to determine what materials were being worn by Australian riders, what the dynamic coefficient of friction was for these different materials against a biofidelic skin surrogate and whether these factors had any bearing on the likelihood of the rider suffering an abrasion injury.

2. Methods

2.1. Data collection

This study involved an in-depth investigation of 92 motorcycle crashes occurring within a 3 h drive of Sydney between August 2012 and July 2014. Eligible participants were motorcyclists aged 16 years and older who had crashed on public roads and been admitted to hospital as a result of the crash. Participants were recruited by research nurses from three Sydney hospitals and one regional hospital. Ethics approval for collection of data from motorcycle riders involved in crashes was by a lead NSW Department of Health Ethics Committee (RPAH zone) and ratified by the University of New South Wales Human Ethics Committee.

Motorcyclists were required to complete a face-to-face interview in order to outline the details of the crash including the rider's estimate of the speed of the crash. Details collected from the rider interview were verified through in-depth investigation of the scene, motorcycle and other equipment used. Where rider consent was provided, the details were also corroborated with police reports and in some cases (approximately 30%), details were supplemented by witness statements collected during police investigations of the crash. The medical records were examined to obtain the injury details of the rider following the crash and the clothing that the rider was wearing at the time of the crash was inspected for signs of damage as a result of the crash. Abrasion injuries were identified from medical records where clinicians made the assessment based on the following definition of abrasion: where the skin appears to be worn away through mechanical means. This is separately coded from lacerations and burns.

During rider interviews and clothing inspections, all materials worn by each rider were identified. This included undergarments worn by the rider and clothing which had different lining in different regions, for example Kevlar lined pants where the Kevlar only covered the knees. For some riders, the undergarments were unknown and these were excluded from the analysis ($n = 39$). For each material worn by each rider, it was determined whether abrasive contact had occurred in the body region covered by that material ($n = 90$). This was achieved through observation of any abrasion damage to the clothing, or abrasion injury to the skin that would have been covered by clothing. Abrasion damage to the clothing which had completely holed the clothing, or abrasion injury which occurred where there was no clothing covering that body region were excluded as any injuries in these body regions were due to the skins exposure rather than the clothing material. For the materials where abrasive contact may have occurred, medical records were then examined to determine whether any abrasion injury from that location was present.

2.2. Friction measurements

The dynamic coefficient of friction between the clothing worn and an artificial skin substitute, Lorica® Soft, was determined for each of the 92 riders who participated in the study and all of the materials that each rider wore which was adjacent to their skin. Lorica® Soft is an artificial leather which consists of a polyamide fleece with a polyeurethane (PUR) coating, and has been used for testing the slip resistance of floor coverings in barefoot areas. It is characterised by a surface structure similar to that of skin and has surface roughness parameters in the same range. It has been validated as a suitable substitute for skin in friction testing experiments against materials for normal forces of approximately 10 N [23].

The coefficient of friction was measured using a custom made friction testing apparatus which utilises a biaxial materials testing machine (Instron 8874, MA, USA) to apply a constant normal (axial) force and rotate a moment arm at a constant speed (Fig. 1). The normal force and resultant torque were measured using a biaxial transducer (Instron 56,148 force/56,303 torque). This method was validated prior to testing with materials of known coefficients of friction for rotational speeds of 0.1, 0.5 and 1 deg./s. All friction experiments took place at a temperature of (20.5 ± 0.5 °C) and humidity of ($52.5 \pm 2.5\%$).

For this study, the material which would be in contact with the rider's skin was attached to a circular sample holder with a contact area of 196 mm^2 (diameter = 50 mm). The moment arm from the sample holder to the centre of rotation of the testing machine was 132.5 mm. The material was positioned so that the fibres were at

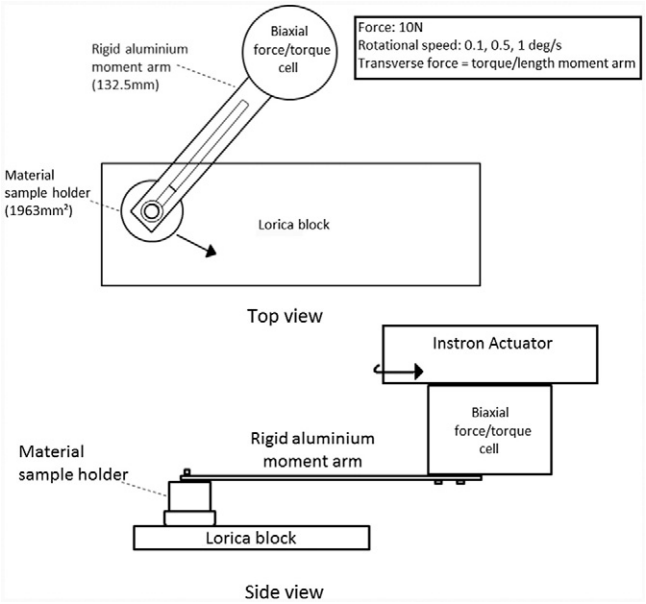

Fig. 1. Experimental set-up of the Instron testing jig.