Thermal insulation properties of argon used as a dry suit inflation gas

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Risberg J, Hope A, Thermal insulation properties of argon used as a dry suit inflation gas. Undersea Hyper Med 2001; 28(3):137–143.—Uncontrolled observations from the "technical" diving community claim superior thermal comfort when replacing air with argon as dry suit inflation gas during diving. The objective of the present experiment was to evaluate the effectiveness of argon compared to air during cold water diving. Body weight, urinary output, and rectal and skin temperatures were measured in six naval divers during two dives to ~10 m for 60 min. Level of thermal comfort was reported. Dry suit gas was either argon or air, divers and scientists were blinded for gas identity. Urinary output was ~200 ml less ($P < 0.05$) during the air than the argon dives. Rectal and all skin temperatures decreased significantly in both groups during the dive but no difference was measured between argon and air dives. Thermal comfort was not different between the groups. Replacing air with argon neither improves subjective impression of thermal comfort nor attenuates core or skin cooling during cold water diving to 10 meters of sea water for 60 min.

diving, body temperature, cold/adverse effects, skin temperature, argon, naval medicine, dry suit, inflation gas

Diving in most natural water (pools and artificial environments excluded) will expose the diver to cold water. Even tropical water can be colder than the temperature (33°–35°C) (1) required to keep the unprotected body thermoneutral. To prevent or decrease heat loss, most divers will dive using diving suits made of either neoprene (wet and dry suits), latex, or other watertight material (dry suits). A thin layer of water is present between the skin and the neoprene material in the wet suit, while direct water exposure is avoided using a dry suit. Wet suits provide less insulation than a properly constructed and fitted dry suit, and only dry suits are used in commercial and military diving in Nordic countries. The main reason for this is a water temperature of 3°–4°C in deeper water layers [>15–20 meters of sea water (msw)] independent of season.

A number of factors will affect thermal insulation of the dry suits. Major factors are dry suit material (latex, neoprene), suit fitting (tight, loose), leakage, and undergarment. Norwegian naval divers are exposed to cold seawater most of the year, and thermal comfort is of prime concern to ensure efficient operation with optimal physical and cognitive performance. The naval diving community has shown increased interest in the potential benefit of argon used as a dry suit inflation gas. Recreational divers, diving either deep and/or requiring prolonged water exposure (e.g., due to decompression obligation), have explored the use of argon as a dry suit inflation gas. Argon has certain theoretical potential benefits when used as a dry suit inflation gas. The heat conductivity is $1.7\ \mathrm{W \cdot cm^{-1} \cdot K^{-1} \cdot 10^{-4}}$, which is 32% less than that of air (2) and the specific heat capacity is $20.79\ \mathrm{J \cdot mol^{-1} \cdot deg^{-1}}$ which is ~30% less than air (3): Except from one report (4) discussing different insulation properties of suit inflation gases, there is a lack of scientific public reports evaluating the effects of argon in operational diving.

The purpose of the present study was to evaluate whether the thermal insulation of argon could be demonstrated superior to air when used as a dry suit inflation gas during cold water diving.

METHODS

Subjects: Six medically fit naval clearance divers, age 21–33, mean 26, volunteered to participate in the current project. Their mean body weight was 80.8 kg (range 70.6–88.2 kg). No diving was allowed 1 day ahead of the experiments. After thorough information (verbal and written), the subjects signed a form of consent. Special care was taken when presenting the importance of underwear clothing and in-water behavior (*see Diving equipment* and *Dive procedure* below). The regional ethics committee at the University of Bergen approved these experiments. The experiments adhered to the Helsinki declaration.

Diving equipment: Standard military diving equipment (scuba 2 × 10 liter, 200 bar, AGA full face mask, two-way communication) was used for the present purpose except for the slightly modified dry suit. The exhaust valve of a standard military 6.5-mm neoprene dry suit (Poseidon Unisuit Professional, Poseidon Industri AB, Västra Frölunda, Sweden) was modified to allow the signal cables to pass out. The divers expelled the dry suit inflation gas, when needed, through the sleeves. This worked technically without any problem. The divers were using "wooley-bear" undergarment, identical to that used for operational diving. To control for any confounding effect of the undergarments, the divers were thoroughly instructed to wear identical clothing for both dives.

Dry suit inflation gas: Air or argon was used as the dry suit inflation gas. Argon was obtained from a local manufacturer (AGA Gas, Trondheim) with a purity exceeding 99.994%. Air was obtained from a compressor at the technical department of the naval base. This gas is produced according to Norwegian navy purity standard, with a maximum water (moisture) content of 50 mg · m $^{-3}$. The gas (either air or argon) was transferred to a 0.8-liter, 200-bar gas cylinder ("pony bottle"). Each cylinder was marked with a number, but the cylinders were otherwise identical. The person responsible for gas filling did not participate in the operational part of the experiment, and the code key was kept secret in a sealed envelope until all experiments were finished. In this way, neither the experimental staff nor the divers were aware of the content of the individual tanks.

Dive procedure: The experiments were done during February 1997 at "KNM Draug", a Norwegian clearance diving tender, docked at Ramsund Naval Station. Skin and rectal thermistors (*see Measurements* below) were connected to the divers and the divers were dressed conventionally.

Each diver dove two dives, separated by 24 h, one with argon (termed "argon dive" and "argon diver" in the following text) and one with air (termed "air dive" and "air diver") as the dry suit inflation gas. The sequence (air–argon or argon–air) was chosen at random and unknown to the divers and staff.

After completing the pre-dive checks, the two divers entered the water simultaneously and submerged minimally below surface. To ensure proper evacuation of any air left inside the suit, the divers squeezed the dry suit completely and then filled the suit as much as practically possible (either until gas was leaking from arm seals or the suit was feeling uncomfortable) from the pony bottle. This procedure of squeezing the suit and filling it with inflation gas was repeated 3 times. The divers then expelled gas through the arm sleeve to allow negative buoyancy and descended to sea bottom. At sea bottom, the suit was filled according to the diver's personal preference of neutral buoyancy. The divers were instructed to remain at sea bottom for 60 min or until the cold felt intolerable. Further, the divers were instructed to remain as inactive as possible during this period and equally inactive during both dives. The divers remained prone during this part of the dive. After finishing the dive, the divers ascended directly to surface, entered the diving tender, and undressed.

To determine the effectiveness of suit inflation procedure, a verification dive was completed after the experiments. One diver was dressed with diving gear identical to that used during the experiments, using argon as the dry suit inflation gas. A 170-cm PVC tube with ID 5 mm was introduced through the neck seal of the suit to the middle part of thorax. The other end was connected to a calibrated Servomex 570A Oxygen Analyzer [Servomex (UK) Ltd, Crowsborough, Sussex, England]. The diver entered the water and oxygen concentration in the suit inflation gas was measured continuously. Before suit flushing, oxygen concentration (F_{O_2}) was 20.9%. After the first flushing, F_{O_2} was decreased to 1.5%. F_{O_2} was 0% after the second and third suit inflation flush. Each flush procedure consumed ~9 liters (STPD) of the suit inflation gas (totally ~26 liters for three flushing procedures) and additionally ~6 liters for buoyancy control when established at seabed.

Measurements: The divers urinated immediately before the experiment started and were then weighed on a domestic scale with 200 g resolution index marks on the display. Six skin thermistors (EUS-U-V5-0, Grant Instruments, Cambridge, England) were taped to the skin on the dorsal aspect of right hand, anterior side of the right forearm, chest, back, thigh (frontal, right side), and the dorsal aspect of right foot. Additionally, a rectal probe (REC-U-UV5-0, Grant Instruments) protected by a condom was positioned ~6 cm into the rectum. Manufacturer's data on maximum thermistor (skin and rectal) tolerance was 0.2°C with a typical tolerance half of this or less. Typical drift is quoted as ±0.02°C.

The thermistor wires were collected and penetrated the dry suit in a common cable through the exhaust valve. The signal cable extended to the water surface and connected to a data logger (Grant Squirrel Series 1200 and Grant Squirrel series 1000, Grant Instruments). Temperature measurements were sampled in 1-min intervals and stored in the logger. Measurements started at surface (control situation) and continued during the dive until the diver exited the water. The content of the logger was dumped off-line to a laptop computer after each experiment. The thermistors were not calibrated before the dives since no controlled temperature source was available. The thermistors were, however, compared interindividually and difference between measured air temperature remained within ± 0.2°C before and after each dive.

During the dives, the divers were asked in 15-min intervals about their subjective impression of thermal comfort. The divers could describe the situation with one of six alternatives (very warm, somewhat warm, comfortable, somewhat cold, very cold, or intolerably cold).

After completing the dive, the divers undressed, urinated in a measuring cylinder, and were then weighed. Regrettably, no formal controls of time span between urine and weight measurements were secured. However, other records showed that these measurements have been done with intervals between 1 h 45 min and 2 h 15 min. To estimate urine flow rate, mean urinary output measurements of all individuals have been calculated based on a 2-h interval.

After the last dive, all divers were asked whether one of the two dives was considered convincingly better with respect to thermal comfort compared to the other. They were not forced to score such preference unless positively convinced, since it was considered inappropriate to compare minor differences in experienced/subjective thermal comfort in two situations separated by 24 h.

Calculation and statistics: Mean skin temperature (T_{Mskin}) was calculated based on a modified formula of Ramanathan (5): $T_{Mskin} = 0.2\ T_{chest} + 0.2\ T_{back} + 0.2\ T_{arm} + 0.4\ T_{thigh}$. The groups have been compared with either paired Student's t test (thermal comfort, weight and urine measurements, temperature measurements in control situation) or two-way analysis of variance (ANOVA) with repeated measures (effects of time and inflation gas on skin and rectal temperature). P values <0.05 were considered statistically significant. While differences in total urinary output have been tested statistically, no statistical test on estimated urine flow rate has been done due to the uncertainty of measurement interval.

RESULTS

Water temperature varied between −1°C and +4°C, mean 2°C, but temperature varied maximum ±1°C between the two dives for each diver. Due to tidal water, depth varied between 7.5 and 10.0 msw, with a maximum variation of ±1.5 msw between the two dives for each diver.

Weight loss after and urinary outputs during the dives are listed in Table 1. Post-dive weight measurements were omitted twice (one measurement after an air dive, one measurement after an argon dive). Maximum weight loss was 1.2 kg while maximum urinary output was 875 ml, both reached during dives with argon as dry suit inflation gas. Urinary output was 48% larger during the argon dives ($P < 0.05$), whereas body weight loss was nominally 85% larger during the argon dives (not significant). Estimated urine flow rate averaged 3.3 ± 0.5 $ml \cdot min^{-1}$ and 4.9 ± 0.8 $ml \cdot min^{-1}$ during air and argon dives, respectively.

Table 1: Weight Loss and Urinary Output

	Air Divers	Argon Divers
Weight loss, kg, $n = 5$	0.3 ± 0.1	0.5 ± 0.3
Urinary output, ml, $n = 6$	398 ± 62	591 ± 101^a

Mean ± SD. $^aP < 0.05$ compared to air.

No diver ever considered the dive as "very warm" or "somewhat warm". One diver (argon dive) finished the dive prematurely (after 51 min) due to intolerable cold, while another diver (air dive) experienced intolerable cold when 60 min bottom time was reached. The time elapsed before thermal comfort was either "somewhat cold" or "very cold" is shown in Table 2. There is no statistically significant difference between the two groups concerning subjective experience of thermal comfort. No diver considered either of the two dives confidently better with respect to thermal comfort than the other.

Measurements of skin and rectal temperatures at surface, immediately before the flushing procedure (control measurements) are listed in Table 3. Forearm temperature was 1.0°C higher before the air than argon

Table 2: Time (min) Before the Divers Experienced Thermal Comfort as Either "Somewhat Cold" or "Very Cold"

	Air Divers	Argon Divers
Somewhat cold, min	22.8 ± 2.6	23.2 ± 3.7
Very cold, min	43.2 ± 3.4	47.5 ± 1.5

Mean ± SD.

Table 3: Rectal and Skin Temperature (°C) in Control Situation

	Air	Argon
Hand	28.76 ± 3.21	27.52 ± 2.68
Forearm	32.40 ± 2.26	31.60 ± 0.74^a
Chest	32.78 ± 1.90	32.56 ± 1.46
Thigh	29.60 ± 1.05	29.19 ± 2.10
Foot	29.37 ± 1.25	28.43 ± 1.45
Rectal	37.50 ± 0.24	37.37 ± 0.27
Mean skin	31.69 ± 0.96	31.20 ± 1.45

Mean ± SD. $^aP < 0.05$ compared to air.

dives ($P < 0.05$), whereas all other skin temperatures, rectal and mean skin temperature were equal between air and argon dives in the pre-dive control situation (*t* test). Decreased skin and rectal temperature was observed in all divers during the dives (ANOVA) (Figs. 1 and 2). Mean skin and rectal temperature were significantly ($P < 0.01$) lower after 60 min compared to control in both situations. Temperature reduction was most pronounced in hands (Table 4). Temperature loss was not statistically different comparing air and argon measurements. In spite of equal skin temperature in control, back temperature decreased significantly ($P < 0.01$) less than chest after 60 min, and this was observed both during the air and the argon dive (Table 4). Though the nominal reduction in rectal temperature was greater during air compared to argon dives (0.57° vs. 0.44°C, Table 4, Fig. 2) this difference did not reach statistical significance.

DISCUSSION

General considerations: A number of restrictions were applicable to the present study. First, the study is a field study, providing limited access to laboratory equipment. Care was taken to standardize areas considered to be of major importance to test results, e.g., identical clothing/diving suit, positioning of thermistors, pre-dive and in-water activity, etc. Facilities for blood sampling and handling were not, however, readily available and such measurements had to be omitted.

Diver selection and dive procedure: No effort was made to restrict the experimental sample on criteria like age, body fat, or similar. On the other hand, no individual showed thermal responses deviating strikingly from the rest of the group. Resource limitation is the reason for the small number of experimental subjects (six) in the present study. However, the fact that each person served as his own control allows increased study sensitivity compared to group analysis of data. The experimental dive procedure dictated the divers to descend to seabed and remain at rest for 60 min. This has no apparent operational parallel, but was chosen to provoke a major fall in skin and core temperature. A dive requiring some muscular effort, e.g., manual work or swimming, would be closer to the operational reality for these divers, but would be much harder to standardize (between the two dives). In addition, it was anticipated that a more strenuous dive would produce increased metabolic heat and possibly mask minor differences in thermal insulation provided by the two suit inflation gases. Finally, a 60-min resting situation at sea bed was chosen to simulate a staged decompression stop restricting access to muscular activity and added metabolic heat production. Indeed, the dive procedure seemed successful in respect of cold stress, since all divers reported "very cold" at the end of the dive, rectal temperature fell ~0.5°C and major skin surfaces cooled by 7°–10°C (Table 4).

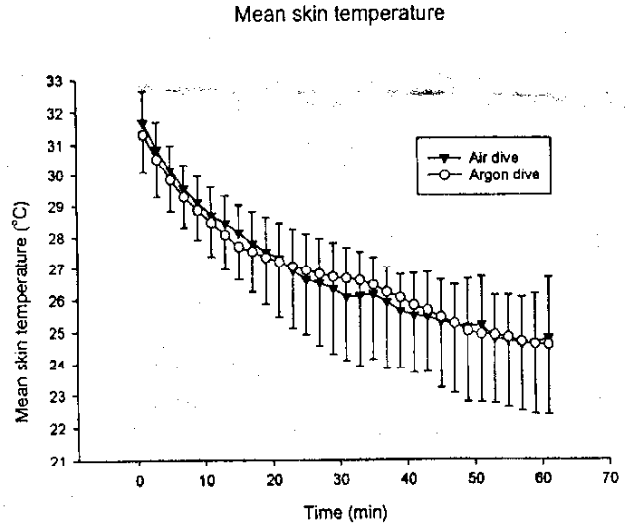

FIG. 1—Mean skin temperature during 60-min dive to ~9 msw using either air (*arrow head*) or argon (*circles*) as dry suit inflation gas. Mean plus or minus SD.

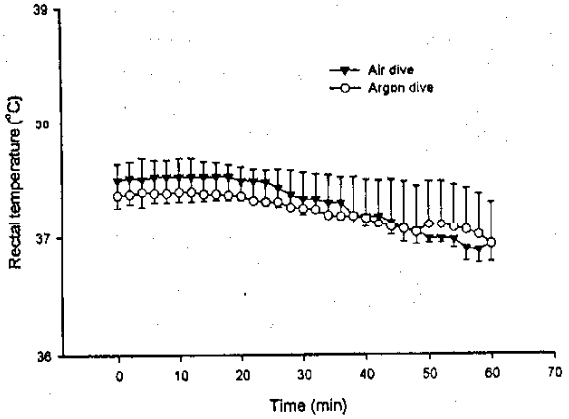

FIG. 2—Mean rectal temperature during 60-min dive to ~9 msw using either air (*arrow heads*) or argon (*circles*) as dry suit inflation gas. Mean plus or minus SD.

Argon concentration was not measured during the experiments. However, oxygen fraction decreased by 19.4% absolute (93% relative) after the first squeeze/fill procedure of the dry suit using argon, and no oxygen was present after the following flush procedure. These results suggest that the flushing procedure was effective. Whether air pockets still could be trapped outside the thoracic sampling area is not possible to exclude, but the divers descended vertically in water during the flushing procedure to ensure proper squeeze of the dry suit. Even if some air should remain in the suit, the flushing procedure exceeds that used during operational "technical"

Table 4: Rectal and Skin Temperature Decrease (0°C) Compared to Control (Surface) and 60 min Submersion Using Either Air or Argon as Dry Suit Inflation Gas

	Air		Argon	
	mean ± SD	variation	mean ± SD	variation
Hand	17.26 ± 1.64	13.20–22.20	12,73 ± 1.55	8.00-18.05
Lower arm	9.42 ± 1.83	5.00–17.20	10.44 ± 1.06	7.50-13.20
Chest	7.11 ± 2.24	3.10–16.80	6.03 ± 1.52	1.25-11.80
Back	2.87 ± 0.57**	1.60–4.40	3.13 ± 0.33**	2.40-4.40
Thigh	6.75 ± 1.31	3.60–11.20	6.92 ± 0.63	5.60-9.40
Foot	7.86 ± 0.83	4.50–9.80	8.04 ± 0.58	6.60-9.95
Rectal	0.57 ± 0.12	0.30–1.00	0.44 ± 0.06	0.25-0.60
Mean skin	6.40 ± 2.19	5.28–10.15	6.52 ± 1.55	4.85-9.23

**$P < 0.01$ compared to chest.

diving and the practical implications of the measurements should be relevant.

Weight and urine measurements: Body weight was measured with a conventional domestic scale. Small weight changes were therefore not easily detected. Two divers omitted post-dive weight measurement by mistake (one after the air dive, another after the argon dive). A reported higher urinary output than the weight loss is probably due to this inaccuracy. Accordingly, caution should be taken when considering the nominal weight loss for each diver during an individual dive, but a group comparison between air and argon dive should be valid in spite of this. Both weight loss and urine flow rate were nominally larger after the argon dives than the air dives (Table 1), but only urinary output difference reached statistical significance ($P < 0.05$). This measured difference is probably better explained as a statistical type I error rather than a physiological phenomenon. A diuretic effect of argon absorbed through skin seems unlikely and, to the best of our knowledge, no report has claimed renal effects of argon per se. An alternative physiological explanation, cold diuresis during the argon dives, would contradict a firmly established physical property of argon (thermal conductivity less than air) and is highly unlikely.

No baseline measurements of urinary output were taken in the present study and there is no definite proof of increased urinary output during the dive. However, previous reports have repeatedly confirmed increased urinary output during diving caused by immersion (6) as well as cold (7). Urine flow rates in this study (3.3 and 4.9 ml · min^{-1} for air and argon dives, respectively) compare well with those obtained during 90 min unprotected cold immersion to 18°C (4.4–4.7 ml · min^{-1}) (8).

Thermal comfort: An arbitrary scale was used to indicate level of thermal comfort. All divers reported comfortable when the dive started. Time until the diver considered the dive as "somewhat cold" was not statistically different between the two groups, neither is time until the dive is experienced as "very cold" (43.2 ± 3.4 min vs. 47.5 ± 1.5 min, $P = 0.06$). It seems relevant to consider whether this lack of statistical significance may be a type II error due to the low number of experiments performed. Interestingly, although anecdotal reports (Ronny Arnesen, personal communication, 1998) and general opinion strongly enforce the benefit of argon due to improved thermal comfort, such personal experience was not expressed during these experiments. None of the divers were confident in their preference of inflation gas.

Why do technical divers prefer argon to air as the dry suit inflation gas? First, anecdotal experience is claimed to show argon superior to air during operational diving (9). Lippitt and Nuckols (4) discussed thermal protection requirements for cold water diving based on theoretical models and insulation properties of different gases. On the basis of these findings, they recommended further studies using different suit-inflation gases. As far as we know, the theoretical benefit and subjective experience with argon have previously not been challenged by blinded tests. Having a density ~25% higher than air, technical divers claim to hear and feel the difference in suit inflation rate. Blinding may thus be difficult for divers having used argon previously. There is a possibility that the superior thermal comfort is anticipated rather than real. Second, many divers use an Ar–CO_2 blend commercially available as welding shield gas. The added CO_2 may theoretically form carbonic acid (H_2CO_3) at skin surface moistened with sweat or water. One may speculate whether this weak acid (pKa = 6.4) may irritate the skin sufficiently to cause a sensation of thermal comfort. Finally the technical diver's movement would not be completely restricted. This would be associated with an increased metabolic heat production and accordingly higher skin temperature to increase convective and conductive heat loss. If the benefit of argon was of physiological importance mainly before maximal vasocon-striction occurred, one would assume that a difference in skin temperature should be evident during the first minutes of the dive in these experiments. As evident from Fig. 1, however, there is no difference using either gas even during the initial part of the dive in which skin temperature was relatively high.

Skin and rectal temperature: Calculation of skin temperature was modified from Ramanathan (5). We did not measure leg temperature, and the thigh temperature was used as a representative measure of average lower body skin temperature. This value was therefore assumed to represent 40% of total skin surface. The other three sites (chest, back, and arm) represented the upper body and accounts for 60%. This main weighing percentage is in accordance with Ramanathan (5). Skin temperatures and rectal temperature measured in control situation are within the thermal comfort zone. Forearm skin tempera-ture was 1.0°C higher ($P < 0.05$) in control measurement at surface using air compared to argon. We have no ready explanation for this. At this time, divers were positioned at water surface, but no (or minimal) flushing of dry suit had occurred. The fact that only arm temperature was different indicate that this may be a statistical coincidence (type I error) rather than a methodologic error. One may speculate whether this difference in control value might mask later changes in surface skin temperature at the same site. Skin temperatures at other sites were not statistically different between the two situations, showing that skin areas constituting most of the body surface area (thorax, abdomen, thigh, arms) dissipate heat similarly using either gas. This is supported by core tem-perature measurements showing equal temperatures and individual (subjective) impression of thermal comfort in the two situations. As Fig. 1 shows, the mean skin temperature fell identically during the dive irrespective of dry suit inflation gas.

Thermal conductivity of argon is ~32% less than that of air (2). The lack of difference in skin and core temperature between divers using argon and air is therefore striking. One would assume at least a small difference between the two groups. We doubt that inadequate flushing of the dry suit explain this observation. However, there are at least two possible explanations. First, the diver may have compensated for the increased heat loss by shivering (metabolic heat). Although this is possible, one would assume that at least a minor, consistent difference in skin temperature would occur to initiate the shivering. In that case one would assume the diver to claim the air dive colder than the argon dive. Though no such difference could be demonstrated with the established statistical confidence (Table 2), one should note that the low number of subjects imposes restriction on the study sensitivity. Statistically the power is 0.38 and 0.90 to verify, respectively, a 1° and 2°C difference in mean skin temperature between argon and air divers ($P = 0.05$). Similarly, low statistical power may have masked the borderline-significant change concerning time before the dive was considered "very cold" (test power 0.91 to acknowledge a 15-min difference, $P = 0.05$). Second, the diver may decrease heat loss in areas not covered by the dry suit. Indeed, hand temperature fell significantly more using air compared to argon (Table 4), which supports this possibility. There are, however, no other observations supporting increased vasoconstriction during the air dives compared to argon.

If body heat loss only occurred at skin surfaces protected by suit inflation gas, one would expect to observe evident differences in thermal comfort and temperature measurements between argon and air divers. However, major alternative pathways contribute to heat loss such as unprotected skin (hands, face), skin areas minimally protected with suit inflation gas due to hydro-static squeeze, respiratory heat loss, etc. Skin heat loss will be maximal at areas with minimal or no gas interface between undergarment and suit. Consistently lower skin temperature at chest compared to back (Table 4) support the concept of important regional differences in thermal insulation. At such pressure areas (e.g., chest when the divers were lying horizontally), the gas layer is too thin to provide significant thermal protection, and heat flux will depend mainly on insulation properties of undergarment and suit fabric [thermal conductivity of Neoprene is 5.3 and wool 9.3 $W \cdot cm^{-1} \cdot K^{-1}$ (10) vs. 2.5 for air (2)]. One would expect to observe changes in skin temperatures between air and argon dives mainly on places were the thickness of the protective suit gas is large, e.g., the back. However, no difference in back skin temperature is observed between air and argon dives (Table 4). The study design did not allow measurement of alternative pathways for heat loss like evaporative heat loss, radiant heat loss, or respiratory heat loss.

The study design does not provide the required sensitivity to detect minor changes in heat loss between air and argon dives. Limited number of subjects and an indirect measure of heat loss (surface and core temperature rather than heat flux sensors), no control of respiratory heat loss or metabolic heat production are some of the limitations. However, the objective was not to measure minor changes in heat flux but to observe whether argon provided the diver with improved sensation of thermal comfort and, if so, whether objective measurement could support this impression.

Practical and operational consequences: The objective of these experiments was to evaluate whether argon would provide superior thermal insulation compared to air as a dry suit inflation gas. Neither subjective reports from the divers nor objective measurements of skin and rectal temperature demonstrated significant differences between the two gases. Introducing argon as a dry suit inflation gas has certain medical and practical considera-tions. Introducing an ambient (suit inflation) gas different from the one breathed *at depth* may in certain circum-stances elicit urticaria and even serious vestibular dys-function caused by isobaric counterdiffusion (11). This is probably of minimal risk during conventional bounce diving, since tissue is unsaturated and diffusivity of Ar and N_2 are almost identical [2.0 and 2.1 $cm^{-2} \cdot s^{-1}$, respectively (12)]. Of greater importance is the practical, logistic and safety problems associated. The gas cannot be produced readily at site, but has to be bought from commercial gas manufacturers. This will affect both economic and logistic resources. Second, introducing a "new" inert gas will represent a possible hazard for erroneous gas mixture in *other* diving gases. Filling a breathing gas cylinder (e.g., reserve pony bottle) with argon may cause death due to hypoxia. These negative consequences have to be balanced with the potential positive effects. The results of this study indicate a lack of positive thermal effects in operational diving, forcing us to recommend air as dry suit inflation gas for military diving and probably also in recreational (technical) diving.

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