Sixth Int. Conf. on Envir. Ergon. Montebello, Canada, Sept. 2530,1994 eds. J. Frim, M.B. Ducharme & P. Tikuisis

ARRHYTHMIAS FOLLOWING BREATH HOLDING DURING COLD WATER SUBMERSIONS

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INTRODUCTION

The hazards of the initial cardio-respiratory responses to immersion in cold water have been documented (1) and cardiac ectopics have been noted during the initial stages of head-out cold water immersions (2). Although less well documented, cardiac arrest is now recognised as a rare but definite cause of sudden incapacitation and death when water enters the nostrils *(2).* Incidents of arrhythmia including abnormal P waves, nodal rhythms, idioventricular rhythms and premature beats have been reported during breath hold (BH) diving and swimming (3,4,5). However, the majority of the literature on the diving response suggests normal cardiac rhythm is immediately restored on breaking BH in water (6). In the present paper, the ECG abnormalities of subjects undertaking resting BH submersions in cold water are described. These abnormalities were observed during an experiment designed to determine the protection provided by immersion suits against the cardio-respiratory responses to cold water.

METHOD

Following ethical committee approval, informed consent in accordance with the code of ethics of the World Medical Association was obtained from 12 healthy male volunteers who were not cold habituated. The following submersions were completed by each subject: 1) 5°C wearing an immersion "dry" suit (DS 5), designed to keep the body dry with the exception of the face and hands. This was worn over the following underclothing: swimming trunks, cotton underwear, woollen pullover and a cotton coverall. 2) 10°C wearing the same clothing (DS 10). 3) 10°C wearing a *trunk* and arms neoprene `*wet'* suit (WS 10) over the same underclothing.

Throughout the experiments the subjects assumed a standardised upright seated posture on a metal chair. They wore a noseclip and breathed through a mouthpiece during each submersion. Prior *to* submersion the subjects rested for ten minutes in air at thermoneutral temperatures while baseline measurements were taken, including maximum breath hold time. At the end of the pre-submersion period the subjects were lowered into the water at $0{\cdot}2\ m{\cdot}s^{-1}$, by means of **an** electric winch attached to the chair, until the top of the head was just submerged. The subjects were instructed to take a slightly larger breath than normal and begin breath holding as the water crossed their chin. The subjects held their breath for as long as they could whilst submerged and were lifted from the water ten seconds after breaking their BH. During this ten second period the subjects were able to breathe through a mouthpiece open to room air. **A** 3-lead (lead 11) ECG (408 monitor, Tektronix, Oregon, U.S.A.) was obtained from all subjects throughout the experiments and was recorded continuously on a pen recorder. Heart rate was calculated from R-R intervals. **An** analysis of variance was performed on the BH and heart rate data.

RESULTS

No arrhythmias were observed during, or immediately following, breath holding in air in any of the subjects. The breath hold times did not differ significantly between conditions in air or water. The average heart rates recorded during BH in water (average across conditions 57 $bts{\cdot}min^{-1}$) were less than those recorded during rest in air (average across conditions 80 $bts{\cdot}min^{-1}$) and just prior to submersion (average across conditions 120 $bts{\cdot}min^{-1}$). When breath holding underwater the majority of subjects had heart rates which were below 60 $bt{\cdot}min^{-1}$ and eight subjects developed a heart rate of less than 50 $bt.min^{-1}$ in at least one of the conditions.

Eleven of the twelve subjects, in 29 of the 36 submersions, demonstrated ectopic arrhythmias during at least one submersion. These arrhythmias occurred predominantly just prior to, and within 10 seconds following the end of breath holding. Single supraventricular extrasystoles (SV[S]), including premature atrial and junctional complexes, were the most prevalent arrhythmias and were observed in ten subjects in a total of 23 breath holds during submersion. Pairs of supraventricular extrasystoles or runs of supraventricular tachycardia (SV[M]) were observed at end BH in ten of the subjects in a total of 14 submersions.

Using lead II it is difficult to determine the origin of supraventricular ectopic arrhythmias. However, some of these arrhythmias demonstrated upright P waves with a non-sinus morphology and a shortened P-R interval consistent with an atrial origin; whereas others had no evidence of a P wave suggestive of a nodal origin. Some of the arrhythmias appeared to be related to respiratory rhythm; this could, however, represent atrial bigeminy with a heart rate coincidental with respiration.

Premature ventricular contractions (PVCs) were observed in three subjects immediately following breath hold termination in the DS 5 condition. No PVCs or SV(M) were noted during breath holding. No complex (multiformed or repetitive) ventricular arrhythmias were observed.

CONCLUSION

It is noteworthy that the majority of the ectopic arrhythmias observed immediately following breath holding, occurred within *10* seconds of restoration of breathing, when the head was still submerged. With continued submersion both positive and negative chronotropic inputs to the heart are most likely to be occurring simultaneously: the negative chronotropic effect will result from a vagal drive which, although smaller than that seen during apnoeic face immersion, has been reported to be present in snorkel breathing face immersed humans *(7)*. A positive chronotropic effect may result from: continued sympathetic stimulation from the peripheral cold receptors in areas other than the face; the cyclical reduction of vagal drive with the restoration of respiratory movement; and postvagal tachycardia (8).

The suggestion that an augmented sympathetic and parasympathetic influence on the heart may provoke these arrhythmias is supported by the absence, or reduced incidence, of arrhythmias in situations where the sympathetic or parasympathetic response predominates. For example ectopic arrhythmias have only rarely been reported during both head out naked immersions in cold water (sympathetic predominance) or face-only immersion (parasympathetic predominance). From a practical viewpoint the clinical implications are unclear. The evidence from the present study suggests that while the arrhythmias occur in cold water in certain conditions, the majority have little clinical importance, being of short duration, supraventricular in origin and producing no symptoms. Alternatively, their occurrence may be significant in susceptible individuals, such as those with underlying conduction defects.

It is concluded that, after breath hold termination during cold water submersion, there may be a short time period in which the heart is particularly susceptible to ectopic arrhythmias in individuals who remain submerged. The significance of this for individuals undertaking practical pursuits such as snorkelling is currently being examined.

REFERENCES

1. Tipton M.J. *1989,* The initial responses to cold water immersion in man, *Clin. Sci 77, 581-588.*

2. Keatinge W.R. *1969, Survival in cold water,* (Blackwell Scientific Publications, Oxford).

3. Hong **S.K.,** Song S.H., Kim P.K., Suh C.S. *1967,* Seasonal observations on the cardiac rhythm during diving in the Korean Ama, *J. Appl. Physiol* 23, *18-22.*

4. Jung K. and Stolle W. *1981,* Behaviour of heart rate and incidence of arrhythmia in swimming and diving, *Biotel. Pat. Mon 8, 228-239.*

5. di Jakopin J. and Rakovec P. *1982,* Heart rate and rhythm during underwater swimming, *Boll. Soc. Ital. Cardiol* 27:205-210.

6. Elsner R. and Scholander P.F. *1965,* Circulatory adaptations to diving in animals and man, in H. Rahn and T. Yokoyama T (eds.) *Physiology of Breath-Hold Diving and the Ama of Japan* (Nat Acad Sci/Nat Res Council, Washington DC).

7. Paulev P.E. and Hansen H.G. *1972,* Cardiac responses to apnea and water immersion during exercise in man, **J.** *Appl. Physiol* 33, *193-198.*

8. Prystowsky E.N. and Zipes D.P. *1985,* Observations on postvagal tachycardia in humans, in D.P. Zipes and J. Jalife (eds.) *Cardiac Electrophysiology and Arrhythmias* (Grune and Stratton, Orlando), *177.*