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TECHNICAL REVIEW AND APPROVAL

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The experiments reported herein were conducted according to the principles set forth in the current edition of the "Guide for the Care and Use of Laboratory Animals," Institute of Laboratory Animal Resources, National Research Council.

This technical report has been reviewed by the NMRI scientific and public affairs staff and is approved for publication. It is releasable to the National Technical Information Service where it will be available to the general public, including foreign nations.

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Aspects of temperature regulation, exercise capacity, and passive rewarming were evaluated during planned 6 h immersions in 5 °C (41 °F) water. A total of 16 divers (12 First Class divers, 4 SEALs) performed 63 manned immersions. Each diver wore a full face mask (modified AGA mask) and breathed compressed air at 6.1 msw (20 fsw). A butyl-nylon dry suit with M-600 Thinsulate thermal protection undergarments was worn. Hands were protected with a M-200 Thinsulate glove worn beneath a water-tight latex glove; a neoprene outer gauntlet mitt was worn over the latex glove.

The divers completed two 5 day air saturation dives at 6.1 msw, with a week separating dives. Each diver made two immersions during the dives, with 54 hours between immersions. One immersion began at 1000 hours (AM dive) and the other at 2200 hours (PM dive). The order of presentation of AM and PM dives was varied among the subjects. During one saturation dive the divers were fed a high carbohydrate diet, while during t

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second dive the divers were fed a standard American mixed diet. Both diets provided 3000 kcal per day.

Urine and venous blood samples were obtained before and after each immersion. Urine was also collected during the immersion. Body temperatures, regional heat fluxes, oxygen consumption, and EKG recordings were obtained throughout the immersion. In one series of dives, 8 divers performed 9 min of submaximal bicycle exercise each hour, while in a second series the same exercise was done only every 3 h by the other 8 divers. Passive rewarming, using commercially available systems, was done after each immersion.

Biomedical results are presented in separate NMRI Technical Reports. This report outlines the general protocol and methods. Overall, the immersion times averaged 287 ± 83 min, with 43% lasting the full 6 h. Sixteen percent of immersions were terminated prematurely because of research equipment failure, while 41% were aborted for medical reasons. Only 5 of the medical aborts were due to low core temperature, whereas 14 immersions were terminated medically because of low finger or toe temperatures. These results indicate that the passive thermal protection used in this study protected core temperature reasonably well, but insulation of the extremities was inadequate. Thus, from a technical standpoint, the results of this study indicate that 6 h missions may be accomplished in very cold water with use of a dry suit.

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INTRODUCTION

Long-term exposures to cold water produce a variety of physiological changes in a diver that may compromise successful completion of an assigned task. Loss of body heat in this type of environment is the main perturbation that impacts on many bodily functions.

There are many types of active and passive diver thermal protection garments available to U.S. Navy divers. Each has its own characteristic insulating value for a given water temperature and depth. Mobile swimmers, such as Special Warfare divers, are restricted to passive thermal suits. It is of practical importance that Special Warfare divers be able to select a suit that provides the optimal amount of insulation relative not only to water temperature, but also to mission duration, level of mobility, comfort, and utility at land-water interfaces.

Computer modelling of regional body heat fluxes has been used to predict decreases in core temperature as functions of water temperature and immersion time (1,2). At present, however, there is little experimental confirmation of these predictions according to known suit insulating properties. Therefore, the first objective of this study was to obtain regional heat flux data that could be compared to computer predictions. If the computer model accurately predicted the thermal data obtained experimentally, then it would be possible for mission commanders to use the computer model to predict what type of thermal protection would be required for a particular mission. However, if the computer predictions deviated significantly from actual data, then the model could be refined to provide a more accurate prediction.

From an operational standpoint, maintenance of body core temperature is a secondary concern to a diver's physical and mental performance. It is well recognized that cold water immersion in thermally unprotected subjects reduces physical performance, both in terms of muscle strength (3,4) and endurance (5,6). Fewer studies have been conducted to determine changes in physical work capacity in thermally protected divers (7,8,9). Thus, the second objective of this study was to examine physical work capacity in divers undergoing immersion profiles that might be representative of Naval Special Warfare scenarios.

Mental performance is likewise known to be adversely affected by the development of hypothermia (10). However, laboratory studies have not examined mental cognition over long duration cold water exposures in thermally protected divers. Anecdotal reports of subjective changes in diver mentation lack the objective criteria necessary for formal definitions of impaired mental performance during cold water immersions. The third objective of the study was to quantify changes in psychomotor performance during the 6 h of cold water exposure.

A very important question for special diving missions is whether the time of day has an important bearing on the Special Warfare diver's response to stress. It is widely known, for example, that circadian rhythms exist for body temperature and hormones that regulate stress responses (11,12). In general, body temperature and stress hormones reach their low points in the early morning hours, a time of stress for clandestine nighttime operations. There are also reports in the literature that variables associated with physical exercise show some diurnal variations (13). With these points in mind, the fourth objective of the study was to examine thermoregulation and work capacity both during daytime and nighttime immersions.

Dietary patterns are known to have an influence on both temperature regulation and exercise capacity (4,14,15). Diets that deplete muscle glycogen stores have been reported to impair thermoregulation through loss of shivering and to minimize physical performance (15,16). Our fifth objective therefore, was to determine whether a high carbohydrate diet (to minimize glycogen depletion) would be more beneficial than an ordinary mixed diet of the same caloric value.

Lastly, the question of post-immersion rewarming methods for operational settings is one that weighs efficiency against available resources. In the absence of such weighing, the method of choice would be active rewarming in warm water, an approach often not available in many diving situations. Passive rewarming in warm air requires about twice as much time as the warm water method (7,19). Passive rewarming in an insulated garment offers the potential for being more efficient than warm air rewarming and this procedure could be easily implemented in many locations. The sixth objective of this study therefore, was to compare two commercially available passive rewarming systems.

The study was conducted from May to August 1986. Results from many aspects of this project have been published elsewhere (20-26).

DIVER SELECTION

A total of 16 U.S. Navy divers participated in the study, after giving informed consent. The research protocol was approved by the NMRI Human Use Committee. Twelve of the divers were First Class divers stationed at NMRI, while the remaining 4 were SEAL divers assigned temporarily to NMRI. The physical characteristics of the divers are presented in Appendix A.

The divers had a relatively low percentage body fat as determined by hydrostatic weighing. Appendix A indicates that their maximum aerobic capacity, measured by maximum O_2 uptake on a bicycle ergometer, was in the range expected for highly fit individuals.

Prior to the cold water immersion testing, each diver had 2-6 practice sessions where they donned the diving gear, entered the water, and performed each of the tasks that would be required during experimental immersions. Baseline bicycle exercise testing, at the same workloads used during immersion, was conducted in the dry with divers wearing only shorts and shoes. Psychomotor performance testing was done in the dry and during practice immersions to familiarize subjects and to obtain baseline data.

DIVING DRESS

The divers wore an AGA full face mask identical to the type used with the MK-15 closed circuit underwater breathing apparatus. The mask was modified to include a microphone in the oronasal mask. A Hans-Rudolph mouthpiece with check valves was used to accomodate the low resistance inspiratory and expiratory hoses. It became obvious during pre-dive tests that the bouyancy of the mask would produce neck muscle soreness during long exposures. Therefore, the mask was counter-weighted to keep the diver's head in a neutral position without undue effort.

Inspired gas was delivered to a double hose regulator attached to an Integrated Divers Vest (IDV). The gas supply hose to the regulator was coiled in the water, and provided an inspired gas temperature within 0.1 °C of water temperatue (5 °C). The diver's exhaust hose was directed out of the water and attached to a dry gasometer to measure expired gas volume for calculation of O_2 consumption during immersion. This arrangement necessitated building a back pressure valve into the exhaust line that would prevent free-flow of gas to the surface. The in-line back pressure valve was attached to the IDV and vertically positioned in reference to the scuba regulator so that breathing resistance was minimal and no free-flow of air occurred.

Selection of a thermal protection garment was based on the types of suits available to the Special Warfare community, and on the subjective likelihood that the suit would provide enough thermal protection to complete a 6 hour immersion in 5 °C water. For these reasons, a dry suit was chosen over a wet suit. The dry suit was a front entry type made of butyl rubber with nylon bonded to both sides (Diving Unlimited International, San Diego, CA). Its latex neck and wrist seals facilitated both entry and use for divers of all sizes. The suit inflator valve was located on the thigh and the exhaust valve on the upper arm. Two penetrations were made on the left side of the suit to accomodate research cables for temperature, heat flux, and EKG signals. A tubing penetrator was located on the suit for overboard discharge of urine.

The effective insulating value of the dry suit was achieved by use of Thinsulate undergarments that provided 4.98 clo/in of insulation (as compared to 3.16 clo/in for 0.25 inch neoprene). Even when wet, the Thinsulate would have a higher insulating value than a neoprene wet suit. Each diver wore a single-piece M-600 Thinsulate garment that had an average insulating value of 1.4 clo. A polypropylene anti-chaffing garment was worn beneath the Thinsulate; wool socks and M-600 Thinsulate boots were worn on the feet. The head was thermally protected by an M-400 Thinsulate hood worn underneath a 0.25" neoprene dry suit hood.

Several approaches were tried for thermal protection of the hands that afforded some flexibility to push the buttons on a psychomotor performance paddle. The selected choice was a M-400 Thinsulate mitten worn underneath a 5-fingered heavy duty rubber glove. An aluminum ring was mounted on the neck of the rubber glove and mated to a ring attached to the sleeve of the dry suit (via O-ring seals) to provide a watertight seal for the hands. A 0.25" neoprene gauntlet mitt was worn over the rubber glove.

Urine was collected during the immersion using a condom attached to a urine collection bag worn inside the suit (DUI, San Diego, CA). Tubing and a one-way valve arrangement was used to direct the urine outside the suit to a larger bag. In practice, this system proved unsatisfactory; urine would often back-flow around the condom and into the suit. Also, because there was limited space inside the suit, the inner collection bag would often leak, especially during exercise periods. About halfway through the research protocol we discovered an improved method for waste management. A different type of condom was found (Urinary External Catheter, Hollister Inc, Libertyville, IL) that had adhesive on the inner side to secure it to the shaft of the penis. The ribbed distal end of the condom had enough compliance and rigidity to allow it to be attached directly to a quick connect plastic adapter with an in-line check valve (Colder Products Company, St. Paul, MN). A female connector (also with an in-line check valve) was used to mate the adapter with rubber tubing that penetrated the outer dive garment. This arrangement permitted the inner collection bag to be discarded, and allowed the diver to urinate directly into the outer collection bag. This improved system eliminated urine leakage inside the suit.

The urinary catheter, connectors, and tubing were connected predive while in the chamber at 20 fsw. Subsequent experiences have shown that connecting the system at the surface, then diving to depth, can result in penis squeeze. This squeeze can be avoided simply by urinating through the system before starting a dive.

IMMERSION PROFILE

Water temperature for all immersions was 5.0 ± 0.1 °C. Dressing of the diver began approximately 1 h before immersion in the "R" chamber of the Man Rated Chamber Complex (MRCC). Rectal probe, skin temperature probes, heat flux sensors, and EKG leads were attached to the subject and signal quality checked. The urine collection catheter was applied to the penis. Anti-chaffing garments and wool socks were donned. A venous blood sample was taken approximately 15 min before immersion. The divers donned the Thinsulate undergarments and dry suit outer garment prior to entering the "D" chamber of the MRCC located above the wet pot.

Once in "D" chamber the divers sat on the edge of the wet pot and donned the IDV, Thinsulate hood, and outer hood. Umbilicals for physiological signals were attached to the suit penetrators. The full face mask was donned, air supply checked, and diver communications established. After the gloves were put on, the diver entered the water and checked for mask and suit leaks. If leaks were encountered the diver exited the water and the malfunction was corrected. Immersion timing was not begun until the diver was seated comfortably on the ergometer seat. The time from donning the Thinsulate to entry into the water was kept as short as possible (usually 15-20 min) to prevent hyperthermia. Delays longer than 20 min were usually related to equipment problems, in which case the diver undressed to the anti-chaffing garment.

Leaks encountered during the course of an immersion were corrected after the diver had temporarily exited the water. These out-of-water periods were generally less than 5 min. Delays greater than 10 min were subtracted from the total immersion time. If the diver had been in the water for more than 1 h and then had to exit to fix a problem that took more than 45 min, the immersion was aborted. Such premature terminations were listed among the equipment category in Appendix D.

During immersion, the diver sat in a seat with the legs extended and the feet inserted into toeclips of an underwater cycle ergometer. This position was equivalent to approximately 120-130 degrees of hip flexion. A quick release harness was used to stabilize the diver's position on the seat. No effort was made to quantify the amount or distribution of air inside the suit. However, since most of the free air collected around the neck region, only small amounts of suit inflation could be tolerated without discomfort in the chest and neck areas. Generally, there was little free air in the foot regions. The divers usually rested their hands underneath the bar holding the performance paddle at chest level. Small amounts of air were kept in the gloves during resting phases, but the air was vented back into the suit during performance paddle tests and during exercise periods.

The psychomotor performance paddle test was conducted every hour on the half hour during immersion and lasted 10-15 min. In one series (8 divers), subjects performed 9 min of submaximal leg exercise every hour on the hour during immersion. This is denoted as Series 1 in the Appendices. The other 8 subjects (Series 2) performed the same exercise test but only during the 3rd and 6th hours of immersion. At all other times during immersion subjects were at rest.

IMMERSION ABORT CRITERIA AND IMMERSION SUCCESS

Concern for the safety of the subjects and the ability to obtain useful research data required the establishment of criteria for terminating an immersion before 6 h. These criteria were classified as being either related to medical or equipment problems.

Of all immersions, 41% were terminated early because of medical reasons. An immersion was aborted if the diver's rectal temperature dropped to 35 °C. Appendix D indicates that 5 immersions were terminated due to low rectal temperature, representing only 8% of all immersions. In addition, it was the Diving Watch Medical Officer's perogative to stop an immersion if finger or toe temperature was below 10 °C for 30 min, or if the diver complained of cold-induced pain. These criteria resulted in 14 immersions being aborted before 6 hours, representing 22% of all immersions. The diver could voluntarily terminate an immersion. Seven such terminations occurred, which were related to gastrointestinal (G.I.) disturbances or headache. Four of the 5 G.I. disturbances were attributed to gas swallowing, while the other disturbance appeared to be gastroenteritis. The headache symptoms probably were related to effects of cold water and tight fitting mask straps, and not to CO_2 retention.

Equipment malfunctions resulted in 10 immersions being terminated prematurely, and represented 16% of all immersions. Of these, 6 resulted from major leaks in the suit (4 from leaking suit penetrators, 2 from urine spillage). Three equipment problems were due to the temperature probe dislodging from the rectum, thereby producing an artificially low reading. One equipment failure was due to mask flooding when the diver tugged too vigorously on the mask straps.

Overall, 42.9% of the immersions were completed to the full 6 h (Appendix B). Interestingly, the appendix indicates that 50% of the dives that began at 1000 hours (A.M. dives) were successful, while only 35.5% of immersions that began at 2200 hours were completed. Appendix C presents the average immersion times classified according to series, diet, and A.M./P.M. start times. Slight differences occurred with immersion times between the high carbohydrate and mixed diets, but the differences were not statistically significant. The P.M. immersion times tended to be slightly shorter than A.M. immersions, but the difference was not significant. Also, there was no significant difference between Series 1 (exercise every hour) and Series 2 (exercise every 3 h). Overall, the immersions averaged 287 min (4 hrs:47 min).

Operationally, the probability of successfully completing a 6 h mission in 5 °C water with this particular suit is likely to be higher than our success rate. The aborts due to research equipment failure would not be encountered in actual diving situations, thereby raising the success rate to about 60%. Interestingly, only 5 immersions were aborted (out of 63) because of low core temperature. This finding would suggest that the thermal protection provided by the M-600 Thinsulate was adequate to protect core temperature under the present immersion conditions. From another viewpoint, a large number of immersions (14 of 63) were aborted because of low finger or toe temperatures, often associated with pain. This is evidence of inadequate thermal protection for the distal extremities, a persistant problem in design of diving suits. Fortunately our cases of finger and toe problems did not involve long-lasting symptoms usually associated with non-freezing cold injury.

SATURATION DIVE PROFILE

Each immersion was conducted during a 5 day air saturation dive at 6.1 msw (20 fsw). Four subjects comprised each saturation diving team; 2 subjects underwent immersion each day. The 2 subjects not immersed on a particular day were not used as diver tenders. Tenders were compressed each day to care for the subjects undergoing immersion.

For each subject, two immersions were conducted during the course of a 5 day saturation dive. One immersion began at 1000 hours and the other began at 2200 hours. A period of 54 h elapsed between immersions for each diver.

Each diver subject participated in two 5 day saturation dives. One dive was conducted while the divers were fed a high carbohydrate diet (see below), while the second dive was conducted with the divers eating a mixed diet. During one 5 day dive the order of immersions was A.M. first, followed by a

P.M. immersion. This order was reversed for the second 5 day dive to minimize effects due to order of presentation. There was a 9 day interval between each saturation dive for a particular dive team.

Meals were provided 3 h before the start of A.M. and P.M. immersions to minimize thermogenic influences. No specific sleep periods were provided before or after P.M. immersions. Normal sleep hours of 2200-0600 were observed for non-immersed subjects. No physical exercise program, except that occurring during immersion, was conducted during the saturation dives.

The storage depth of the chamber was maintained at 20 ± 1 fsw. During immersion the divers were actually at a depth of 22-23 fsw (chamber depth + depth of wet pot water over their heads). Decompression from storage depth on the 5th day occurred about 4 h after the scheduled end of an immersion. Decompression was directly to the surface at a rate that did not exceed 60 fsw/min. No cases of decompression sickness occurred in any subject or diver tender.

RESEARCH EVOLUTIONS

Detailed results for thermal, exercise, and metabolic, aspects of this research protocol can be found elsewhere (20-24). Auditory evoked responses are described in two reports (25,26). Thermal balance and rewarming data can be obtained from NMRI investigators (RPW,DJS). The ensuing paragraphs provide a cursory outline of each research area.

Thermal measurements were made by attaching 12 heat flux sensors to areas of the body surface to measure regional heat flux and local temperature. In addition, a rectal probe was used to monitor core temperature, and thermistors were placed on an index finger and a first toe to record temperature. Heat flux and body temperature measurements were made prior to dressing the diver, throughout immersion, and during the passive rewarming period. All heat flux and temperature signals passed through two suit penetrators and were recorded on computer for later analysis. Rectal, hand, finger, and toe temperatures were also displayed in real time for medical monitoring of the subject.

Psychomotor performance testing was done using a paddle arrangement of 4 lights, each connected to a thumb operated button. One test involved the subject pressing a button as soon as a light came on in order to measure reaction time. Other tests involved responding to a series of lights in order to assess both response time and short term memory.

Physical work capacity was assessed by having the subject pedal an ergometer at 50 rpm for 3 min each at workloads of 50, 70, and 90 watts (23). Heart rate was measured continuously during the exercise. Plots of heart rate versus workload provided a linear relationship to calculate the workload that would have been done at a heart rate of 170 beats/min. This analysis is known as the Physical Work Capacity 170 test (PWC170) commonly used to assess exercise capacity (17). In Series 1 the exercise test was conducted every hour to determine the temporal change in PWC170 associated with cold water exposure. In Series 2 the PWC170 test was conducted every 3 hours beginning at the 3rd hour of immersion. This latter series was used to estimate changes in physical performance that might be encountered with a mission scenario involving a 3 h transit to target (at rest), performing work, then 3 more hours of transit before attempting another work cycle.

Oxygen consumption measurements were made every 10 min while at rest and during the last minute of each workload during exercise (23). The measurement technique involved directing the subject's exhaust gas through a dry gasometer to measure minute ventilation. Free flow of exhaust gas was prevented by the back-pressure valve described in the DIVING DRESS section. Gas sampling lines were located on the outflow side of the gasometer to measure expired oxygen and CO_2 concentrations for calculation of O_2 consumption.

Passive rewarming of the diver after immersion was accomplished mainly by the use of one of two commercially available systems (PSS-04 Passive Survival Support System, Kinergetics Inc, Tarzana, CA; and FPB2T Passive Protection System, DUI, San Diego, CA). The Kinergetics system employed "polargard" insulation, and the subject wore a hooded insultation jacket while inside a comparably insulated outer bag. With the DUI system, the diver subject wore a polypropylene undergarment while inside the Thinsulate insulated rewarming bag. In both systems, a hooded mask was worn that acted as a partial rebreather by scrubbing CO_2 and warming the inspired gas. Passive rewarming was scheduled to last for at least 2 h or until the diver's core temperature had returned to within 0.5 °C of his pre-immersion value. In general, the divers complained of the restrictive nature of both rebreathing masks and would often voluntarily remove it. Each subject drank 16 oz of either cranberry or apple juice prior to entering the rewarming bag to ameliorate the immersion-induced dehydration. The subjects were lying on a bunk throughout the rewarming period, and no effort was made to regulate sleep-wake states during rewarming. Passive rewarming was also accomplished in 4 subjects using flame-retardent chamber approved blankets to contrast the efficiency of the two commercial systems.

Auditory evoked responses (P-300) were obtained during passive rewarming in an effort to quantify changes in mental performance with changes in body heat content (25,26). A set of scalp electrodes were placed on the subject and a series of tones transmitted through a headset. The diver was told to count the number of high tones, which formed 10% of all tones present. This counting results in brain electrical responses that reflect the speed of cognitive processing (18). Evoked responses were obtained pre-dive and at the beginning and end of the rewarming period.

Blood hormonal and metabolic changes associated with the stress of cold water immersion were assessed by comparing samples obtained before each immersion to those obtained 10-15 min after the immersion ended (24). Venous blood samples were drawn in the chamber by a diving medical officer, processed and frozen shortly thereafter for analysis at a later date. Similar measurements were made on urine samples obtained before, during, and after immersion (22). Control blood and urine samples were obtained during a non-diving week.

During each saturation dive the subjects were fed a 3000 kcal per day diet. The caloric requirement was based on an estimate for an 80 kg person not involved in a daily exercise program. Breakfasts and dinners were each about 1000 kcal, and served 3 h prior to A.M. or P.M. immersions respectively. During A.M. immersions the non-immersed subjects were provided with lunch. Caloric make-up for the immersed subjects was achieved by increasing their food portions for the dinner meal. Two types of diets were employed. During one saturation dive the diet consisted of 74% carbohydrate, 10% fat, and 16% protein (termed a high carbohydrate diet). For the second dive, subjects were provided a diet comprised of 37% carbohydrate, 47% fat, and 16% protein (termed a standard American mixed diet). For 3 days prior to the start of a particular dive the subjects were instructed to follow a dietary plan similar to the one to be served on that dive. Diet survey cards were used to record food and liquid intake during these 3 days, and analyzed later for daily caloric and nutrient intakes (21).

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APPENDIX A

DIVER PHYSICAL CHARACTERISTICS

SUBJ. NO.	AGE (yrs)	HEIGHT (cm)	WEIGHT (kg)	BODY FAT (%)*	MAX O2 UPTAKE (ml/min/kg)**	MAX HEART RATE (beats/min)**
1	30	170	78.20	13	44	186
2	26	183	77.20	11	50	192
3	24	185	81.20	9	43	186
4	26	185	80.64	9	47	186
5	25	173	72.91	10	--	---
6	26	170	75.42	16	38	214
7	31	180	81.36	12	50	188
8	25	178	81.18	14	44	204
9	23	178	78.31	10	52	188
10	32	170	71.48	8	41	172
11	32	178	73.90	11	48	192
12	29	188	87.10	22	40	188
13	23	193	90.10	14	49	168
14	33	180	73.08	11	48	192
15	29	183	84.82	18	42	192
16	26	185	85.84	13	45	188
MEAN	27	180	79.55	13	45	189
±SD	±3	± 7	±5.50	±4	±4	±11

* determined by hydrostatic weighing

** determined by incremental bicycle workloads, breathing air, under dry laboratory conditions

Note: subjects 1-8 were in Series 1 (exercise every hour) and subjects 9-16 were in Series 2 (exercise every 3 hours)

APPENDIX B

IMMERSION SUCCESS RATE
(number reaching 6 hours)

		Immersions	No. to 6 hours	% Success Rate
Series 1 (8 divers)	A.M. DIVES	16	10	62.5
	P.M. DIVES	15	5	33.3
Series 2 (8 divers)	A.M. DIVES	16	6	37.5
	P.M. DIVES	16	6	37.5
TOTAL	A.M. DIVES	32	16	50.0
	P.M. DIVES	31	11	35.5
OVERALL	A.M. + P.M.	63	27	42.9

Series 1 = exercise every hour
Series 2 = exercise every 3 hours

APPENDIX C

IMMERSION TIMES
(minutes)

SUBJECT	DIET	A.M. DIVE	P.M. DIVE
1	carbo	370	257
	mixed	234	370
2	carbo	160	323
	mixed	164	215
3	carbo	370	237
	mixed	190	---
4	carbo	370	207
	mixed	370	370
5	carbo	370	97
	mixed	370	263
6	carbo	208	192
	mixed	370	163
7	carbo	315	370
	mixed	370	272
8	carbo	370	251
	mixed	370	370
9	carbo	200	340
	mixed	370	210
10	carbo	220	258
	mixed	260	189
11	carbo	276	285
	mixed	370	370
12	carbo	268	370
	mixed	300	204
13	carbo	233	60
	mixed	217	370
14	carbo	370	250
	mixed	370	370
15	carbo	370	279
	mixed	370	370
16	carbo	225	282
	mixed	180	370

IMMERSION TIMES
(minutes)

SUBDIVISION MEAN TIMES (+ SD)		A.M. + P.M. DIVES	
carbo diet	293	254	274
(all subjects)	±77	±86	±83
mixed diet	305	298	302
(all subjects)	±82	±83	±81
subjects 1-8	311	264	288
Series 1	±86	±84	±87
(carbo + mixed)			
subjects 9-16	287	286	287
Series 2	±72	±90	±80
(carbo + mixed)			
TOTAL	299	275	287
Series 1 + 2	±79	±86	±83
(carbo + mixed)			

Series 1: exercise every hour
Series 2: exercise every 3 hours

APPENDIX D

CAUSES OF ABORTING IMMERSION BEFORE 6 HOURS

	EQUIPMENT			MEDICAL			
	Probe	Suit	Mask	Rectal	Finger/Toe	G.I.	Headache
Series 1 A.M.	0	1	0	2	3	0	1
P.M.	0	2	0	1	5	0	1
Series 2 A.M.	2	1	1	2	3	1	0
P.M.	1	2	0	0	3	4	0
TOTAL ABORTS (n=36)	3	6	1	5	14	5	2
% OF TOTAL ABORTS	8	17	3	14	39	14	6
% OF TOTAL IMMERSIONS (n=63)	5	10	2	8	22	8	3