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Headform mounting performance in cricket standard testing

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Abstract

The current British Standard for head protectors for cricketers specifies a projectile test to ensure that a helmet can prevent the ball penetrating the peak-grille gap and deformation of the grille onto the face. For practical reasons, it is specified that the headform is mounted onto a grounded frame. This study aims to determine whether this "Fixed" mounting technique influences the response of the headform relative to a theoretically preferable "Free" suspension. A pressurised air cannon was used to project a "BOLA"™ ball at three nominal speeds (22, 25 and 28 m/s) and at three target impact locations (136 (Top), 108 (Middle) and 80 (Bottom) mm from the base). High speed video was used to identify the contact duration and accelerometer data were used to assess the peak resultant headform acceleration and velocity during this period.

Generally, good agreement between the two scenarios was found in regard to peak resultant headform acceleration, particularly at the 25 and 28 m/s impact speeds. In terms of headform velocity, the two scenarios showed greater variation when the full contact duration was considered, with root mean square deviations ranging from 1.77 – 5.6 in all testing conditions. However, some portions of the impact were considerably more consistent than others. These initial results indicate that the result of the penetration test, as specified in BS 7928:2013, would be independent of the suspension technique particularly given the convergence of results at the specified standard velocity (28 m/s). Future work should look to identify the loading and unloading phases of an impact, and use this to compare headform response. Thus allowing a more in-depth investigation of headform mounting performance and provide more clarity on the use of the Fixed technique in cricket standard tests.

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Keywords: headform; mounting; standard test; impact; projectile impact; cricket helmet

1. Introduction

Head protection is commonly available in many sports. A participant's use of a helmet may be mandated in the rules of a competition, for example in Formula 1™ motor racing [1] and snowboarding [2]. In some sports helmet use may be permitted in the rules, but ultimately be a personal decision aimed at reducing the risk of injury. Until recently, this was the case in cricket [3], however the England and Wales Cricket Board (ECB) have now mandated helmet use in professional cricket from the 2016 season. In extreme cases, the function of a helmet is to prevent death or life changing injury, although in many cases, the role of a helmet is to protect or reassure against more minor injury, disfigurement or discomfort.

Walker et al. [4] reported that, over a 5 year period in New Zealand, 21% of all injuries resulting in the hospitalisation of professional and recreational cricketers were sustained to the head. In elite level cricket, the speed of the ball can exceed 85 mph when bowled or thrown, or higher still when hit by the bat. Although lower speeds are more common at recreational levels of the game, direct contact between the ball and the head, or contact as a result of helmet deformation can still cause injury such as concussions, eye injuries, facial fractures, lacerations [5] or even death [6, 7].

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In order to be sold in Europe, protective helmets must satisfy current standards tests and therefore adhere to certain quality controls [8]. These tests must provide an appropriate performance benchmark without being overly costly to implement and thereby avoid excessive cost being passed to the consumer. For this reason, many standards tests utilize an energy equivalent collision, as proposed by Johnson [9], where a high mass low velocity impact is used to simulate a real life collision. Using this technique, a pass fail criteria can be set and implemented with relative ease. These types of test have however been shown to be dissimilar to the case of a real ball projected at the peak-grille gap of a typical cricket helmet [10]. For this reason, a projectile test was incorporated into the revised British Standard specification [11] for head protectors for cricketers, to ensure that a helmet is capable of preventing facial contact either directly as a ball passes through the peak-grille gap, or as a result of deformation of the faceguard onto the face.

When subjected to a tactile stimulus, human response times have been shown to be no faster than a few milliseconds [12]. Therefore, in such a short duration impact as that seen in a ball-head impact in cricket, the passive stiffness of the neck would likely determine the response of the head, since there would be insufficient time to alter this. The passive stiffness of the human neck has been reported to be no greater than 0.1 Nm/deg in the range of $\pm 20^{o}$ [13], suggesting that, in order to create a more accurate real-life representation of an impact, a freely suspended headform would be more appropriate than a rigid mounting. In various cases where impacts have been broadcast and a player has recoiled or been knocked to the ground, these movements occur after tenths or whole seconds have elapsed, suggesting that recoil is not entirely due to the force imparted by the ball during contact.

During an impact, the responses of the colliding bodies are determined by the masses of the bodies and the forces that are applied. However, if contact duration is sufficiently short, the stress waves induced by the impact may not propagate sufficiently to recruit all of the mass of the larger body before they separate, suggesting that the method by which the greater body is suspended is unlikely to be significant. If, as is the practical case, both bodies have a finite stiffness, some deformation will occur and contact duration will be dependent on a more complex series of parameters. When contact cannot be assumed to be negligibly short in duration, the method by which the greater body is suspended is likely to have a more significant effect on the collision.

The British Standard for head protectors for cricketers specifies the use of a rigidly mounted standard headform during projectile testing. The aim of this study was to consider this practical case and determine whether a rigidly mounted headform, preferred for reasons of practicality, offers sufficient similarity to a freely suspended headform (recommended to best represent the theoretical case) to justify its inclusion within testing protocols. This was investigated through high-speed video based observations of the behavior of both colliding objects and accelerometer measurements representing the motion of the headform.

2. Methodology

A bespoke experimental arrangement allowed for the suspension of an instrumented British Standard magnesium headform (size 575) [14] (mass 4.7 kg) in Free and Fixed scenarios. In reality, neither of the scenarios is truly free nor fixed but lies somewhere between these two extremes. In the Free scenario the headform was inverted and suspended with bungee cords (10 mm diameter) attached to the base. In the fixed scenario the headform was mounted via an anti-vibration type bushing onto a grounded frame. The bushing includes a silicon rubber element (PT Flex 60, Polytek, Pennsylvania) which enabled constraint of the headform, while allowing some rotation about the pivot (105 mm from the base of the headform) upon disturbance from rest. The stiffness values of the two suspension techniques were determined by applying a force to the headform in line with the basic plane and measuring the resulting static displacement. The stiffnesses were found to be 1.8 N/mm for the Free scenario and 185 N/degree (equivalent of 49.8 N/mm at the basic plane) for the Fixed.

Throughout all tests the same type of “BOLA”™ cricket training ball (mass 150 g, diameter 71 mm), as specified in the BS 7928:2013 [11], was used. A pressurised air cannon was used to project the ball toward the headform at three impact speeds, nominally 28, 25 and 22 m/s. The experimental arrangement allowed for the vertical position of the headform to be adjusted and therefore allowed for impacts to occur at three impact locations, nominally 136 (“Top”), 108 (“Middle”) and 80 (“Bottom”) mm from the base of the headform. The Top and Middle impact locations are aligned with the headform Reference and Basic planes respectively, and the Bottom location is the same distance from the Middle that the Top is, but in the opposite direction. In the British Standard, a helmet is fitted onto the headform thereby adding compliant materials which would influence the impact mechanics. However, as any differences between the mounting techniques would be most pronounced with bare headfrom impacts, no helmets were used throughout the testing.

A PCB 356B21 triaxial accelerometer was fitted inside the headform using a mount. The accelerometer was secured on the central axis, 127 mm from the base of the headform and was orientated relative to the headform such that the x, y and z axes corresponded to superior-inferior, medio-lateral and anterior-posterior movements respectively. Once conditioned the