A comparative study of vent designs for effective ventilation in cricket helmets

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Abstract

It has been reported that wearing a protective helmet reduces airflow around the head and leads to an increase in heat-related stress and discomfort due to excessive sweat. The main objective of this study is to investigate vent designs in order to improve the air ventilation and heat dissipation in cricket helmets. An experiment was conducted in a research wind tunnel using a thermal manikin headfoam at a constant wind speed of 2.3m/s. Thermal comfort was measured in terms of heat dissipation and heat gain with ten K-type thermocouples. A comparison was made between four different helmets in terms of the vent design variations and temperature distributions. An increase in heat dissipation and a reduction in temperature in thermocouples were observed in the design incorporating suspension straps. The heat dissipation increases when there is an air gap between the head surface and the helmet shell/liners and where an air gap allows cooling air to circulate through the helmet. The thermal manikin experiment provided an efficient investigation of heat gain and/or loss for different vent designs, whereby its application is restricted to controlled experimental conditions.

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1. Introduction

Helmets protect cricket players from head injuries. However, they reduce the air flow over the head [1]. Reducing airflow rapidly increases the head temperature and affects the heat dissipation from the head to the

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environment. This could lead to an increase of heat related stress during long period of play in the sun and subsequently will make players feel discomfort by producing excessive sweat [1].

Over the years, many studies have shown that wind speed has differential effects on thermal transfer in different conditions. In high-velocity wind conditions (high-rise building construction or competitive cycling) forced convection is a significant factor affecting thermal comfort [2]. Most studies reported in literature focus on forced convection to determine heat loss or heat gain for motorcycle and cycling helmets. However, low-velocity wind conditions, such as in cricket games, involve little wind and practically no aerodynamic effects [1].

The objective of this study is to investigate the performance of four different vent designs in cricket helmets. Specifically, the research aims to: a) investigate heat gain and loss beneath the helmet to reduce heat related stress; and b) identify helmet vent design effects on heat loss for possible further design improvements.

2. Materials and Methods

2.1. Helmet models

Four cricket helmets with different vent designs were examined (Fig. 1). The M1 helmet has one circular hole with a diameter of 11mm on each side of the crown. The N1 helmet has several vent holes, with a diameter of 10mm each to assist ventilation [1]. The A1 helmet has three circular holes with diameter of 13mm each and a cross-shaped opening at the crown. The E1 helmet has four radial openings across the shell with a small cross-shaped opening at the crown.

![Fig. 1. Helmets with different vent designs used in the study](image)

2.2. Experimental setup

An aluminum headform was installed in the RMIT University research wind tunnel (Fig. 2), which is not a climatic wind tunnel, and its ambient temperature was not controlled. During the experiment, the wind speed was controlled at an average wind speed of 2.3 m/s, which represents typical average wind speeds during a cricket match played in Melbourne Cricket Ground (MCG) [3]. The wind speed was constantly measured using a Thermo-anemometer VT100 (KIMO® Instruments), with an accuracy of 0.05 m/s [1]. A pumping system was used to supply and draw warm water from the water boiler to the manikin head through insulated pipes. The two insulated pipes were connected to the neck of headform; one pipe, which was connected to the pump system, continuously supplied warm water from the water boiler, the other constantly drew the water out from the headform back to the water boiler. The surface temperature of the headform was controlled to achieve a constant temperature of 35.5°C to simulate the skin temperature of a human head [1]. The headform surface temperature was measured using ten K-type thermocouples, which can measure a wide range of ambient temperature from -50 to 250°C, and have an accuracy of 1.5°C [1]. The thermocouples were connected to a DT85 series 2 dataTaker® [4] (Fig. 3). The data taker was connected to a computer to record the temperature increment/decrement of K-type thermocouples for every
The data taker produced an Excel spread sheet that provides the temperature of each thermocouple; hence, the average headform temperature can be determined.

The locations of the thermocouples, as shown in Fig. 4, were assigned to obtain representative measurements of the mean head surface temperatures beneath the helmet shell and liner. The experiments were classified according to headform arrangement: (1) the manikin headfoam with helmet facing the wind direction (Front condition); and (2) the manikin with helmet slightly angled (20°) to the wind direction (Angled condition). All helmets were tested in both arrangements, and each experiment was repeated three times to ensure the statistical significance.

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3. Results

Fig. 5 summarizes the temperature change of the manikin head for the entire duration of the experiment. In order to depict the relative impact of each helmet on the heat exchange between the manikin head and the environment, the test was organised into three phases:

I. Phase I, between 0 and 120 seconds, temperatures of the manikin head without helmet and no wind;
II. Phase II, between 121 and 1020 seconds, temperatures of the manikin head with helmet and no wind,
III. Phase III, between 1021 and 1920 seconds, temperatures of the manikin head with helmet and with wind speed of 2.3m/s.

Once the helmet was fastened to the manikin headform, the surface temperature increased drastically in Phase II, or first five minutes (between 150sec and 450sec) of the test period. Then, the temperature increased gradually and became stable. On average, the surface temperature of the headform increased by 3.5°C for all helmets in still condition (with no wind). However, during forced convection conditions, the average temperature dropped to around 34°C for all helmets.

4. Discussion

The manikin measurements were carried out with and without forced convection. In order to investigate the overall performance of the different ventilation designs, the temperature gain and/or loss for the front and angled configurations were plotted individually (Fig 6). Each thermocouple data was investigated to identify the heat gain/loss and hotspots in the headform at the end of the forced convection condition.

Fig. 6 showed that the highest average temperature increments for most helmets were detected at the thermocouples 6, 9 positions (Parietal lobes) and 8 (Occipital lobe) of the headform. A significant temperature drop was observed at thermocouples 2 (Frontal lobe), 4 and 5 locations (Side temples) for helmets N1, A1 and E1; however, helmet M1 recorded temperature increases at these locations.

For the angled condition (Fig. 7), helmets N1, A1 and E1 recorded temperature drops for most locations except at the thermocouples 3, 6, 8, and 9 of the headform. Helmet M1 recorded a temperature drop for all thermocouple locations in angled condition.
locations indicated that the head surface covered by a helmet was not well ventilated and can therefore impede heat dissipation. Also, when the helmet rests on the headform, there is no gap between the helmet liner and the headform for air circulation.

A previous study [1] indicated that adding extra vent holes to a helmet might improve air circulation and reduce the temperature. Helmet N1 has more vent holes in the Temple and Parietal regions than helmet A1. When facing the wind from the side angle, cool air can flow through the front vent to the rear vents around the Temple and Parietal regions. Therefore, helmet N1 achieved a temperature reduction in the crown (thermocouple 1) and Parietal regions (thermocouples 3, 4 and 10) due to more airflow through the vents compared with the A1 helmet.

Helmet M1 has suspension straps that increased the gap between helmet shell/liner and the headform. The increased gap facilitated greater airflow, which led to significant reductions in temperatures at the Parietal and Occipital regions compared with other helmets in the angled condition.

There are limitations in this study as its application is restricted to controlled experimental conditions [5] whereby all the radiation sources were not considered. However, this thermal manikin experiment provided a detailed investigation of heat gain and/or loss of different vent designs, which has provided greater insight into which design features influence the most ventilation efficiency in cricket helmets.

5. Conclusions

The following conclusions could be drawn from this study:

- Experimental results showed that the helmets cause headform surface temperature to rise primarily around the Parietal regions, which cause heat related stress.
- During the forced convection conditions, extra vent holes allowed more air flow through the helmet and improved air circulation, especially around the parietal and front regions.
- Suspension straps result in gaps, which allow air to circulate through the helmet and assist heat dissipation in the Parietal and Occipital regions.

Based on these findings, it can be concluded that the following design strategies can produce greater ventilation efficiency:

- Inserting circular vent holes at the forehead and parietal regions
- Inserting suspension strap to increase gaps between the head and helmet

References