Effect of rebreathing on psychomotor skills when wearing integral crash helmets

A. F. MALINS,* J. S. CURNOW,† P. J. F. BASKETT‡ AND R. GREENBAUM§

*Department of Anaesthetics, Queen Elizabeth Hospital, Birmingham; †Department of Physics, Bristol Royal Infirmary, Bristol; ‡Department of Anaesthetics, Frenchay Hospital, Bristol; §Department of Anaesthetics, University College Hospital, London

SUMMARY

Nine volunteer subjects underwent psychomotor testing when wearing an integral crash helmet in a variety of conditions which lead to rebreathing. There was a wide individual variation in the extent of rebreathing. In the worst conditions the minimum inspired carbon dioxide tension ($P_I\text{CO}_2$) increased to 2.6 kPa. The psychomotor test was a tracking test based on a microcomputer. There was a significant deterioration in the ability to perform the test when the helmet was worn with the visor down and restricted airflow into the helmet ($P = < 0.05$). In those tests when the minimum $P_I\text{CO}_2$ exceeded 0.5 kPa the decrease in performance was more highly statistically significant ($p = < 0.005$).

Rebreathing wearing integral crash helmets results in a variable impairment in the subjects' ability to perform a tracking test.

We recommend that the maximum level of CO_2 retention inside integral crash helmets should not exceed 0.5 kPa minimum $P_I\text{CO}_2$.

INTRODUCTION

It has been demonstrated that rebreathing occurred in a subject wearing a variety of integral crash helmets under differing conditions (Greenbaum *et al.*, 1982). Carbon dioxide retention inside integral 'full face' helmets has been confirmed by another study (Aldman *et al.*, 1981).

In the worst conditions the maximum inspired oxygen can decrease to 16.0 kPa with a concomitant increase in minimum inspired carbon dioxide tension ($P_i\text{CO}_2$) to 2.1 kPa (Greenbaum *et al.*, 1982).

At altitude with minor degrees of hypoxia causing hyperventilation and hypocapnia there is interference with visual discrimination, night vision and a worsening of psychomotor performance (Cotes, 1979; Guyton, 1979). If these or similar effects occur with individuals wearing integral helmets then recommendations may be required to limit the extent of rebreathing.

METHODS

Nine male volunteer subjects were recruited, five regularly wore crash helmets, four did not. They were physically fit and not receiving any medication. Each acted as his own control.

Psychomotor skills were assessed using a two dimensional compensatory tracking test, an established test of psychomotor performance (Hammerton, 1981). This was based on a microcomputer which generated a target and a cross in the centre of a television monitor. The cross randomly moved away from the centre of the target and the task was to keep the cross in the centre by means of a hand held joystick. Every 30 ms the distance of the cross from the centre was calculated by the computer. Each test period lasted 3 min and the results from the first 30 s disregarded. The score was recorded as the root mean squared distance (units). A maximum deflection from the centre of the target to the edge of the monitor screen was 110 units.

Prior to the day of testing each subject was allowed a period of practice. Each session began with a further practice period of up to 30 min to establish stability and a control score. The last 3 practice scores were used to calculate a mean control score.

The tests were performed in the same well lit room between 2.00–6.00 pm with the subject positioned 1 m from the monitor.

Minimum inspired CO_2 ($P_i\text{CO}_2$) was measured with a Gould Godart Capnograph. The sampling was made via a tube taped to the subjects upper lip to permit breath by breath analysis of respired air. The mean minimum $P_i\text{CO}_2$ was calculated as a mean of 20 consecutive breaths under steady state conditions.

The test conditions with the helmet with a clear scratch-free visor worn were—(A) visor open; (B) visor closed; (C) visor closed with balaclava and scarf. The last condition attempted to maximize the extent of rebreathing by reducing airflow into the helmet. Each subject was randomly allocated to one of six sequence conditions (A,B,C; B,A,C; C,B,A, etc.). Tests were performed in static conditions i.e. no airflow over the helmet.

The results were analysed using 't' tests for paired data.

RESULTS

Rebreathing occurred in all subjects when wearing a crash helmet with the visor closed with or without the balaclava and scarf (Table 1). The minimum $P_i\text{CO}_2$ varied widely

between individuals (range 0.15 kPa to 2.6 kPa). Under these circumstances there was a significant deterioration in the subjects ability to perform the tracking test in conditions B and C ($p = < 0.05$) as compared with control scores. Impairment of the subjects' ability to keep the cross in the centre of the target results in a higher score. When the minimum $P_i\text{CO}_2$ exceeded 0.5 kPa (Table 2) there was a greater impairment of psychomotor performance ($p = < 0.005$).

Table 1 The effect of wearing an integral crash helmet on mean tracking scores

Condition	Score	$P_i\text{CO}_2$ range kPa (mm Hg)	
Control	19.95 (3.5)	< 0.1	
Helmet on			
A Visor open	20.8 (2.9)	0.07–0.16	(0.5–1.2)
B Visor closed	22.1 (3.0)*	0.15–1.17	(1.1–8.8)
C Visor closed with balaclava and scarf	22.7 (3.8)*	0.8–2.6	(6.0–19.5)

Mean tracking test scores ($\pm$ SD) and minimum $P_i\text{CO}_2$ kPa (mm Hg) $n = 9$

* statistical significance $p = < 0.05$ as compared with controls

conversion factor 1 kPa = 7.5 mm Hg

Table 2 Mean tracking test scores ($\pm$ SD) and mean minimum inspired carbon dioxide tensions ($P_i\text{CO}_2$) in kPa (mmHg)

$P_i\text{CO}_2$ (range)	Test score	Control score
0–0.5 kPa (0–3.75 mmHg)	21.2 (3.0) $n = 10$	20.4 (3.6)
0.5–2.6 kPa (3.75–19.5 mmHg)	22.0 (3.5)* $n = 17$	19.7 (3.4)

* statistical significance $p = < 0.005$ as compared with controls

DISCUSSION

Rebreathing occurs when wearing integral crash helmets. This study demonstrates an associated decrease in psychomotor skills as assessed using a tracking test. A similar study (Aldman *et al.*, 1981) revealed no impairment of psychomotor performance when breathing 0%, 3%, 5% CO_2 in air. However, the study did not take into account the hypoxia which results from rebreathing.

The extent of rebreathing did vary between individuals and this may be as a result of; differing head and neck morphology; the variation in respiratory patterns; the seal around the base of the helmet—all affecting the inflow of fresh air.

Our results should not be interpreted as condemning the use of crash helmets. The incidence of head injuries in Kansas rose by 70% when the law requiring compulsory wearing of helmets was repealed. The mortality in those not wearing crash helmets was increased threefold.

With the impairment of tracking test performance when the minimum $P_{\text{I}}\text{CO}_2$ exceeds 0.5 kPa (0.5%) we recommend this level of carbon dioxide retention as a limit. On the road there will be airflow over the helmet which will reduce rebreathing. However, in certain circumstances this limit may be exceeded when the rider restricts airflow into his helmet (Greenbaum *et al.*, 1982; Aldman *et al.*, 1981).

Although the previously quoted study (Aldman *et al.*, 1981) showed no impairment of psychomotor performance the authors recommended a similar limit to CO_2 retention inside integral crash helmets.

Wearers of integral crash helmets should be encouraged not to obstruct airflow into the helmet. The visors should be designed as to permit easy opening when a motor cyclist stops.

We believe that the impairment of psychomotor performance may adversely affect a motorcyclists ability to control his machine although other factors may be involved. Rebreathing could be eliminated by minor modifications to helmet design with the instruction not to obstruct airflow into the helmet.

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