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Aerodynamic Efficiency and Thermal Comfort of Road Racing Bicycle Helmets

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Abstract

The main ambition of using bicycle helmet is to provide protection for riders especially from head injuries. However, for world class events a helmet becomes more important for its aerodynamic efficiency and thermal comfort. Those two factors have a proportional relationship and it is challenging to gain them at a high level. The features of the bicycle helmet (area and number of vents, position and geometry shape) are playing an important role for influencing heat transfer and aerodynamic drag. In this study, four commercial road racing helmets were tested in a wind tunnel environment for both aerodynamic and thermal evaluation. The RMIT Industrial Wind Tunnel was used to measure aerodynamic drag and profiling the heat transfer characteristics for each helmet at a range of wind speeds (20-40 km/h) and three different pitch angles (0°, 45° and 90°). Each helmet was ranked based on their aerodynamic and thermal performance.

Introduction

Thousands of bicyclists are being killed each year worldwide due to the head injury during accidents. In the USA, around 726 bicyclists died in 2011 and about 48000 were injured in traffic in the same year [1]. At present many governments around the world implemented and enforced laws to wear a helmet while riding to ensure the passengers safety.

Although the main purpose of using bicycle helmet is to provide protection for riders especially from head injuries, it becomes very important equipment for providing aerodynamic advantage and thermal comfort to the riders. Therefore, an optimal design of a bicycling helmet is a perfect combination of aerodynamic efficiency and thermal comfort alone with the safety requirements as shown in Figure 1.

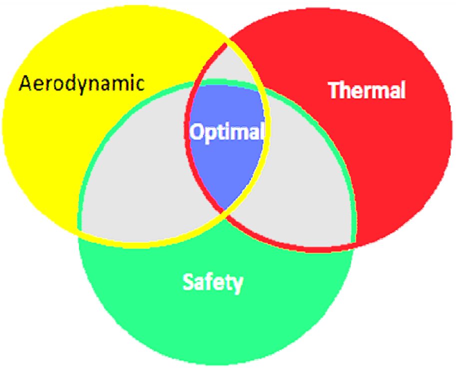

Figure 1. The concept optimal cycling helmet.

The features of the bicycle helmet (area and number of vents, position and geometry shape) are playing an important role for influencing heat transfer and aerodynamic drag. The aerodynamic efficiency of the helmet depends on its shape [2-4] whereas the thermal comfort can be produced by having more vents on it [5-6]. Several studies [4, 6-9] have been carried out on aerodynamic efficiency and thermal comfort on time trial helmets; however, no ranking procedure has been indicated for the combined effect of these two. Therefore, the main objective of this study is to measure the aerodynamic drag and temperature profiles for several commercially manufactured road-racing helmets and rank them based on their combined performance for optimal design.

Materials and Methods

Four commercial helmets were tested in this project for aerodynamic efficiency and thermal comfort. All these four selected helmets were made by different manufactures having distinct features (external shape, vent number, vent area, vent geometry and vent placement on the helmet) and all 4 helmets comply with the Australian Standard (AS2063) according to Australian Cycling Organisation website [10]. Figure 2 shows the helmets and Table 1 shows the details of all 4 helmets used in this study.

a.

b.

c.

d.

Figure 2. Helmets: (a) Giro, (b) Blast, (c) Nitro and (d) Zenith.

Helmet	Number of vents	Mass (gms)	Frontal area (m²)
Giro	26	190	0.2095
Blast	15	225	0.198
Nitro	20	265	0.193
Zenith	16	400	0.2016

Table 1. Physical properties of 4 helmets.

In order to measure the aerodynamic drag experimentally, the RMIT Industrial Wind Tunnel was used. The tunnel is a closed return circuit wind tunnel with a maximum speed of approximately 150 km/h. The dimensions of the rectangular test section are 3 m (wide), 2 m (high) and 9 m (long). The tunnel is equipped with a turntable to yaw a suitable sized model. More details about the tunnel's physical properties including turbulence intensity and physical dimensions can be found in [11]. A purpose-made mannequin was designed and manufactured to simulate the body position and size of a representative road cyclist (see Figure 3). Body measurements were taken of several male cyclists and the averaged dimensions were used to shape the model.

The head of the mannequin was connected to a rotating mechanism in order to change the pitch angle (θ). The mannequin was mounted on a rectangular platform which was connected through a threaded stud to a six-component force sensor (manufactured by JR3 Inc, USA). The sensor was capable of measuring all three forces (drag, side and lift forces) and 3 moments (yaw, pitch and roll moments) simultaneously. Initially, the force measurements were taken on the bareheaded mannequin for baseline comparison. Then the drag forces were measured for each helmet by fitting the helmet onto the mannequin head (see Figure 4). Drag coefficients (C_D) were calculated by using equation (1).

$$C_D = \frac{D}{\frac{1}{2}\rho V^2 A} \tag{1}$$

Figure 3. Experimental setup in RMIT Industrial Wind Tunnel.

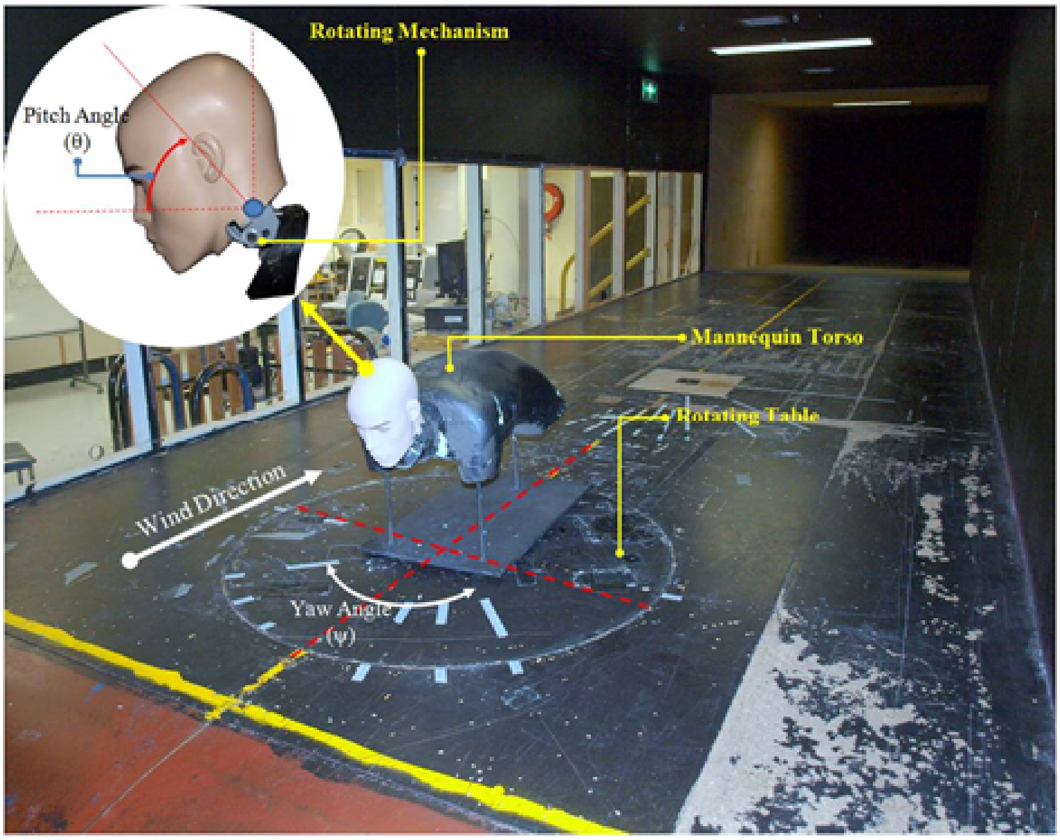

Figure 4. Experimental setup in RMIT Industrial Wind Tunnel.

A temperature controlled heat pad was used to simulate the head temperature of the cyclist during the riding. The heat pad was mounted around the bare mannequin head and then the helmet was fitted over the heat pad providing a few millimetre gap where four thermocouples were mounted at different positions. Real time temperature data were recorded using an 8-channel data logger. Study by Chowdhury [4] indicated that the average speed of the road racing cyclists in Tour de France tournament is about 40 km/h. Hence, in this study, all four helmets were tested over a range of wind speeds (20 to 40 km/h).

Results and Discussion

Figure 5 shows the variation of drag coefficient with wind speeds at three different pitch angles (0°, 45° and 90°). It can be clearly seen that the Giro helmet has the lowest drag coefficient at all the three pitch angles whereas Nitro has the highest drag. Experimental data from the wind tunnel testing also indicate that the drag coefficient decreases with the increase of wind speed for all helmets. It can also be noted that the value of drag coefficient is slightly higher at 0° pitch angle compared to 90°. Hence, pitch angle can play an important role for the reduction of aerodynamic drag during cycling. It was found that the helmet helps lowering the drag from a bare headed mannequin in all three pitch angle tested. Each helmet shows the consistency in drag reduction with respect to others regardless the pitch angle.

Figure 6 shows the variation of temperatures with wind speeds at three different pitch angles (0°, 45° and 90°). As expected, the bare headed mannequin shows the lowest temperature as there is no obstruction to trap the heat over the head. The data also indicate that Giro helmet keeps the temperature down compared to any other helmet tested. Table 1 shows that Giro helmet has more holes than any other helmets. As a result, heat can easily escape for the head surface. On the other hand, Zenith shows the highest temperature in 0 and 45 pitch angles as a result of fewer holes on the helmet. Similarly, helmet with less number of holes as seen with Blast helmet traps more heat and the thermal efficiency goes down. The experimental data also shows that head temperature decrease with the increase of wind speed for all helmets. Pitch angle has notable effect on heat transfer characteristics of a helmet. Data indicate that at 45 pitch all helmets shows lower head temperate that other pitch angle (0 and 90). Positioning of the holes (front and back) on the helmet is also important as incoming air enters into the head surface to remove the heat.

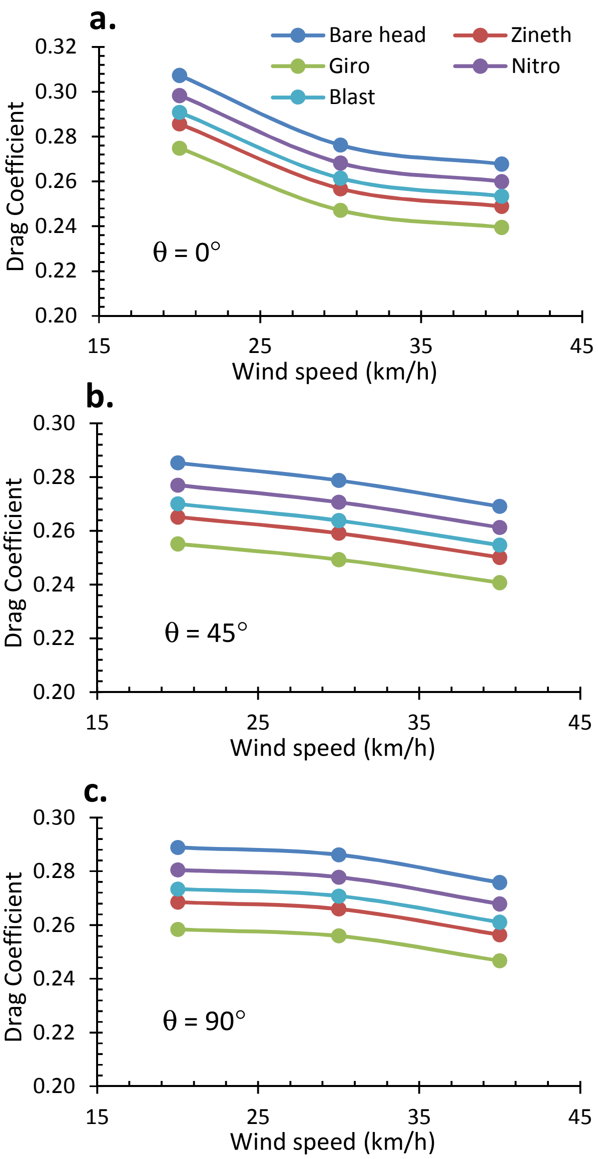

Figure 5. The variation of drag coefficient with speeds at: (a) θ = 0°, (b) θ = 45°, and (c) θ = 90°.

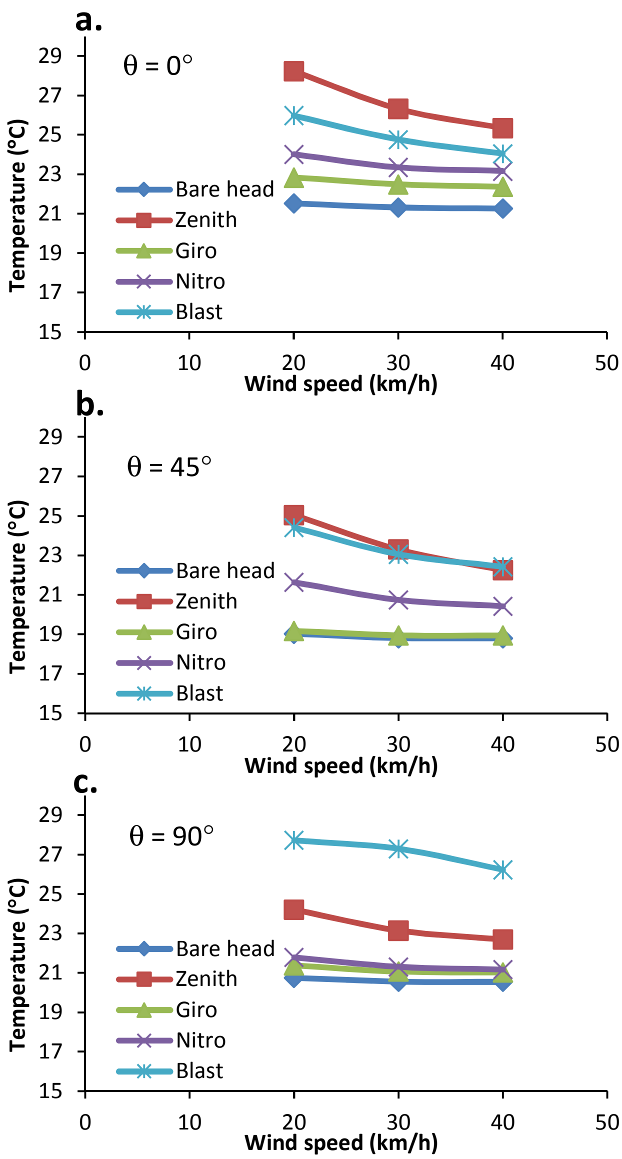

Figure 6. The variation of temperature with speeds at (a) θ = 0°, (b) θ = 45°, and (c) θ = 90°.

The four helmets were ranked based on their three combined performance on aerodynamic properties, heat transfer properties and physical properties. For aerodynamics efficiency, each helmet was separately ranked by allocating 4 points for lowest drag and 1 point for highest darg. This point based ranking was done for all 3 pitch angles. On the other hand, for thermal efficiency, 4 points were given for lowest temperature and 1 point for highest one. Similarly, for the physical properties, raking was done based on the number of holes. After summing all the points for different categories, the graphs as shown in figure 7, is plotted. The Figure 7 shows that Giro has the highest point (Rank 1) and Zenith is 2nd whereas Blast and Nitro have less points. The combined ranking helps the riders to choose their helmet depending on their applications.

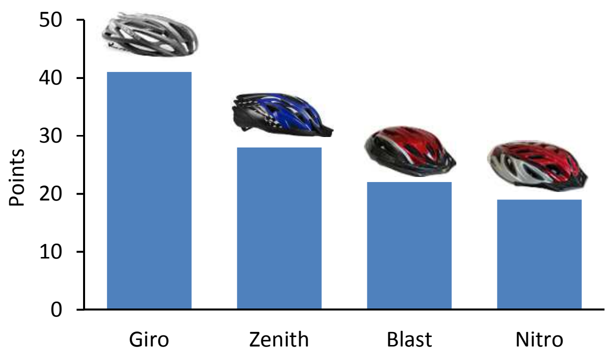

Figure 7. Ranking of helmets.

Conclusions

The study indicates that the shape of the helmets including the number, position and area of vents are very important parameters of helmets for drag reduction and better thermal efficiency. The results show that Giro is the most aerodynamically efficient helmet and Nitro was the worst performing helmet. Additionally, Giro is the most optimal helmet in terms of thermal comfort whereas Blast and Nitro are the worst performing helmets. The design and venting position need to be selected based on aerodynamic and heat dissipation characteristics as the position of the vent can increase aerodynamic efficiency while keeping thermal comfort intact.

References

[1] Bicycle Helmet Statistics. 2014. Helmets.org, available at: http://www.bhsi.org/stats.htm. [accessed on 26 August 2014].

[2] Kyle CR and Burke ER (1984) Improving the racing bicycle. *Mechanical Engineering* **106 (9):**34–35.

[3] Lukes, RA, Chin, SB, Haake, SJ (2005) The understanding and development of cycling aerodynamics. Sports Engineering 8:59-74.

[4] Chowdhury H and Alam F (2012) Bicycle aerodynamics – an experimental evaluation methodology. *Sports Engineering* **15(2):**73-80.

[5] Brühwiler P A, Buyan M, Huber R, Bogerd C P, Sznitman J, Graf S F and Rosgent T (2006) Heat transfer variations of bicycle helmets. *Journal of Sports Sciences* **24(9):**999-1011.

[6] Alam F, Chowdhury H, Elmira Z, Sayogo A, Love J and Subic A (2010) An experimental study of thermal comfort and aerodynamic efficiency of recreational and racing bicycle helmets. *Procedia Engineering* **2(2):**2413-2418.

[7] Alam F, Subic A, Akbarzadeh A and Watkins S (2007) Effects of Venting Geometry on Thermal Comfort and Aerodynamic Efficiency of Bicycle Helmets. In: Fuss F K, Subic A and Ujihashi S (ed) *The Impact of Technology on Sport II*. Taylor & Francis, UK, pp 773–780.

[8] Alam F, Subic A and Watkins S (2006) A Study of Aerodynamic Drag and Thermal Efficiency of a Series of Bicycle Helmets. In: Proc. of the *6th International Conference on Engineering of Sports*. Germany: ISEA.

[9] Blair K B and Sidelko S (2008) Aerodynamic Performance of Cycling Time Trial Helmets. In: Estivalet M and Brisson P (ed) *The Engineering of Sport. Paris*: Springer. pp 371-377.

[10] Helmet Regulations: AUSTRALIAN STANDARD AS/NZ 2063 - Bicycle Helmets [Online website: Australian Cycling Organisation]. Retrieved from http://www.cycling.org.au/?Page=17678 [accessed on 26 August 2014].

[11] Alam F, Zimmer G and Watkins S (2003) Mean and time-varying flow measurements on the surface of a family of idealized road vehicles. *Experimental Thermal and Fluid Sciences* **27(5)**:639–654.