HEAT TRANSFER OF FULL-FACE MOTORCYCLE HELMETS

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INTRODUCTION

Motorcycle helmets can cause disturbances to the wearer by factors such as altered CO_2 and O_2 concentrations (Brühwiler et al., 2005; Iho et al., 1980). Also thermal discomfort has been shown to be an issue with bicycle helmets (Gisolfi et al., 1988), industrial helmets (Liu et al., 1999), and the same can be expected for motorcycle helmets (Patel and Mohan, 1993). Airflow influences these factors and is therefore important for the level of comfort experienced by the wearer.

We studied forced convective heat loss of modern full-face motorcycle helmets to investigate the state-of-the-art of helmet ventilation, including the effectiveness of the vents provided on these helmets. The helmets were assessed on a thermal manikin headform, and were examined under different conditions, e.g., different wind speeds, and with or without a wig installed between the helmet and the headform. An overview of the most important results from these studies will be given in this paper.

(a) (b) (c)

Figure 1: The headform at the exit of the wind tunnel (a), with a helmet and scarf installed (b), and with the wig equipped (c).

METHODS

27 Modern full-face motorcycle helmets (9 flip-up and 18 integral models) from 13 manufacturers were examined on a thermal manikin headform described previously (Brühwiler, 2003). The surface temperature of the headform was stabilized at 35 °C, and the power needed to maintain this temperature in a 20 min steady state period was recorded. This heating power corresponds to the forced convective heat loss (C). Values for the scalp (C_s) and face (C_f) sections were obtained separately.

The headform was placed at the exit of a wind tunnel, in an upright position (Fig 1a). Wind speed (v_w) was measured along side the head, using a MiniAir2 anemometer (Schiltknecht, Gossau, Switzerland). This setup was located in a climate chamber, maintained at 22.90 ± 0.05 °C and 50 ± 1% relative humidity and no applied radiant flow (lights off). A scarf (Fig 1b) covered the neck section to avoid an unnecessarily large C there; this also simulates a realistic situation, since many motorcyclists wear such protection.
All helmets except for helmet 161 were equipped with at least one operable vent in the face section, and all with at least one in the scalp section. The visor remained closed throughout the entire experiment. Each helmet was measured with the vents alternately all open and all closed consecutively, in random order. Three such measurements were carried out, with fresh helmet placement between the measurements. All helmets were placed based on a broadly-used impact test standard (ECE/324, 2002), with a specified space of about 3.9 ± 0.2 cm between the bridge of the nose and the upper edge of the helmet facial opening.

The following three conditions will be presented here:
i) REF: All 27 helmets were measured at 50.0 ± 1.0 $km \cdot h^{-1}$;
ii) WIG: Six helmets were measured at 50.0 ± 1.0 $km \cdot h^{-1}$ with a wig (Fig 1c) installed between the headform and the helmet;
iii) SPEED: Three helmets were measured at ten different wind speeds between 0.0 and 78.8 $km \cdot h^{-1}$. These results were corrected for warming of the air by the engine of the ventilator of the wind tunnel.

ANOVA was used for statistical analysis, with a Tukey test for post hoc comparisons if a significant difference was found ($p < 0.05$). The statistical analysis was carried out with SPSS 13.0 and 14.0 for Windows.

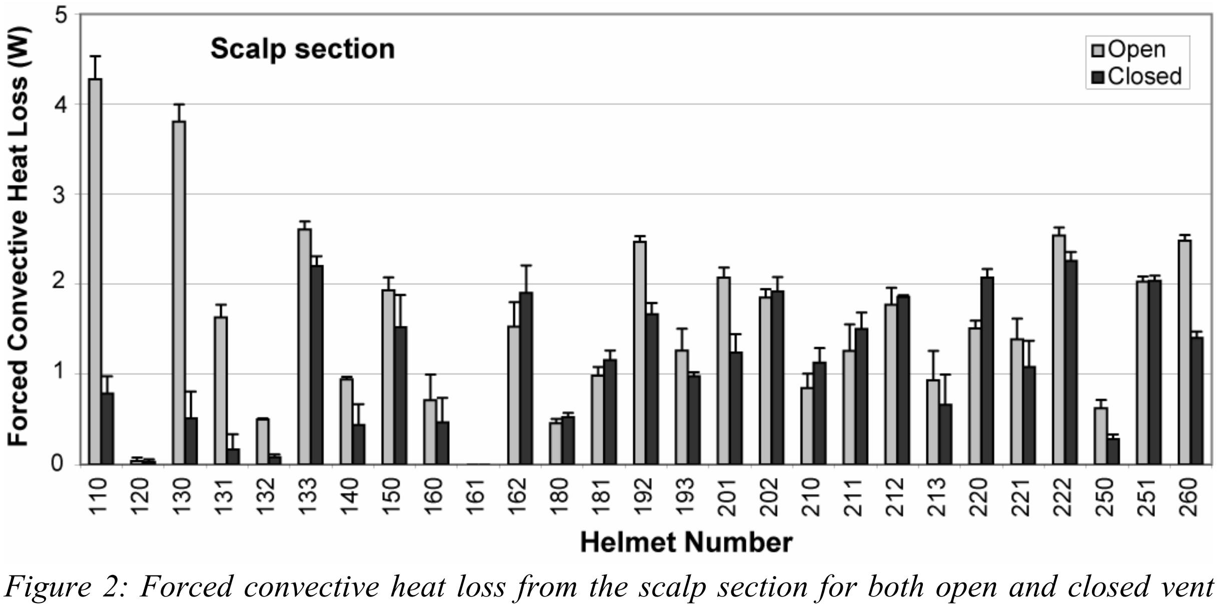
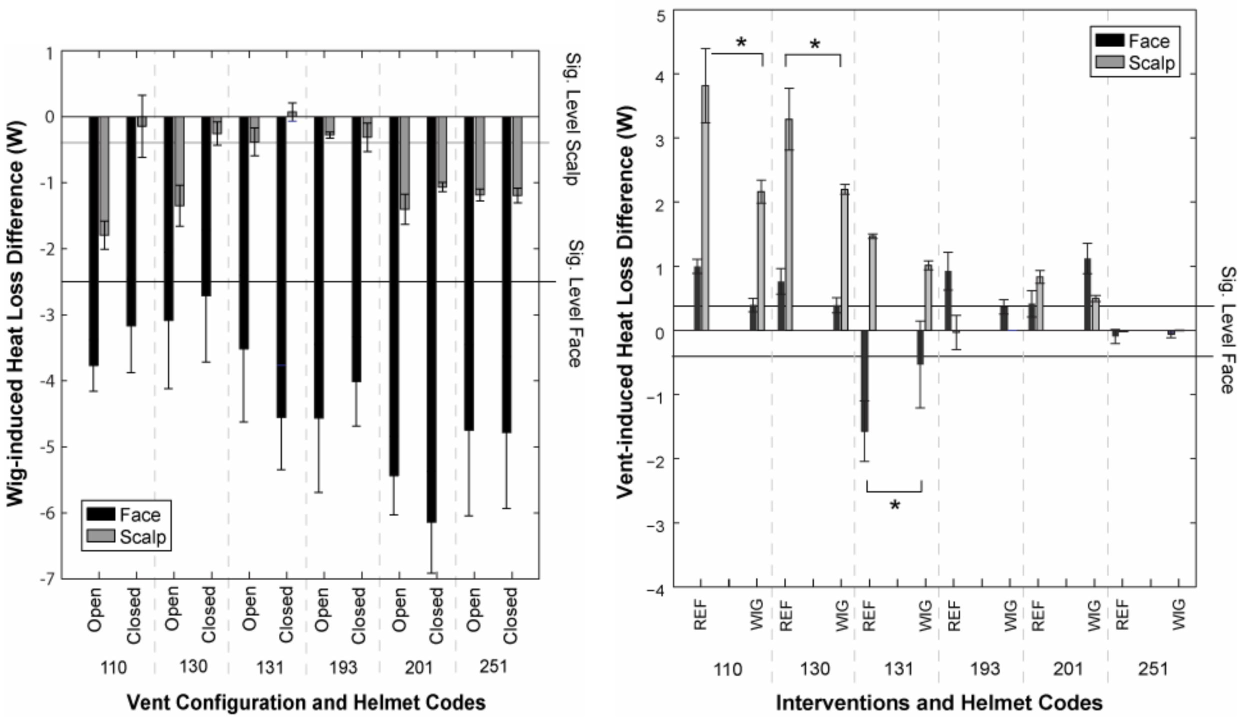


Figure 2: Forced convective heat loss from the scalp section for both open and closed vent configurations as indicated. The error-bars indicate one standard deviation.

RESULTS AND DISCUSSION

C_s is shown in Fig 1; similar qualitative results are found for C_f ranging from 8 – 18 W. Large variations in C among the helmets were observed in both the scalp and face sections. Previous studies have shown that variations in heat transfer are sensible for humans of the order of 1 – 2 W for the scalp (Brühwiler et al., 2004) and face (Buyan et al., 2006). Surprisingly, changing the vent configuration only had a small effect on ΔC for most helmets; e.g., in the scalp section only four helmets showed $\Delta C_s > 1.0$ (two $\Delta C_s > 2.0$), and in the face section six (one) helmets, respectively.

The wig decreased C_f with a factor of 1.5 ± 0.1, in all cases ($p < 0.01$). C_s was decreased with a factor of 2.3 ± 1.8 ($p < 0.001$) (Fig 3a). ΔC_s was significantly reduced in two cases ($p < 0.05$) (Fig 3b), and in the face section one significant case was found ($p < 0.05$).



(a) (b)

Figure 3: (a) WIG relative to REF, the indicated lines show the significance level (p ≈ 0.05) as indicated, and (b) ΔC of REF and WIG, an asterisk (*) indicates a significant difference. The error-bars indicate one standard deviation.

The scalp section showed good linear correlations between C_s and v_w, for both vent configurations and ΔC_s; average $r = 0.92 \pm 0.13$ ($p < 0.01$) (Fig 4a-c). Also for the face section good linear correlations are found; average $r = 0.96 \pm 0.11$ ($p < 0.01$). Interestingly helmet 131 shows a negative correlation for ΔC_f.

CONCLUSIONS

We found large variations in forced convective heat loss among a large sample of modern full-face motorcycle helmets. Furthermore, only a minority of helmets shows an effect of changing the vent configuration that could be sensitive to humans; ~20% and ~15%, for the face and scalp sections respectively. In a first attempt to investigate the effect of hair, a wig was used. It was found that the wig used reduces the forced convective heat loss through a head - motorcycle helmet combination with a factor of ~2, under these conditions. However, it remains unclear how this wig relates to real hair. Furthermore, good linear relationships exists between forced convective heat loss and wind speed (0 km·h^{-1} – 80 km·h^{-1}), making predictions of forced convective heat loss behavior easier based on a limited number of measurements.

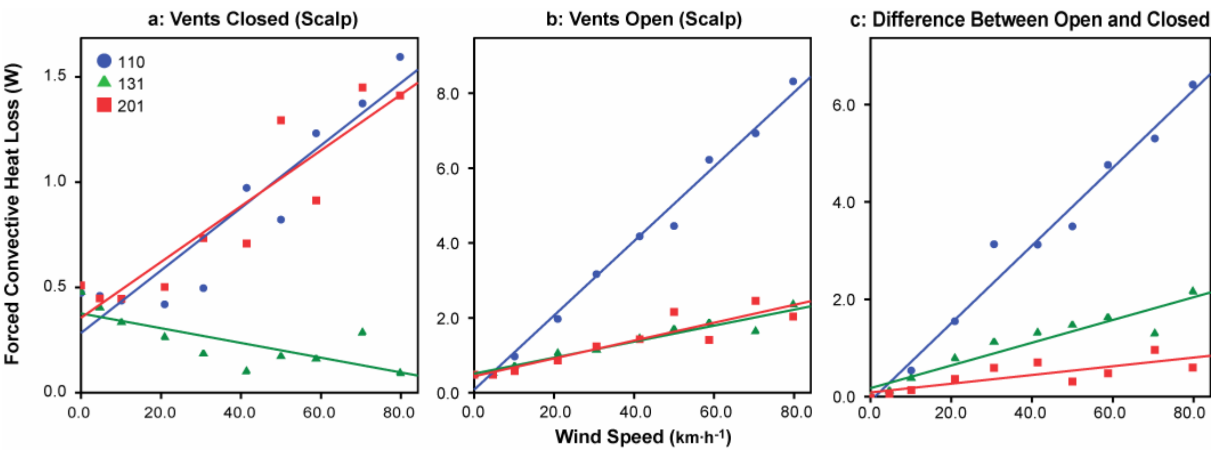


Figure 4: Regression lines for the forced convective heat loss from the scalp section and wind speed for vent configuration closed (a), open (b), and the difference between both configurations (c).

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