

No difference in core temperature or thermal sensation in male and female scuba divers using wetsuits or semi-drysuits in 22.6°C sea water

Fabian N Möller^{1,2,3}, Kavi Dodge¹, Tucker Orman², Igor Glavičić⁴, Željko Dujić⁵, Nikola Foretić⁶, Andrew T Lovering¹

¹ University of Oregon, Department of Human Physiology, Eugene, OR, USA

² Massachusetts Institute of Technology, Department of Aeronautics and Astronautics, Aerospace Physiology Lab, Boston, MA, USA

³ German Sport University, Cologne, Institute of Professional Sport Education and Sport Qualification, Cologne, Germany

⁴ Department of Marine Studies, University of Split, Croatia

⁵ Department of Integrative Physiology, University of Split School of Medicine, Split, Croatia

⁶ Faculty of Kinesiology, University of Split, Split, Croatia

Corresponding author: Professor Andrew Lovering, Department of Human Physiology, 1240 University of Oregon, Eugene OR, 97403-1240, USA

ORCID: [0000-0001-7826-4290](https://orcid.org/0000-0001-7826-4290)

lovering@uoregon.edu

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Abstract

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Introduction: Scuba diving in water below thermoneutral temperature (< 30°C) can reduce core temperature and impair comfort and performance. Semi-drysuits are presumed superior to wetsuits because they presumably limit water entry into the suits, but changes in core temperature and thermal sensation have not been previously published in males and females wearing semi-drysuits. This study assessed the influence of anthropometrics and thermal protection from wetsuits and semi-drysuits on core temperature and thermal sensation in males and females performing recreational scuba dives.

Methods: Core temperature (telemetric pill) and thermal sensation (Young's scale) were measured in 39 recreational divers (17 females) wearing wetsuits (mean 6 [SD 1] mm thickness, $n = 19$, 6 females) or semi-drysuits (7 [1] mm, $n = 20$, 11 females) during a 45-minute dive in mean 22.6 (1.1)°C water.

Results: The wetsuit group had approximately 2 mm thinner suits ($P < 0.001$) and a 0.2 m² greater body surface area ($P = 0.035$), while age, body mass index, body fat percentage, and water temperature did not differ between groups. No significant differences were observed between suit types for absolute core temperature change or thermal sensation. In semi-drysuit divers, body fat percentage negatively correlated with the change in temperature per minute of dive time (rate of temperature change, $R^2 = 0.29$, $P = 0.014$). However, when anthropometric values were multiplied by suit thickness, there were no significant correlations with the rate of temperature change in either suit type.

Conclusions: Semi-drysuits did not confer superior thermal protection in 22.6°C water during recreational scuba diving activities.

Introduction

Decreases in body temperature from cold air or water exposure in professional, occupational, and/or recreational settings lead to physiological adaptations and symptoms ranging from discomfort and shivering to decreased physical and psychological performance.¹ The severity of possible symptoms depends on the air and/or water temperature, thermal protection, and time of exposure, as well as on body composition and physiological reactions for heat loss prevention that include peripheral vasoconstriction and shivering or non-shivering thermogenesis.²

With scuba diving, individuals choose to wear various types of diving suits for thermal protection. Conductive heat loss is increased in water compared to air, depending on the temperature difference between the skin and the surrounding medium, the material's thickness and thermal conductivity, and the medium's conductance.³ Furthermore, high body surface area to mass ratios tend to create the greatest decreases in core temperature in cold environments due to the greater surface area for heat conduction,^{4,5} and it has been suggested that skin temperature and the locations of greatest heat loss might differ between sex assigned at birth.⁶ Acknowledging the relationships of these factors with the chosen suit type might improve thermal protection

during cold water immersion. However, current operational exposure criteria in scuba diving and cold-water immersion research generally define limits in terms of physiologic responses (e.g., acceptable changes in core temperature) and do not formally incorporate diver anthropometrics, suit type, or sex into the definition of thermal exposure limits.⁷ While the type of suit may play a role in preventing decreases in body core temperature and thermal sensation, the studies performed thus far have focused on wetsuits and drysuits under various conditions in studies with mostly male subjects that were within a narrow range of demographic parameters like age, height, and body composition,^{8–10} and under extreme conditions that are not likely for the majority of recreational scuba divers.¹¹ Previous work from our group reported temperature changes in recreational divers using wetsuits¹² and drysuits.¹³ Still, no data exist on the impacts of wetsuits versus semi-drysuits on changes in core temperature and thermal sensation in male and female recreational scuba divers.

When considering suit types, thermal protection in wetsuits is primarily achieved by limiting convective heat loss through minimising water circulation between the skin and the suit by a snug fit. Nevertheless, during a dive, some degree of intermittent water exchange with the ambient environment can occur, particularly in wetsuits without an ideal fit, which can lead to repeated bouts of cooler ambient water entering the suit and increased heat loss. Conversely, suits commonly referred to as ‘semi-dry’ are designed to further restrict water inflow and outflow compared with conventional wetsuits through close-fitting smooth-skin neoprene seals at the wrists, ankles, and neck, typically combined with a watertight back- or front-entry zipper, sealed seams, and, in some models, an attached or integrated hood, rather than through fundamentally different insulation principles. Both suit types use closed-cell neoprene of comparable construction, so the dominant insulation mechanism, the reduction of conductive and convective heat loss via the trapped gas in the neoprene matrix, is shared between designs. As a result, and assuming an ideal fit, semi-dry suits may reduce the magnitude of water exchange with the environment and thereby attenuate temperature fluctuations inside the suit following the initial heat conduction after water entry, as minimal as it may be. To date, a search on PubMed for “*semi-drysuits*” and “*dive*” (with or without hyphen, plural or singular) yields just one publication that examined the utility of using heating pads in seven male divers wearing semi-drysuits in 7.2°C water.¹⁴ Accordingly, there are currently no data-based recommendations for choosing semi-drysuits over wetsuits for scuba diving in any water temperature, particularly with respect to the inclusion of both male and female participants.

The purpose of this study was to measure core temperature and thermal sensation before and after a ~45-minute scuba dive in ~22.6°C water temperature in males and females scuba divers using either semi-drysuits or wetsuits. Furthermore,

we sought to quantify individual anthropometrics and suit thickness on the rate of change in core temperature per minute of dive time. It was hypothesised that the (I) decrease in core temperature and thermal sensation would be less with semi-drysuits than wetsuits, and (II) that a higher body mass index, higher percentage of body fat, and a lower body surface area to mass ratio would be associated with a reduced change in core temperature per minute of dive time.

Methods

This study was approved by the University of Oregon’s Office for Protection of Human Subjects (RB# 00000951), the University of Split (#2181205020523020), and the German Sport University Cologne (108/2023). All subjects had English language proficiency, were provided with documents outlining the study in English, and gave written approval prior to participating in the study. All experimental procedures were conducted in accordance with the Declaration of Helsinki, except for registration of this study.

The study included 39 divers with dives times set for 45 minutes. Data were collected in September 2023 in Roses, Spain, and Bol, Croatia. Twenty subjects used semi-drysuits that allowed only minimal water exchange with ambient water, and 19 subjects used wetsuits without seals at the neck, arms, or legs. All participants were healthy, active, and without any self-reported cardiovascular or pulmonary disease.

All dives were conducted under optimal visual and water conditions without any exhausting tasks and using open-circuit apparatus with air as breathing gas. No further restrictions were placed on the dive profile. Maximum depth, mean depth, water temperature, and dive time were assessed at 1-second intervals by individual dive computers. Tank pressure was recorded before and after each dive, and total air consumed reported normalised to 1 bar ambient pressure. Temperature was assessed directly before water ingress and after egress by a single measurement using a telemetric pill (Jonah core body temperature capsule; Mini Mitter, Bend, OR) and by statement of thermal sensation on a scale from 0 (unbearably cold) to 8 (unbearably hot).¹⁵

The changes in core temperature ($\Delta T_{c\cdot\text{min}^{-1}}$) and thermal sensation ($\Delta T_{s\cdot\text{min}^{-1}}$) were normalised for total dive time in minutes to acknowledge the entire exposure duration impact on these variables and allow future comparisons to various dive durations.

Thermal protection was categorised as either wetsuits or semi-drysuits and total suit thickness was stated as the maximum thickness in millimetres around the core from all suit layers combined. All wetsuits and ~10% of the semi-drysuits were the personal property of the divers, while the other 90% of the semi-drysuits were provided by a university diving group.

Body mass index (BMI) was assessed indirectly as a calculation of body mass (BM) in kg divided by height (m)², and body surface area (BSA) by the du Bois formula where $BSA (m^2) = 0.007184 (x \text{ height}^{0.725}) (x \text{ weight}^{0.425})$.

Regression analyses were calculated as $\Delta Tc \cdot \text{min}^{-1}$ with the anthropometric variables BM, BMI, BSA, BSA/mass, and suit thickness. Additional analyses were calculated with anthropometric variables normalised for suit thickness.

An estimation of physical exertion during the dive, ventilation ($\dot{V}_E$, L·min⁻¹) was calculated as total air consumption $\times$ dive time⁻¹ $\times P_{\text{Mean depth}}^{-1}$, with total air consumption derived from the dive tank pressure delta multiplied by the tank volume ($\Delta P_{\text{tank}} \times V_{\text{tank}}$), like before.¹⁶

The percentage of body fat (BF%) was calculated using $[(1.39 \times \text{BMI}) + (0.16 \times \text{age}) - (10.34 \times \text{sex}) - 9]$,¹⁷ where males are depicted by '1' and females by '0', respectively.

Differences in all anthropometric and descriptive data between sex and suit types were analysed using Student's *t*-tests. Repeated measures ANOVAs were calculated for thermal sensation (Ts) and core temperature (Tc) on the factors time (pre-dive vs. post-dive) and suit type (semi-drysuit vs. wetsuit), based on post-hoc power analyses using G*Power on $\Delta Tc \cdot \text{min}^{-1}$ (Effect size: 0.51, $\alpha = 0.05$, Power: 0.99) and $\Delta Ts \cdot \text{min}^{-1}$ (Effect size: 0.51, $\alpha = 0.05$, Power: 0.72). Sex differences were not investigated due to insufficient statistical power.

The relationships between the rate of change in Tc ($\Delta Tc \cdot \text{min}^{-1}$) and wetsuit thickness (mm), anthropometric factors, including, body mass (kg), BSA (m²), BMI, %BF and BSA to mass ratio (BSA/BM), were analysed using linear regressions. The potential effect of ventilation per minute ($\dot{V}_E$, L·min⁻¹), as an indicator of physical activity and metabolic demand, on $\Delta Tc \cdot \text{min}^{-1}$ was investigated using linear regressions.

Statistical significance was accepted at $P < 0.05$. All data are presented as mean (SD). All analyses were completed in GraphPad Prism 10.2.0 (GraphPad Software, La Jolla, CA).

Results

Out of the 39 divers that participated in the study, 22 were males and 17 females, aged 27 (10) years. Twenty subjects (11 females) used semi-drysuits and 19 subjects (six females) used wetsuits. All dives were no-decompression dives conducted between 09:30 and 10:30 in the morning or between 15:30 and 16:30 in the afternoon. The core temperature (Tc) pill was ingested 6–10 hours before the start of the dive. All wetsuit dives were conducted within 18 days at a measured water temperature of 22.8 (1.2)°C, while semi-drysuit dives were conducted over eight days at a water temperature of 22.3 (0.9)°C. Water temperatures were not significantly different between suit types. For

all participants combined, the dive time was 45 (7) min ($P = 0.468$ between groups), with a depth of 10.4 (3.2) metres of seawater (msw) ($P = 0.999$ between groups) and a water temperature of 22.5 (1.0)°C ($P = 0.168$ between groups). The thermocline ranged between 24 (1.5)°C on the surface and 21 (1.8)°C at maximum depth (Table 1).

Males and females were represented in both suit type groups (semi-drysuit vs. wetsuit). The two suit type groups differed only in suit thickness, hood thickness, and BSA. While BSA was calculated and is presented using the DuBois equation, repeating the between-group comparison with the Mosteller and Haycock equations yielded virtually identical estimates, $\Delta = 0.158$ and 0.165 m^2 , respectively, vs. 0.145 m^2 for DuBois, with $t = 2.15$ – 2.17 and $P = 0.038$ – 0.040 in all three cases; pairwise $r \geq 0.99$. Wetsuits and hoods were both approximately 2 mm thinner than in those wearing semi-drysuits ($P < 0.001$). Ancillary protective equipment (e.g., hoods and handwear) varied between individuals; however, no group differences were observed except for greater hood thickness in the semi-dry suit group. BSA was 0.2 m^2 higher in the wetsuit group than in the semi-drysuit group ($P = 0.035$). Dive suit groups were not different in age ($P = 0.119$), BMI ($P = 0.119$), body fat percentage ($P = 0.390$), or water temperature ($P = 0.157$). $\dot{V}_E$ was not significantly different between the two groups ($P = 0.169$). That did not change when normalising ventilation for body weight ($P = 0.999$). Please refer to Table 1 for full anthropometrics, dive data and thermal protection characteristics.

All participants had a significantly reduced post-dive core temperature (Tc) ($\Delta -0.4$ (0.5)°C; $P < 0.001$) and thermal sensation (Ts) ($\Delta -1.0$ (0.7); $P < 0.001$) with no effect of suit type (wetsuit: $\Delta -0.4$ (0.6)°C Tc, $\Delta -1.1$ (0.7) a.u. Ts; semi-drysuit: $\Delta -0.4$ (0.4)°C Tc, $\Delta -0.9$ (0.7) a.u. Ts) (Table 1).

The rate of core temperature change per minute was not different between suit types ($\Delta Tc \cdot \text{min}^{-1}$) ($P = 0.873$; wetsuits: $\Delta Tc \cdot \text{min}^{-1} = -0.008$ °C; semi-drysuits: $\Delta Tc \cdot \text{min}^{-1} = -0.008$ °C; Figure 1A). Nor was there a difference in change of thermal sensation change per minute ($\Delta Ts \cdot \text{min}^{-1}$) ($P = 0.509$; wetsuits: $\Delta Ts \cdot \text{min}^{-1} = -0.024$ arbitrary units (a.u.); semi-drysuits: $\Delta Ts \cdot \text{min}^{-1} = -0.021$ a.u.; Figure 1B).

No significant associations were observed for either ΔTs a.u.·min⁻¹ or $\Delta Tc \cdot \text{min}^{-1}$ with BF% (Figure 2A+B), BM (Figure 2C+D), BMI (Figure 2E+F), or BSA divided by BM (Figure 2G+H) when normalised for suit thickness (Figure 2) to quantify the combined thermal protection effects of anthropometrics and suit characteristics (all $r < 0.180$; $P > 0.062$).

When not normalised for suit thickness, $\Delta Tc \cdot \text{min}^{-1}$ was significantly and negatively correlated to the BF% in the semi-drysuit group, with higher BF% increasing the rate of temperature loss ($P = 0.014$, $R^2 = 0.292$). In the wetsuit group, body fat percentage was positively correlated with $\Delta Tc \cdot \text{min}^{-1}$ though this association was not significant.

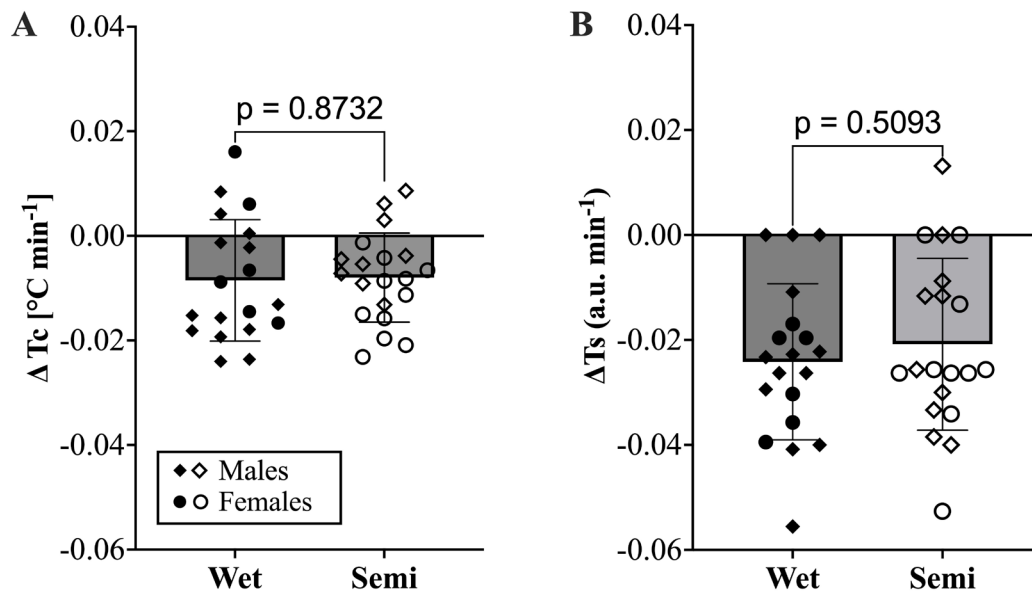
Table 1

Anthropometric data, body mass (BM), body surface area (BSA), body mass index (BMI), dive data, and specifics about thermal protection from all participants, separated by wetsuit and semi-drysuit, and males and females; data are presented as mean (standard deviation). Hoods, gloves, and boots are indicated with the number of participants who wore them and mean (SD) thickness (n; mm). Temperatures are displayed as pre-dive, post-dive, and delta values for core temperature and the statement of perceived thermal sensation on a scale from 0 (unbearably cold) to 8 (unbearably hot).¹⁴ Significant differences between the suit type groups are depicted with *, and pre- to post-dive comparisons are indicated by #

Variable	Wetsuit, n = 19			Semi-dry suit, n = 20		
	All (19)	Women (6)	Men (13)	All (20)	Women (11)	Men (9)
Anthropometric data						
Age, years	29.8 (13.2)	21.2 (3.0)	33.8 (14.3)	24.8 (4.9)	23.5 (2.1)	26.4 (6.7)
Height, cm	177.7 (8.3)	169.8 (5.2)	181.4 (6.9)	174.0 (8.5)	169.1 (6.7)	180.0 (6.5)
BM, kg	82.3 (22.0)	64.5 (12.9)	90.6 (20.5)	70.6 (10.7)	64.0 (5.3)	78.7 (10.2)
BSA, m ²	1.99 (0.24) *	1.74 (0.17)	2.10 (0.17)	1.84 (0.16) *	1.73 (0.09)	1.98 (0.13)
BMI, kg·m ⁻²	26.0 (7.1)	22.3 (3.9)	27.8 (7.7)	23.3 (2.8)	22.4 (2.1)	24.3 (3.3)
BSA/BMI, m ² ·kg ⁻¹	0.025 (0.003)	0.027 (0.003)	0.024 (0.003)	0.026 (0.002)	0.027 (0.001)	0.025 (0.002)
Body fat, %	24.9 (9.8)	25.3 (5.2)	24.7 (11.5)	22.7 (5.4)	26.0 (2.9)	18.7 (5.2)
Dive data						
Water temperature, °C	22.8 (1.2)	23.6 (0.7)	22.5 (1.2)	22.3 (0.9)	22.0 (1.0)	22.7 (0.5)
Depth, m	10.3 (1.2)	9.1 (0.0)	10.8 (3.2)	10.3 (3.2)	10.9 (3.8)	9.5 (2.0)
Dive time, min	46.4 (7.7)	48.0 (10.3)	45.6 (6.4)	44.6 (7.2)	42.7 (7.7)	46.7 (6.4)
Air consumed, L	1824 (403)	1420 (334)	2011 (279)	1591 (339)	1435 (274)	1782 (325)
Ventilation, L·min ⁻¹	21 (8)	16 (5)	23 (8)	18 (4)	17 (4)	20 (3)
Thermal protection						
Suit thickness, mm	5.8 (1.3) *	5.7 (1.2)	5.9 (1.3)	7.4 (0.8) *	7.5 (0.7)	7.2 (1.0)
Thickness/BSA, mm·m ⁻²	3.0 (0.8)	3.3 (1.1)	2.8 (0.7)	4.0 (0.6)	4.4 (0.4)	3.7 (0.5)
Thickness/BMI, mm·kg ⁻¹ ·m ⁻²	0.3 (0.1)	0.3 (0.1)	0.2 (0.1)	0.3 (0.1)	0.3 (0.1)	0.3 (0.1)
Hoods, n; mm	16; 4.0 (1.7) *	5; 4.0 (1.7)	11; 4.4 (1.5)	17; 6.3 (1.2) *	10; 6.6 (0.9)	7; 5.9 (1.6)
Gloves, n; mm	3; 3.5 (2.1)	N/A	3; 3.5 (2.1)	7; 4.0 (1.1)	4; 3.7 (1.2)	3; 4.3 (1.2)
Boots, n; mm	9; 4.9 (1.5)	1; 5.0 (-)	8; 4.9 (1.4)	19; 5.1 (1.2)	10; 5.2 (1.1)	9; 5.1 (1.4)
Measured and perceived temperature changes						
Core temperature °C	Pre	37.5 (0.3)	37.7 (0.5)	37.5 (0.6)	37.6 (0.3)	37.5 (0.5)
	Post	37.1 (0.7)	37.5 (1.0)	36.9 (0.6)	37.3 (0.3)	37.4 (0.3)
	Δ	-0.4 (0.6) #	-0.2 (0.7)	-0.5 (0.5)	-0.4 (0.4) #	-0.2 (0.4)
Perceived temperature scale	Pre	4.9 (0.8)	5.1 (0.7)	4.9 (0.9)	5.0 (0.5)	4.9 (0.7)
	Post	3.8 (0.6)	3.8 (0.4)	3.8 (0.7)	4.1 (0.6)	3.9 (0.2)
	Δ	-1.1 (0.7) #	-1.3 (0.4)	-1.0 (0.8)	-0.9 (0.7) #	-1.0 (0.7)

Figure 1

Changes per minute of dive time in A: Core temperature ($\Delta T_c \cdot \text{min}^{-1}$) and B: Thermal sensation ($\Delta T_s \cdot \text{min}^{-1}$); males (diamonds) and females (circles) are depicted with full symbols for wetsuits (Wet) and empty symbols for semi-drysuits (Semi); a.u. – arbitrary units



Linear regressions of $\dot{V}_E$ and $\Delta T_c \cdot \text{min}^{-1}$ were not significant for females wearing wetsuits ($P = 0.503$, $R^2 = 0.119$) or semi-drysuits ($P = 0.542$, $R^2 = 0.043$) or males wearing wetsuits ($P = 0.071$, $R^2 = 0.266$) or semi-drysuits ($P = 0.946$, $R^2 < 0.001$).

Discussion

All participants combined experienced a significant decrease in core temperature (-0.4 [0.5] $^{\circ}\text{C}$) and thermal sensation (-1.0 [0.7]) over the 45-minute dives in 22.6 (1.1) $^{\circ}\text{C}$ water temperature. Participants wearing wetsuits had a greater BSA than the semi-drysuit participants (2.1 m^2 vs. 1.8 m^2), and thermal protection that was 1.7 mm thinner. Under the study conditions, no differences were observed between wetsuits or semi-drysuits to maintain body core temperature within established US Navy exposure limits of 1°C .

Many studies have examined thermoregulatory variables in scuba divers, however, previous reports typically had small numbers of participants who were mostly males diving under extreme conditions,^{8,9} and/or highly specialised and selected groups, like Navy SEALs.¹⁸ In some cases, these studies used specialised equipment such as argon as the insulation gas in a dry suit.^{19,20} While being instrumental in laying the groundwork for male divers in extreme conditions, their applicability may be limited for the much greater percentage of male and female Scuba divers diving for recreational purposes in less extreme conditions. Additionally, no published study has directly compared wetsuits and semi-drysuits, despite both being commonly used in recreational diving. In part, this likely reflects the genuine difficulty of

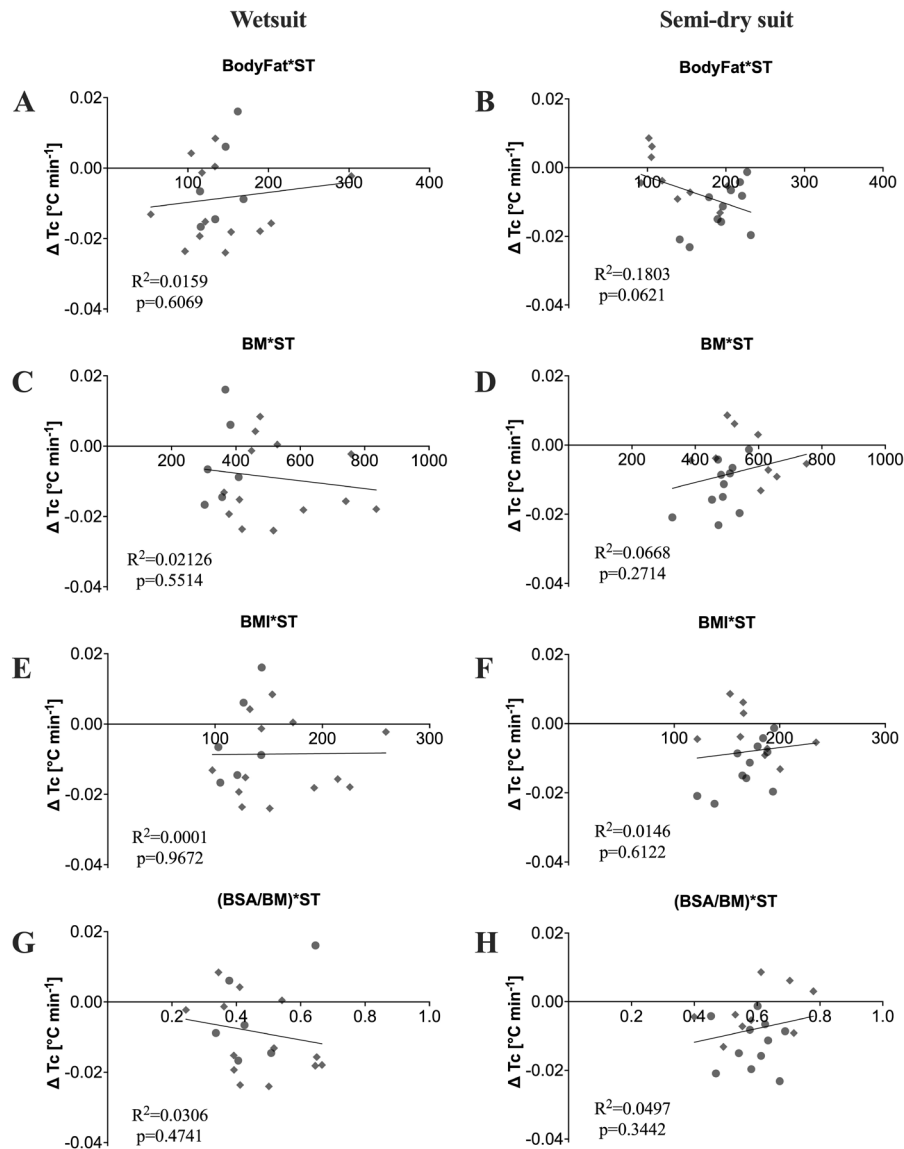
the comparison rather than a simple gap in the literature, as thermal protection depends not only on suit category and thickness but also on regional fit, flexibility, seal integrity, and gaps at the interface between skin and suit.

Previous work from our group reported temperature changes in scuba divers wearing wetsuits, normalised for bottom times of long, relatively shallow (47 minutes at 18 msw) and short, relatively deep dive profiles (20 minutes at 30 msw). These measurements were conducted in water $\sim 4.0^{\circ}\text{C}$ colder than in the current study and resulted in core temperature changes of -0.9 (0.5) $^{\circ}\text{C}$.¹² This change in core temperature was more than twice that of the -0.4 (0.6) $^{\circ}\text{C}$ recorded in the wetsuit group in the current study, emphasising the significant influence of water temperature on core temperature maintenance. Measures of thermal sensation were not made in the previous study and were only assessed in the current study at $\sim 22.6^{\circ}\text{C}$ water temperature. However, we did not detect any differences in thermal sensation between wetsuits and semi-drysuits, aligning with the lack of differences in core temperature measurements. These findings indicate that any differences in skin and core temperature changes between wetsuits and semi-drysuit users were insufficient to be perceived as thermally different. Thus, the perceived and/or actual benefits of semi-drysuits over wetsuits might only emerge in colder water temperatures, which have not yet been studied.

The degree to which shivering, non-shivering thermogenesis, or physical activity contributed to maintaining core temperature is unclear. Earlier work in $\sim 17.5^{\circ}\text{C}$ water temperature found no difference in fibroblast growth factor

Figure 2

Linear regressions between the change in core temperature per minute of dive time ($\Delta T_c \cdot \text{min}^{-1}$) and the anthropometric factors body fat % (A+B), body mass (BM, kg; C+D), body mass index (BMI, $\text{kg} \cdot \text{m}^{-2}$; E+F), and body surface area divided by BM (BSA/BM; G+H) multiplied by total suit thickness (mm) (ST). Males: diamonds. Females: circles. a.u. – arbitrary units



21 as an indicator for non-shivering thermogenesis, although studies in 13.5°C water did report differences,^{21–23} again demonstrating the importance of water temperature in regulating the physiological responses during the dive. It can be assumed that shivering and non-shivering thermogenesis did not play a dominant role in the current study's ~22.6°C water temperature.

Thicker wetsuits, a higher body weight, a higher body mass index, or a lower body surface area to body mass ratio led to a reduced change in core temperature in previous work conducted in ~17–18°C water temperature,¹² suggesting that participants with these anthropometrics might be able to choose a thinner suit for dives in these water temperatures. This could not be replicated by the current findings in ~22.6°C water, with no associations between suit type,

suit thickness, and core temperature change. Correlations between anthropometric factors and core temperature change emerged only for the percentage of body fat in semi-dry suit dives and remained non-significant when normalising body fat percentage for suit thickness (see Figure 2). While these data suggest that the suit types were adequately chosen for that water temperature and personal perception, the negative correlation of body fat% with the rate of temperature change in the semi-dry suits is counterintuitive, as the body fat should theoretically provide additional thermal insulation. When considering the previous study in 17–18°C water and the current study in ~22.6°C water, these two studies suggest that the significant effect of anthropometrics and wetsuit thickness might depend on water temperature. Specifically, at warmer water temperatures, a suit thickness range of 5–8 mm may be sufficient for maintaining core temperature

without considering anthropometrics. Conversely, at lower temperatures, a suit thickness range of 5–8 mm may be insufficient for maintaining core temperature without considering anthropometrics. The temperature threshold where this occurs has not yet been determined. In the current study, it can only be speculated that semi-drysuits might have presented a less ideal fit for individuals with a high body fat percentage, as that was negatively correlated to temperature loss. Commercially available suits are designed for males and females in different sizes, but few are individually tailored to account for individual anthropometrics, which might be addressed in the future by recent advances, such as 3D scanning.²⁴ Therefore, it must be noted that the range in suit thickness and suit fit offered by the manufacturer's rental equipment might not provide the ideal choice for everyone for a given set of environmental conditions. It should also be acknowledged that suit selection in practice involves an individual component: cold tolerance, prior thermal experience, and subjective comfort vary between divers, and no anthropometric formula will fully replace personal experience in choosing a suit. The approach taken here is therefore intended to complement, rather than substitute for, individual judgement, by identifying conditions under which anthropometric and suit characteristics meaningfully predict thermal responses and conditions under which they do not. Future studies should examine the effects of semi-drysuits on core temperature and thermal perception in colder water temperatures than those used for the current study.

LIMITATIONS

Several limitations should be acknowledged. The study did not employ a crossover design, limiting within-subject comparisons between suit types. The sample size was small relative to the number of influencing variables, reducing statistical power and limiting the ability to resolve interindividual variability. Thermal stress was modest, as dives were conducted in relatively warm water (22.6 °C) and exposure times were short, which may have limited the detection of differences in thermal strain between suit types. Dive profiles and underwater activity were not controlled, and depth varied between dives. As water depth influences neoprene compression, this likely introduced variability in suit insulation during exposure. The use of ancillary thermal protection (e.g., hoods and handwear) was not standardised and may have contributed additional variability in heat loss between participants. The insulation properties of individual suits were not quantified. Suit age, prior usage history, material degradation, and individual fit were not systematically controlled and likely influenced thermal insulation. These factors represent important, unmeasured sources of variability. Core temperature was assessed using an ingestible thermal sensor, which is subject to variability related to gastrointestinal transit. Body surface area and body fat percentage were estimated rather than directly measured, introducing additional uncertainty in the assessment of anthropometric influences on thermal responses.

Conclusions

We found that wetsuits and semi-drysuits between 5–8 mm thickness both provided sufficient thermal protection for male and female scuba divers in ~22.6°C water temperature performing recreational dives. Within these specific conditions, sex assigned at birth and individual anthropometrics when normalised for suit thickness were not associated with temperature loss or thermal sensation. Additional studies are needed in male and female scuba divers wearing different suit types across a wider range of water temperatures to determine the temperature and suit thickness thresholds for considering anthropometrics for the maintenance of core temperature.

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