Effectiveness of the GO2Altitude® Hypoxia Training System

Roderick Westerman[1] MB, BS, PhD, MD, FRACGP, Oleg Bassovitch[2] BSc, MSc, Gordon Cable[3] MB, BS, DAvMed, MRAeS, Derek Smits[2] MSc.

Laboratory of Origin:

[2]Oleg Bassovitch, CEO,
Biomedtech Australia Pty Ltd
17 Roberna Street
Moorabbin, Victoria 3189
AUSTRALIA oleg@go2altitude.com

[3]Dr. Gordon Cable,
Aerospace Medical Services Pty Ltd
Adelaide Airport, Level 1, Control Tower Building,
Anderson Drive, Parafield Airport
South Australia, 5106, AUSTRALIA
Email: ggcable@bigpond.com

Correspondence and Reprints:

[1]Dr Roderick Westerman
Consultant Neurophysiologist
Caulfield General Medical Centre
260 Kooyong Road, Caulfield
Victoria, 3162 AUSTRALIA
Phone: +61 3 9859 1443 rwester@bigpond.net.au

Abstract

Aim: This study evaluates the effectiveness of the GO2Altitude® Hypoxia Training System method of normobaric hypoxia awareness training of aircrew by demonstrating and measuring (1) cardio-respiratory adjustments in healthy volunteers to a simulated altitude of 25,000 feet (7620 m); (2) the spectrum of signs and symptoms accompanying such hypoxia; (3) individual variability in susceptibility to hypoxia and oxygen paradox and (4) time of useful consciousness. *Methods:* The The concentration of oxygen in air was reduced by the GO2Altitude® device, and delivered by hand-held mask to 92 subjects, with continuous recording/display of physiological parameters and cognitive functions. *Results:* The GO2Altitude® system shows levels of blood oxygen saturation, heart rate and respiratory frequency displayed on the user screen. The type and frequency of impairments were reaction time (79%), simple mathematical processing (72%), short term memory (65%), colour perceptual acuity (69%), shape discrimination (38%), spatial orientation (18%), and thought block (21%). These are similar to those reported using a reduced oxygen gas mix method. Results may be printed or stored on video CD. *Conclusions:* The GO2Altitude® system simulates 25,000 feet altitude as effectively, safely, and more conveniently than a reduced oxygen gas mix method. Subjects experience their personal time of useful consciousness and hypoxic symptoms without risks of barotrauma or decompression sickness. The GO2Altitude® system provides theoretical revision and practical training for familiarisation with the physiological and cognitive effects of hypoxia and should enhance hypoxia awareness for aviation personnel.

Introduction

A recent review by Cable and Westerman[1] highlighted that problems associated with hypoxia have been common throughout aviation history from the first hypoxia induced fatalities of two French balloonists through to the recent major crash of a Helios Airways B737 in 2005. A number of papers have documented how common and dangerous hypoxia associated aviation incidents are, especially in military operations[1]. Hypoxia at increasing altitude is recognised as the most serious single hazard during flight[1-3].

Although knowledge of the effects of altitude on human physiology and performance is required by CAO20:11, practical hypoxia training for civilian flight crew has not been readily available until recently. Such training would substantially reinforce the required knowledge of and add a further level of safety in the early detection of loss of cabin pressure and hypoxia.

Over the last 10–15 years, physiologists and aerospace medicine researchers have developed and trialled a number of techniques that use normobaric low oxygen gas mixtures to simulate hypoxia at high altitude[4-8] and which reduce the costs and risks associated with hypobaric chambers. The Reduced Oxygen Breathing Device (ROBD) developed jointly by Duke University, and the US Naval Aerospace Medical Research Laboratory (NAMRL) uses a closed-loop breathing circuit with electronically controlled fraction of inspired oxygen[5-6]. This device has been proven effective in inducing hypoxia in subjects under normobaric conditions and hypoxia induced by normobaric ROBD was concluded to be equivalent physiologically and symptomatically to that induced by altitude hypobaria. A non-rebreathing normobaric system has also been studied and found effective in demonstrating hypoxic symptoms to students and Air Ambulance personnel at Monash University[4].

Aims

The primary aim of the study was to evaluate the new GO2Altitude® Hypoxia Training System[7-8], in particular (1) to obtain feedback from participating students and pilots about the educational impact of the GO2Altitude® hypoxia training system; (2) to validate the efficacy of GO2Altitude® system as a hypoxia training method for civilian and military aircrew; (3) to demonstrate the reliability, utility and convenience of this hypoxia training system for the aviation sector; and (4) to consider issues of training fidelity by seeking comment from experienced pilots about using a hand-held mask for hypoxia training. The second aim of this study was to compare the GO2Altitude® Hypoxia Training System with normobaric hypoxic training (using published results of the Westerman Reduced Oxygen Breathing Method[4]) by demonstrating and measuring (1) cardio-respiratory adjustments in healthy volunteers at a simulated altitude of 25,000 feet (7620 m); (2) the spectrum of signs and symptoms accompanying such hypoxia; (3) individual variability in susceptibility to hypoxia and oxygen paradox; and (4) time of useful consciousness.

Methods

Study Design

This study compares data derived from examining the performance of the GO2Altitude® Hypoxia Training System[7-8] with data derived from previous experimentation using the Reduced Oxygen Breathing Method[4]; seeking differences which could be significant.

Induction of Hypoxia

Hypoxia was induced by exposing subjects to the GO2Altitude® system[8] which provides a normobaric reduced oxygen breathing exposure for hypoxia training previously shown to be an efficient and cost-effective tool (Westerman, Bassovitch and Smits[7-8]). The GO2Altitude® system utilises air separation technology to produce two air streams with the desired low and high oxygen concentrations. It provides continuous computer monitoring of cognitive and physiological functions during programmed exposure to simulated altitudes up to 40,000 feet. Time of Useful Consciousness (TUC) was estimated by the presence of more than one cognitive function error. Exposure of subjects to hypoxia was limited to five minutes, with rapid recovery effected by breathing

Normobaric Hypoxia Methods

oxygen. The layout of a GO2Altitude® hypoxia training session is illustrated in Figure 1.

Results from this study were compared to those from a previous study[4] *using a normobaric Reduced Oxygen Breathing Method* (ROBM). In that study subjects breathed a commercial gas mixture (6.5%–7% oxygen, balance nitrogen), via a SCUBA mouthpiece with one-way valves expiring to air via a Wright respirometer. The 452 subjects in that study were continuously monitored for blood oxygen saturation (SpO_2) pulse rate, blood pressure, and ventilation[4]. A written cognitive function test battery lasting approximately 90 seconds was administered repeatedly until obvious impairments were observed[4].

Subject selection and screening

In total, ninety-two (92) healthy male and female, non-smoking subjects, aged 18 to 50 years volunteered for this study and 59 of the subjects were naïve to hypoxia training or hypobaric exposure. Subjects all gave written informed consent after receiving verbal and written information on the study design, risks, and voluntary nature of their participation. The research protocol was approved by The Alfred Hospital Human Research Ethics Committee (project 40/07).

All subjects held current Australian Class 1 medical certificates and underwent a screening medical examination by a Designated Aviation Medical Examiner. Subjects were to be excluded from the study if they suffered from any aeromedically significant illnesses, abnormalities on physical examination or adverse medical history. No subjects were excluded from GO2Altitude® study.

A physician or an Advanced Cardiac Life Support accredited Medical Intensive Care Ambulance paramedic monitored the conduct of the simulated altitude hypoxic exposure at all times.

Education and Briefing:

All subjects received a standard briefing on the effects of simulated altitude, nature of hypoxia, and measurements to be taken prior to the experimental intervention. They were briefed on the potential hazards of hypoxia from simulated altitude exposure and medical conditions which would exclude actual hypoxia exposure. The computerised educational package in the GO2Altitude® hypoxia training system delivers part of this briefing. In addition, the opportunity was given to ask questions and clarify the standard spiel if necessary.

Physiological Testing:

During GO2Altitude® hypoxia exposures the following physiological measurements were recorded at simulated 8,000 feet and 25,000 feet altitude: SpO_2, heart rate, respiratory frequency, heart rate variability by the fully integrated monitoring system.

Fig. 1. Shows the physical arrangement of the human interface portion of GO2Altitude® hypoxia training system. Visible are the facemask held in the non-dominant left hand, index finger SpO_2 probe/pulse plethysmograph, the touch screen displaying physiological parameters in the top right quadrant, altitude in lower right quadrant and cognitive tests continuously displayed in the left half-screen. Also seen are the desktop altitude control unit with LCD display, reservoir bag and a backup oxygen cylinder.

Fig. 2 Closeup of touch screen displaying physiological parameters oxygen saturation (SpO_2), Heart rate (HR) and ventilation frequency (Vf) in the top right quadrant, altitude and fractional inspired oxygen concentration (FiO2) in the lower right quadrant and cognitive tests continuously displayed in the left half-screen. Note the ABORT button.

Neurocognitive Testing:

Cognitive function was assessed continuously during each hypoxia exposure. In the GO2Altitude® hypoxia training system, a computer-presented repeating cognitive test battery was developed and refined from standard subtests similar to those employed in the aviation modules of neuropsychological test batteries. Parameters assessed included simple and choice reaction times, simple maths processing, spatial orientation, memory, shape discrimination and colour vision (BK, Ishihara or similar plates). Subjects were allowed sufficient time before the hypoxia exposure to fully familiarise themselves with the cognitive test batteries.

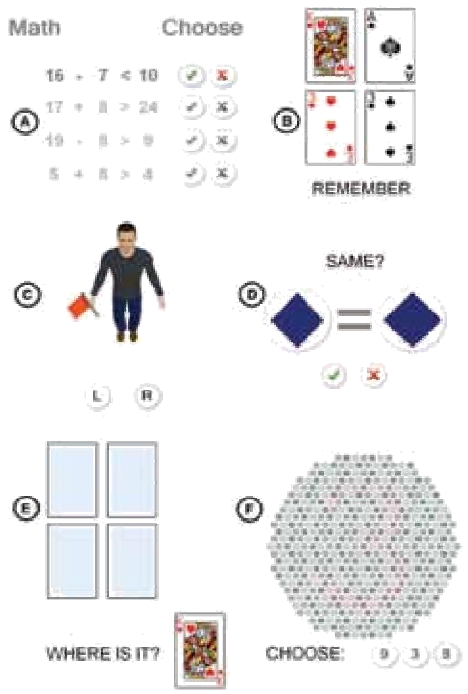

Fig. 3 Shows examples of cognitive subtests: A - group of 4 simple maths statements; B – presentation to remember: a group of 4 different cards; C – Standard Manikin, facing towards or away, upright or inverted, holding a flag in left or right hand; D –Shape discrimination of subtly different or identical shapes; E – remember the location of one card from the previously presented group of 4; F – Colour recognition of embedded numbers (Ishihara or BK plates).

Symptom Survey:

After each hypoxia experience subjects were asked to complete a survey containing a list of hypoxia-specific, non-hypoxia-specific and non-hypoxia symptoms. Key hypoxia symptoms were analysed and compared between the two hypoxia exposures. Comments about the educational impact of the GO2Altitude hypoxia training system, as well as criticisms and suggestions for improving this training system were also sought in the last section of the symptom survey.

Data Analysis and Reporting:

Data was stored on video CD and database and could be analysed from a printed report, together with a graphical plot of cognitive function throughout the hypoxic exposure. Physiological responses were averaged over 15 second intervals to assist estimation of Time of Useful Consciousness (TUC). All data was de-identified and tabulated in Excel 2003 files. Where appropriate, comparative analysis was undertaken from Excel files with Statistical Package for Social Sciences (SPSS v 6.1) using a notional significance level of $p<0.05$.

Results

Normobaric hypoxia induced by GO2Altitude® produced falling SpO_2, and increased heart rate in subjects, as illustrated for one typical subject at the top right in Figure 2. The expected cognitive effects of GO2Altitude® hypoxia at the simulated 25,000 foot altitude were cognitive performance degradation, reduced accuracy, lengthened response time to subtest completion for maths, spatial orientation and shape discrimination, impaired memory and colour perception, deteriorated handwriting, and perseveration - even "freezing" or failure to respond. These cognitive effects of hypoxia are printed for each of the subtests - maths, manikin spatial orientation, shape discrimination, colour vision and delayed recall. The actual responses are shown with trend lines superimposed. The trend in all responses to these subtests was declining accuracy and lengthening response time to task completion.

Varying degrees of motor incoordination were demonstrated by more than half the participants. The hypoxia resulted in impaired coordination, degradation of motor control and ultimately, inability to continue. A representative handwritten sentence from one subject before and at the end of five minutes of hypoxia at a simulated altitude of 25,000 feet is shown in Figure 4.

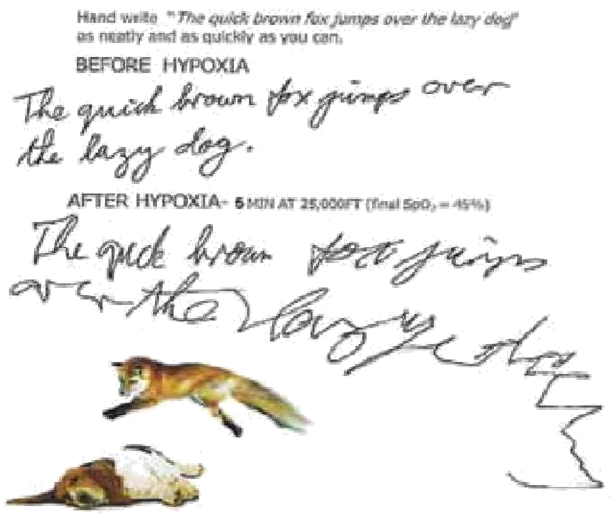

Fig. 4 Shows deterioration in handwriting with impaired visual-motor coordination after 5 mins hypoxia at 25,000 feet simulated altitude.

Of the 92 pilots and students tested there was one instance of 'syncope' and one episode of pre-syncopal bradycardia. All subjects who completed the hypoxic exposure were cyanosed. The range of SpO2 was 48%–74% when the observed impairments of cognitive function led to termination of the hypoxia automatically by the GO2Altitude® system or by the supervisor.

Comparison of group results between ROBM and the GO2Altitude® hypoxia training system.

The 92 subjects showed changes in oxygen saturation (SpO2), heart rate (HR) and ventilation frequency (Vf) displayed on the touch screen monitor. These changes were similar to those observed with ROBM and are summarised for comparison in Table 1. Results of the continuously monitored changes in these physiological parameters, including heart rate variability, symptoms experienced and a graphical plot of their cognitive function throughout the hypoxic exposure are presented to each subject in an individual printed report, and video CD.

In Table 1 there were no significant differences between the mean physiological adjustments resulting from the hypoxia at a simulated altitude of 25,000 feet using the ROBM and the GO2Altitude® method. Although the mean Time of Useful Consciousness (TUC) estimated from the presence of more than one cognitive function error in the GO2Altitude® group was shorter (2.80min vs 3.20min) and the SpO_2 was greater (58% vs 52%), neither difference was significant ($p>0.10$). Differences observed between the mean HR and Vf increase in the two methods were not significant.

Normobaric Hypoxia Methods

TABLE 1: Cardiorespiratory adjustments to reduced oxygen breathing using theGO2Altitude® training system at inspired oxygen level equivalent to 25,000 feet.

Subjects' gender is abbreviated as M, F	n	Mean TUC (min)	Heart rate (/min)		Mean Δ HR (bpm)	Oxygen Saturation at nailbed		Respiratory rate (/min)	
			Start	End		Start	End	Start	End
ROBM	452 (M274, F178)	3.20 ± 0.65	87	120	33	96%	52% ±7.4	11	14.5
GO2Altitude®	N= 92 (M81, F11)	2.80 ±0.85	91	117	26	93%	58% ±7.6	11	16.5

TABLE 2: Symptoms from reduced oxygen breathing from use of GO2Altitude at inspired oxygen level equivalent to 25,000 feet.

SYMPTOMS	ROBM 1995-2004 (n=452)		GO2Altitude® 2007 (n=92)	
Visual symptoms	295	65%	27	29%♦↓
Tunnel vision	152	34%		
Colours reduced	124	27%	20	22%
Blurred vision	61	13%	16	17%
CNS/autonomic symptoms	299	45%		
Headache	169	37%	9	10%♦↓
Dizziness, light-headedness	94	21%	57	62%♦↑
Mental impairment or difficulty in concentration	87	19%	63	68%♦↑
Euphoria	84	19%	37	40%♦↑
Fading of ambient noises	82	18%	11	12%
Anxiety or feelings of apprehension	42	9%	9	10%
Flushing of face	39	9%	30	33%♦↑
Tiredness, sleepiness	23	6%	19	21%♦↑
Neuromuscular symptoms	147	38%	36	39%
Sensory disturbances (eg, dysaesthesia, tingling)	98	22%	24	26%
Motor incoordination	81	18%	47	51%♦↑
Tremor	76	17%	35	38%♦↑

In Table 2, the symptoms reported by subjects after the hypoxia produced by ROBM were compared with symptoms reported after the GO2Altitude® sessions. Some very large disparities were found in the incidence of some reported symptoms. In the GO2Altitude® group there was significantly greater reporting of difficulty concentrating, mental impairment, dizziness, light headedness, euphoria, facial flushing, motor incoordination and tremor, but fewer reports of visual symptoms and headache. All the other symptoms were reported to a very similar extent in the two methods and were not significantly different.

In these 92 subjects there was an impairment of math processing, an increase in simple and choice reaction time, and impairment of short term memory, spatial orientation, shape discrimination and colour perceptual acuity, impaired visual-motor coordination in writing and prolongation of task completion time. These are summarised in Table 3 for comparison with ROBM data.

Subjects experienced a high level of difficulty with the novel presentation of the simple maths computational tasks in the GO2Altitude® system. However they exhibited less memory impairment (only one or two digits incorrect) using the GO2Altitude® method of presenting a seven digit number on a computer screen, compared to writing it from memory in the ROBM study.

Table 3: Observed cognitive effects from use of GO2Altitude at inspired oxygen level equivalent to 25,000 feet

	ROBM 1995-2004 (n=452)		GO2Altitude® 2007 (n=92)	
IMPAIRED MEMORY FUNCTIONS	401	89%	59	64%
Impaired immediate recall (serial 7 subtractions and card locations)	288	64%	46	50%
Impaired delayed recall (name, address and 7 digit number)	213	47%	13/51	25% ♦↓
Impaired graphic memory (clock drawing or screen writing)	84	19%	19	21%
Semantic memory errors (proverbs)	82	18%	n/a	n/a
IMPAIRED COMPUTATIONAL FUNCTIONS	207	46%	76	83%♦↑
Maths Completion time increased	n/a	n/a	81	88%↑
Simple arithmetic errors	207	46%	65	71%♦↑
IMPAIRED CNS DECISIONS or EXECUTIVE FUNCTIONS	175	39%	38	41%
Perseveration (repetition) in writing or calculations	175	39%	29	32%
Impaired visual motor functions	113	25%	33	36%
Motor incoordination (illegible writing, poor drawing)	98	22%	30	33%↑
Poor geometric figure reproduction	81	18%	33	36%↑
Thought or motor block in writing or calculations	73	16%	19	21%
NEUROMUSCULAR DISTURBANCES	96	21%	35	38%↑
Tremor or muscle twitching	96	21%	35	38%↑
COLOUR VISUAL DISTURBANCE	n/a	n/a	25	27%
Colour Detection (prolonged)	n/a	n/a	59	64%
CYANOSIS	452	100%	92	100%

Discussion

This paper presents results from a new training technique using the GO2Altitude® hypoxia training system[7-8] and compares them with hypoxia induced by a more established method of inducing hypoxia under normobaric conditions. Systems such as GO2Altitude® can provide an accessible means of hypoxia training for civilian flight crews where no facility has been previously available. GO2Altitude® hypoxia training utilises a nitrogen concentrator to produce a gas on site with the desired low oxygen concentration, unlike other normobaric methods[4-6] which utilise bulky gas cylinders and have higher maintenance and running costs. The US Navy ROBD[5-6] uses a mixture of oxygen and nitrogen from cylinders to provide normobaric hypoxic experience in a dedicated aircraft simulator. The reduced oxygen breathing method described by Westerman[4] used a reduced oxygen gas mixture and non-rebreathing mouthpiece to produce normobaric hypoxia, with continuous pencil and paper tests of cognitive function. Both were research laboratory developments, relatively inaccessible for civil aviators and neither provided detailed automated printout of physiological data, continuous cognitive test results and video-recorded behavior.

Limitation in comparison of reduced oxygen methods

Although one aim of the present study was to compare effects of hypoxia using two normobaric reduced oxygen methods, the two studies were not originally designed to be compared and each had different specific objectives, which affected the protocol and conduct of the training. Consequently the two studies and their data were unmatched, which precluded formal statistical analysis in comparison of the data. The descriptive statistics used for comparing the data sets are indicative of possible significant differences. The tabular summaries comparing effects of hypoxia using the two methods are set out in Tables 1,2,3. In Table 1 only minor (non-significant) differences in objective physiological responses were observed. In Tables 2,3 there were possibly significant differences in the frequency of some reported symptoms, but not others. The significant differences in symptom reporting are likely to reflect the different pre-test briefing strategy, test protocol and aims of the two studies. ROBM used a briefing lecture and question session prior to the testing and subjects with medical reasons for not continuing opted out. Consenting subjects, in groups of 5 or 6, performed different roles in rotation. The primary emphasis of the hypoxia exposure was to produce some obvious performance deficits in the pencil and paper cognitive function tests being conducted continuously on every subject. Other group members were recorders and observers throughout each hypoxic exposure. In this way the entire group became familiarised with the varying effects of hypoxia on individuals. Reporting of symptoms was undertaken by writing them on a sheet of paper after full recovery had been achieved by breathing 100% oxygen for 2-3 minutes. Individual variability in physiological adjustments, TUC, symptoms and performance deficits were discussed as group feed back after all volunteers had been subjected to hypoxia and results tabulated on a blackboard. The SCUBA mouthpiece, hose and tap connexions to the Douglas Bag constituted a considerable resistance to breathing and some subjects could not tolerate the dyspnoea evoked.

In contrast, GO2Altitude® training commenced with a standardized briefing lecture to a small group, and then individual subjects in pairs sat at the two parallel consoles and independently worked through the educational preamble on the computer. This re-iterated the signs, symptoms, physiological and cognitive effects, and possible risks of hypoxic exposure. Then an explanation of the method, and protocol sequence and touch screen practice, was followed by a consent form, a pulse oximeter was attached to a finger of the hand holding the breathing mask, the face mask was applied, and testing commenced, followed by hypoxia. Immediately at the termination of the hypoxia, cursive writing of their name on the touch screen was followed by presentation of a pictorial and written list of all symptoms from which subjects selected and ticked the symptoms they had experienced. There were several word descriptors for each symptom, and this may have enhanced the likelihood of reporting a symptom. Recovery was effected by breathing 40% oxygen rich air automatically delivered by the GO2Altitude system® rather than 100% oxygen and this may have reduced the incidence of oxygen paradox..

There was a very detailed briefing of effects and risks of hypoxia both before the training and embedded in the software, as part of the ethical informed consent protocol, which potentially raised anxiety levels, resting heart rate, and symptom awareness in the GO2Altitude® group. The ROBM subjects ascended directly to 25,000 feet simulated altitude from sea level, while the GO2Altitude® test started at simulated 8,000 feet for two minutes before the ascent to 25,000 feet. This probably contributed to their somewhat shorter mean estimated TUC and lower SpO_2, having used some of their dissolved oxygen reserves at “cabin altitude”. Differences in the respective resistances of the two different breathing circuits are most likely to have contributed to the higher incidence of headache with increased work of breathing in the ROBM group. The overall higher incidence of symptom-reporting in the GO2Altitude® group is most likely to be attributable to the method of reporting by ticking the multiple word descriptors of symptoms very soon after the end of hypoxia, while fresh in memory or still evident. Finally, 59 of 92 subjects in GO2Altitude® training were naïve to hypoxia, but it is not known how many of the subjects in the earlier ROBM study were naïve. Approximately the same proportion of subjects (>60%) was aborted by the supervisor in both methods of inducing hypoxia. This emphasises the euphoria experienced by subjects, in spite of obvious cognitive impairment.

Efficacy

All subjects in both studies showed some physiological changes, some neurocognitive impairment and reported experiencing some symptoms of hypoxia. ROBM subjects received photocopies of their own written sheets and the tabulated blackboard group summary showing 8-12 individual responses as examples of the variability and range of responses. In the GO2Altitude® hypoxia training, these are individual for each subject, and their personal results are provided to each subject as printed graphs, written material, and a video CD record of their behaviour and responding before, during and after the hypoxia exposure. This included their individual estimated time of useful consciousness and their personal reported symptoms. Clearly, there was a more memorable list of subjective symptoms generated by the GO2Altitude® reporting method. Certainly the GO2Altitude® training system was just as, or more, effective than the previous ROBM – both in recording physiological effects of hypoxia at simulated 25,000 feet altitude, and in continuously monitoring cognitive effects. The overall incidence of cognitive deficits was just as high in the GO2Altitude®, but performance was better captured and compared in relation to group data. The subjective feedback about the educational impact of the GO2Altitude® system was almost unanimous – two persons wanted less theory in the preamble, but these were both student pilots. All the experienced pilots, 48 in total, strongly endorsed the educational preamble and the training value of the practical experience.

Safety

As with ROBM, the GO2Altitude® system allows for a hypoxia session to be aborted by either the subject or a safety observer standing by throughout. However, it also automatically aborts if heart rate exceeds a pre-set safety level or if SpO_2 falls below a pre-set safety minimum. Recovery from hypoxia is hastened by the GO2Altitude® device switching to an oxygen-rich air stream through the hand-held mask. The ultimate safety feature is, if a subject became unforeseeably incapacitated, the mask would fall away from the face allowing room air to be breathed.

Convenience.

GO2Altitude® is a fully integrated hypoxia training package. It starts with theoretical educational material, including full explanation of the risks and effects of hypoxia. A consent form follows, then explanation of the system and instructions for starting and aborting hypoxia, explanation of the monitoring display and how to complete the cognitive tests. Each subject has physiological monitoring of heart rate, breathing, SpO_2, heart rate variability and continuous cognitive function testing throughout the full altitude exposure. There is continuous video recording of the subject's behaviour and responses on the touch-screen. Results are presented on an individual comprehensive report printed, stored on video CD and database. Feedback for the GO2Altitude® training was strongly positive about the convenience and benefits of an integrated system.

Given the limitations of the current study and the significant difference found in the incidence of some symptoms, as well as the findings of Savourey et al[9], it is suggested that a further study specifically designed for direct comparison of ROBM and GO2Altitude®, or better still, hypobaric hypoxia in a chamber and GO2Altitude®, could be conducted to clarify any differences.

Conclusions

Normobaric reduced oxygen breathing by the GO2Altitude® hypoxia training system simulates preselected altitude profiles (eg 25,000 feet) in a safe, convenient and effective way. This instructs and familiarises aviators, aeromedical and paramedical personnel with the subjective, objective, cognitive and behavioural effects of altitude hypoxia. They experience their individual "time of useful consciousness" and hypoxic symptoms, without risks of barotrauma or decompression illness. Such as system, which increases recognition and awareness of hypoxia at altitude, has the potential, if implemented, to prevent or reduce hypoxia related flight accidents.

There may be policy implications or recommendations stemming from this study. Australian aviation policy does not currently make provision for routine practical hypoxia training of flight crews and other flight personnel: only theoretical safety training is mandated by CAO20:11. In the future, with an easily accessible, safe, inexpensive, user-friendly and effective training method now available, legislative changes to training requirements may be contemplated. At least, perhaps it is now time for the civil aviation regulatory authorities to recommend that practical hypoxia training experience be included in emergency procedures training, where practicable.

Keywords

Normobaric Hypoxia, Aerospace Physiology, Aviation Personnel Training, Cognitive Impairment, Hypoxia Awareness, Hypoxia Familiarisation, Flight Safety, Human Factors.

Acknowledgements

The Reduced Oxygen Breathing Method (Westerman[4]) had Monash University Human Research Ethics Committee Approval; GO2Altitude® hypoxia training system[7,8] has Alfred Hospital Human Research Ethics Committee Approval (project 40/07), and complies with CAO20:11.

References:

1. Cable GG, Westerman RA. Hypoxia recognition training in civilian aviation: a neglected area of safety? *JASAM*, in press.
2. Harding RM. Hypoxia and hyperventilation. In: Ernsting J, Nicholson AN, Rainford DJ, editors. Aviation Medicine. Oxford: Butterworth Heinemann; 3rd ed.1999. p. 43-58.
3. Ernsting J. Hypoxia in the aviation environment. *Proc R Soc Med*.1973 June, 66(6):523-527
4. Westerman RA. Hypoxia familiarisation training by the reduced oxygen breathing method. *ADF Health* 2004;5:11-15.
5. Sausen KP, Bower EA, Stiney ME, Feigl C, Wartman R, Clark JB. The reduced oxygen breathing paradigm for hypoxia training: physiological, cognitive and subjective effects. *Aviat Space Environ Med.* 2001 June; 72(6): 539-545.
6. Sausen KP, Bower EA, Stiney ME, Feigl C, Wartman R, Clark JB. A closed-loop reduced oxygen breathing device for inducing hypoxia in humans. *Aviat Space Environ Med.* 2003;74(11):1190-7.
7. Westerman RA, Bassovitch O. Hypoxia familiarisation training using Flight Personnel Simulated Altitude Training System. *Aviat Space Environ Med.* 2007;78(3): 305 Abstract.
8. Westerman RA, Bassovitch O, Smits D. Simulation In Aviation: Hypoxia Familiarisation Training Using The GO2Altitude® System. In: Leigh E, editor. Proceedings of the 13th SimTecT Simulation Conference, Melbourne, 12-15 May 2008. Melbourne: MUP; p 130-135.
9. Savourey G, Lounay JC, Besnard Y, Guinet A, Travers S. Normo- and hypobaric hypoxia: are there any physiological differences? *Eur J Appl Physiol.* 2003 Apr; 89(2):122-126.