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The elderly's physiological and perceptual responses to cooling during simulated activities of daily living in UK summer climatic conditions --Manuscript Draft--

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Abstract:	<p>Objectives: The elderly are the most at risk population for heat-related illness and mortality during periods of hot weather. However, evidence based elderly specific cooling strategies to prevent heat-illness are limited. The aim of this investigation was to quantify the elderly's physiological and perceptual responses to cooling through; cold water ingestion (COLD) or an L-menthol mouth rinse (MENT) during simulated activities of daily living in UK summer climatic conditions. Study Design: Randomised, controlled repeated measures research design. Methods: Ten participants (men n = 7, women n = 3: age; 69 ± 3 yrs, height; 168 ± 10 cm, body mass; 68.88 ± 13.72 kg) completed one preliminary and three experimental trials; control (CON), COLD and MENT. Experimental trials consisted of 40 min rest followed by 30 min of cycling exercise at 6 METs and a six-minute walk test (6MWT), within a 35°C, 50% RH environment. Experimental interventions (every 10 min); cold water (4°C) ingestion (total of 1.5L) or menthol (5 ml mouth swill for 5 s, menthol concentration of 0.01%). Results: Peak rectal temperature (Tre) was significantly ($p < 0.05$) lower in COLD compared to CON ($-0.34 \pm 0.16^{\circ}\text{C}$) and MENT ($-0.36 \pm 0.20^{\circ}\text{C}$). End exercise heart rate (HR) decreased in COLD compared to CON (-7 ± 9 b.min⁻¹) and MENT (-6 ± 7 b.min⁻¹). There was no difference in end exercise thermal sensation (TS) (CON; 6.1 ± 0.4, COLD; 6.0 ± 0.4, MENT; 6.4 ± 0.6) or thermal comfort (TC) (CON; 4 ± 1, COLD; 4 ± 1, MENT; 4 ± 1) between trials. The participants walked significantly further during the COLD 6MWT compared to CON ($40 \text{ m} \pm 40 \text{ m}$) and MENT ($40 \text{ m} \pm 30 \text{ m}$). There was reduced physiological strain in the COLD 6MWT compared to CON (Tre; $-0.21 \pm 0.24^{\circ}\text{C}$, HR; -7 ± 8 b.min⁻¹) and MENT (Tre; $-0.23 \pm 0.24^{\circ}\text{C}$, HR; -4 ± 7 b.min⁻¹). Conclusion: The elderly have reduced physiological strain (Tre and HR) during activities of daily living and a 6MWT in hot UK climatic conditions, when they drink cold water. Furthermore, the elderly's perception (TS and TC) of the hot environment did not differ from CON at the end of exercise with COLD or MENT interventions. Menthol provided no perceptual benefit to exercise in the heat, and provided no functional gain. The thermal sensation data indicate that elderly may be at increased risk of heat illness, due to not feeling hot and uncomfortable enough to implement physiological strain reducing strategies such as cold-water ingestion.</p>

Title:

The elderly's physiological and perceptual responses to cooling during simulated activities of daily living in UK summer climatic conditions

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Dear Editor-in-Chief,

Thank you for considering our manuscript for publication. Please find attached our revised manuscript entitled 'The elderly's physiological and perceptual responses to cooling during simulated activities of daily living in UK summer climatic conditions', which we believe meets all of the peer reviewers' comments. I can confirm these data are not under consideration elsewhere, and all authors have made substantial contributions to various elements of the study including addressing the reviewers comments and approve this submission.

Our previous research (1), published within the special edition of the Public Health Journal- 'heat related harm', was the first study to utilise metabolic equivalents (METs) as an estimation of activities of daily living of elderly people to observe their physiological and perceptual responses to UK summer environments. Our current study builds on the findings from our previous research and investigated practical cooling for the elderly population when completing activities of daily living during a simulated hot UK summer environment. It is essential that strategies focus on the elderly population as they have attenuated physiological ability to dissipate heat (2) and that this places them at greater risk of heat illness compared to younger adults when metabolic heat production exceeds 400W for older men and 325W for older women (3). Previous heat related harm research with elderly individuals focused on the use of fans (4-5). However, little research has look at other practical cooling strategies such as; drinking cold-water.

Therefore, in brief, our research adds to the body of knowledge by observing the novel finding that elderly people (>65yrs) completing exercise that equates to activities of daily living, reduce their physiological strain (*i.e* peak rectal temperature and heart rate) when drinking cold-water (4°C) periodically (every 10 min) during rest and exercise equating to activities of daily living. Furthermore, there were no changes in perception or functional gains when participants swilled menthol, a perceptual cooling substance in the young, periodically (every 10 min) through rest and exercise. The elderly also covered a greater distance in the cold-water ingestion trial compared to control and menthol trials.

With previous literature published in the Public Health Journal investigating elderly (1) and environmental health (6), we believe our research study will add to the existing knowledge base of the journal and the sophistication of the experimental design, coinciding with the investigation of elderly aged over 65, that this experiment is novel and appropriate for submission.

Thank you for considering our manuscript for publication in the Public Health Journal. If there is any further information you may require, please do not hesitate to contact me.

Yours faithfully,

Kirsty Waldock
PhD, MA, BSc (Hons.)

1. Waldock KAM, Hayes M, Watt PW, Maxwell NS. Physiological and perceptual responses in the elderly to simulated daily living activities in UK summer climatic conditions. *Public Health*. **2018**;161: 163-70 <https://doi.org/10.1016/j.puhe.2018.04.012>
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6. McMichael AJ, Butler CD, Dixon J. Climate change, food systems and population health risks in their eco-social context. *Public health*, **2015**; 129:1361-68.

Highlights:

- Cold water ingestion significantly reduces physiological strain of the elderly when active in hot conditions
- Perceptual cooling was ineffective in the elderly
- Practical cooling could prevent or reduce heat illness in the elderly

Response to Reviewers

Reviewer #1: First of all, congratulations to the authors for the work done. However, I have some suggestions for improvement for you:

Thank you for your comments, please see below the way in which we have addressed them.

The last sentence of the abstract should be eliminated or qualified because the level of available evidence does not allow to affirm it with such forcefulness.

Thank you for your comment, the last sentence has been deleted from the abstract and the conclusion, accepting that it goes beyond the scope of the study, even if the evidence suggests this maybe the case. Page 1 Line 36-28.

Line 1: I think instead of; should put:

Thank you, this has been changed from a semi-colon to a colon. Page 1 Line 2.

In Discussion, repeat the results obtained, you can mention or reference indirectly but do not repeat data already exposed in the previous section (which is where they should be reflected).

Thank you for the comment, repetition of results has been removed from the document.

There are bibliographic references with inadequate format in the text. It must be corrected.

Thank you for highlighting the mistake. The document has been checked throughout to ensure the reference format is now correct.

The Ethical approval must include the alphanumeric code of your file.

The Ethical approval number has now been added to the document. Page 4 Line 24.

The titles of the tables should indicate in parentheses that the "information provided is mean $\pm$ standard deviation".

The parentheses have been added to all the tables.

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Reviewer #2: Thank you for the opportunity to review this manuscript, I'd like to commend you on a well-conducted study, and recommend only the minor revisions below.

Thank you for your comments, please see below the way in which we have addressed them.

Please double check semi-colon use throughout - whilst you consistently use it to introduce lists, a colon would be more appropriate, but is not necessarily warranted due to the simplicity of the lists used. Please amend.

Thank you we have gone through the document and amended where necessary.

Page 3 Lines 16 - 40: Here you introduce menthol, and do so largely effectively but you conflate the effects of menthol swilling and topical application of menthol. Whilst all of what is written is correct, it is effectively out of context as you have only explored oral application of menthol. Please consider amending this section to reflect this. The review by Stevens & Best (2017) clarifies these distinctions, as does the recent consensus statement by Barwood et

al., (2020). These papers do not necessarily need to be cited here, but may provide a framework for this important distinction.

Similarly, I recommend here and subsequently considering the work of Frasnelli on trigeminal sensitivity and how this declines with age. Given menthol's role as a trigeminal afferent, this is a potential explanation for the lack of effect seen in your elderly population, compared to the younger athletes of Stevens and Flood. You may need to amend your statement regarding age and menthol on line 46 following this.

Thank you for the advice, we have made it clearer that the section discuss both the effects of oral and topical applications of L-menthol and have added the Barwood 2020 reference (page 3 lines 13 and 20). We have also considered the research by Frasnelli and added their findings to the introduction and discussion to strengthen the interpretation of the data in the manuscript. Page 4 Lines 2– 5 and Page 13 Lines 2-6.

Page 4 Line 42 - is reference 31 necessary here

The reference was used to highlight that previous research with the elderly population had used the same preparation to similar experimental testing. Now on Page 4 Line 26.

Page 6 Line 58 - you show a large effect of time for skin temperature here, but your p-value is not significant. This is not subsequently explored, most likely due to the p-value, but given the magnitude of the effect here, some explanation in the discussion is warranted, especially as this is one of your largest effects.

You are correct the reason we did not originally explore the large effect was due to the p-value. Greater exploration is now in the discussion. Page 11 Line 14.

In your discussion, the difference in the length of cooling exposure between treatments is not discussed. Is it not possible that as participants had longer to drink the cold drink, in comparison to the menthol solution, that a greater number of receptors were stimulated and for a longer duration? I believe this is something that Eccles discusses in his 2000 and 2003 brief reviews, and is also a consideration when applying other tastants that elicit thermal/physiological responses, as discussed by Pickering (2019) with regards to Caffeine, and across a range of tastes in Best et al., (2020). When coupled with the decreased trigeminal sensitivity in the elderly, the nature/duration of the COLD intervention seems a valid explanation for the magnitude of the effects seen.

Thank you for comment, we have now placed length of cooling exposure as a future consideration with a possible explanation for why. Page 16 Lines 9-18.

Page 10 Line 50 - please check reference format here

Thank you for highlighting the mistake. The document has been checked throughout to ensure the reference format is now correct.

Page 12 Lines 22 - 33 - this is a strong opening paragraph to perceptual responses, however it would benefit from some references to support points outlined.

References have been added to the paragraph to provide evidence to support the statement. Now on Page 12 line 18 and 21.

Page 13 - please amend drank to drunk, as this is the correct conjugation for the future perfect tense.

Thank you for highlighting, we used drank, twice and have changed both to drunk. Page 5 Line 20 and Page 13 Line 22.

Page 14 Line 13/14 - I'm curious, what's the possible explanation for the lower rectal temperature in menthol? This is also shown in Figure 1 around baseline. It's fine if there isn't one, but it does appear odd that you have a statistically significant difference in rectal temperature with no-known cause.

We agree with you that it is curious as to why the menthol group had a lower core temperature. I unfortunately do not have an explanation for this, as we conducted the trials in a random order at the same time of day and asked participants to prepare in the same way for each trial to minimise variation in baseline core temperature.

Page 14 Line 59 - it may be worth rephrasing the comment regarding practical applications to either practical relevance or ecological validity.

Thank you for the suggestion, it has been amended to, practical relevance. Page 15 Line 5.

Thanks for some really clear figures and tables; Figure 3 may benefit from jittering points, this can be done using tools provided in the following reference: Weissgerber, T. L., Milic, N. M., Winham, S. J., & Garovic, V. D. (2015). Beyond bar and line graphs: time for a new data presentation paradigm. PLoS Biol, 13(4), e1002128.

Thank you for the very helpful suggestion, please see amended figure 3.

I hope the above makes sense, again, I really enjoyed the manuscript and feel that it is an exciting first step into exploring some of these concepts in the elderly in an applied manner. I look forward to reviewing a revised version, and reading more, similar work in the future.

Abstract

Objectives: The elderly are the most at risk population for heat-related illness and mortality during periods of hot weather. However, evidence based elderly specific cooling strategies to prevent heat-illness are limited. The aim of this investigation was to quantify the elderly's physiological and perceptual responses to cooling through; cold water ingestion (COLD) or an L-menthol mouth rinse (MENT) during simulated activities of daily living in UK summer climatic conditions.

Study Design: Randomised, controlled repeated measures research design.

Methods: Ten participants (men $n = 7$, women $n = 3$; age; 69 ± 3 yrs, height; 168 ± 10 cm, body mass; 68.88 ± 13.72 kg) completed one preliminary and three experimental trials; control (CON), COLD and MENT. Experimental trials consisted of 40 min rest followed by 30 min of cycling exercise at 6 METs and a six-minute walk test (6MWT), within a 35°C , 50% RH environment. Experimental interventions (every 10 min); cold water (4°C) ingestion (total of 1.5L) or menthol (5 ml mouth swill for 5 s, menthol concentration of 0.01%).

Results: Peak rectal temperature (T_{re}) was significantly ($p < 0.05$) lower in COLD compared to CON ($-0.34 \pm 0.16^{\circ}\text{C}$) and MENT ($-0.36 \pm 0.20^{\circ}\text{C}$). End exercise heart rate (HR) decreased in COLD compared to CON ($-7 \pm 9 \text{ b.min}^{-1}$) and MENT ($-6 \pm 7 \text{ b.min}^{-1}$). There was no difference in end exercise thermal sensation (TS) (CON; 6.1 ± 0.4 , COLD; 6.0 ± 0.4 , MENT; 6.4 ± 0.6) or thermal comfort (TC) (CON; 4 ± 1 , COLD; 4 ± 1 , MENT; 4 ± 1) between trials. The participants walked significantly further during the COLD 6MWT compared to CON ($40 \text{ m} \pm 40 \text{ m}$) and MENT ($40 \text{ m} \pm 30 \text{ m}$). There was reduced physiological strain in the COLD 6MWT compared to CON (T_{re} ; $-0.21 \pm 0.24^{\circ}\text{C}$, HR; $-7 \pm 8 \text{ b.min}^{-1}$) and MENT (T_{re} ; $-0.23 \pm 0.24^{\circ}\text{C}$, HR; $-4 \pm 7 \text{ b.min}^{-1}$).

Conclusion: The elderly have reduced physiological strain (T_{re} and HR) during activities of daily living and a 6MWT in hot UK climatic conditions, when they drink cold water. Furthermore, the elderly's perception (TS and TC) of the hot environment did not differ from CON at the end of exercise with COLD or MENT interventions. Menthol provided no perceptual benefit to exercise in the heat, and provided no functional gain. The thermal sensation data indicate that elderly may be at increased risk of heat illness, due to not feeling hot and uncomfortable enough to implement physiological strain reducing strategies such as cold-water ingestion. ~~Therefore, education of when to implement heat illness prevention strategies without perceptual cues is warranted for the elderly population.~~

Key Words: Heat Illness; Cooling; Menthol; Older; Exercise; Climate Change

1 Introduction

2 The elderly are the population most likely to suffer from heat exhaustion, heat stroke
3 and mortality, during periods of hot weather.¹⁻⁴ Indeed, over 65's represent the largest
4 proportion of GP and hospital visits for heat-related illnesses and deaths during
5 heatwaves.^{1,2} These numbers are expected to continue to increase over the next
6 century, most likely due to a growing elderly population and an increasingly warmer
7 climate.^{5,6} Public Health England (PHE) advice, states that for the elderly to avoid
8 severe heat illness they should minimise their exposure to the hot environment and
9 reduce their level of activity.⁷ However, retaining the ability to complete activities of
10 daily living is pivotal for physical and mental well-being.^{8,9} Therefore, there is a need
11 for strategies that prevent minor and severe heat-related illnesses whilst completing
12 activities of daily living in the elderly.^{9,10}

14 The risk of severe heat illness is reduced in young populations through implementing
15 acute and chronic heat-alleviating strategies,¹¹⁻¹⁴ however, there is little evidence of
16 the effectiveness of these strategies in the elderly population. With regard to acute
17 heat-alleviation, research with a focus on the elderly is limited to the effects of electrical
18 fans¹⁵⁻¹⁷ which is surprising given the plethora of research on acute practical cooling
19 strategies to reduce physiological strain within athletic and occupational
20 populations.^{14, 18-20} Consequently, it has yet to be determined whether the benefits of
21 acute practical cooling strategies in young healthy populations can be replicated in an
22 elderly population and attenuate the risk of heat-related illness.

24 Prevention of heat illness in the elderly requires an intervention with cooling modalities
25 pre or during (*i.e.*, per-cooling) activity, in line with existing research conducted with
26 younger population.^{12,14} External, internal and mixed methods cooling have been used
27 to reduce physiological strain and improve performance, both as a method of pre and
28 per-cooling.^{18,19} Internal cooling presents a practical acute cooling strategy for the
29 elderly and includes ice slurry and cold fluid ingestion.¹⁴ Although ice slurry research
30 has provided evidence of reductions in physiological strain, there are reports of ice
31 slurry leading to gastrointestinal distress in participants.^{20,21} Conversely, cold fluid
32 ingestion has minimal gastrointestinal discomfort and may be more practically
33 available. Mündel and colleagues²² found that refrigerated water (4°C) reduced end
34 exercise rectal temperature (T_{re}) by -0.25°C and lowered heart rate (HR) by 5 b.min⁻¹,

1 compared to control (water 19°C). Likewise, Lee and colleagues¹¹ found that water
2 (4°C) given periodically during rest and exercise (every 10 min), reduced end rest T_{re}
3 ($-0.5 \pm 0.1^\circ\text{C}$) and HR ($-8 \text{ b}\cdot\text{min}^{-1}$) compared to control (water 37°C). Furthermore, T_{re}
4 was significantly lower in the cold-water trial compared to control from 10 min into rest
5 until 45 min into exercise and HR was reduced from 25 min into rest until 35 min into
6 exercise. Consequently, cold fluid ingestion could provide the most practical and
7 comfortable intervention to attenuate the rise in markers of heat illness in the elderly.

8
9 In addition to the implementation of acute physical cooling strategies to improve
10 performance, strategies to influence behavioural thermoregulation have been
11 investigated. Behavioural thermoregulation elicits conscious behaviours, such as a
12 reduction in work rate leading to a decrease in heat production and performance.²³
13 The application of L-menthol (MENT), as a mouth swill or as a topical application (e.g.
14 cream, gels or sprays),²⁴ elicits a cooling sensation, which in hot environments, is
15 interpreted as a greater feeling of comfort, leading to improvements in athletic
16 performance of between 3-9%.^{21,25} However, due to L-menthol being a perceptual
17 cooling method, core temperature, a marker of heat illness, can be elevated in
18 comparison to control groups.^{26,27} Schlader and colleagues²⁸ demonstrates the
19 behavioural change by a significant increase in absolute work done and an increase,
20 albeit not significant, change in exercise core temperature in a topical menthol
21 application group compared to control (CON) trials, during cycling exercise with an
22 RPE clamp of 16: CON; $187.4 \pm 16.7 \text{ kJ}$ and $0.74 \pm 0.06^\circ\text{C}$, MENT; $228.7 \pm 23.7 \text{ kJ}$
23 and $0.97 \pm 0.13^\circ\text{C}$.

24
25 L-menthol is within some commercially available cooling products.²⁴ However, to the
26 researcher's knowledge there is no research investigating the effects of L-menthol on
27 function or heat perception in an elderly population. L-menthol may worsen
28 behavioural thermoregulation in an elderly population, by effecting thermoregulatory
29 behaviours such as; seeking shade, taking extra layers of clothing off and opening
30 windows.²⁹ These thermoregulatory behaviours attenuate heat illness risk, therefore if
31 the elderly do not feel uncomfortable enough to implement them, they are unknowingly
32 putting themselves at greater risk of heat illness. Our previous research suggested
33 that the elderly have a reduced perceptual awareness of increasing environmental
34 temperature.³⁰ The use of L-menthol could exacerbate this reduced awareness further

by eliciting a cooling sensation that makes the elderly feel greater comfort in hot environments. Alternatively, L-menthol may have no effect on the thermal sensation, as Frasnelli and colleagues³¹ found an age-related decline in trigeminal sensitivity to L-menthol, therefore the MENT swill may not trigger a response from the transient receptor potential melastatin 8 (TRPM-8) that is required to elicit a cooling sensation.

Currently there is limited research-informed advice on how the elderly should cope during periods of hot weather. Therefore, a research-informed acute intervention that is practical, easy to implement and reduces physiological strain could reduce heat illness risk in the population that is at most risk of heat-related mortality. Furthermore, research-informed evidence of the physiological and perceptual implications of L-menthol use within an elderly population is required to support or refute its use during periods of hot weather. This investigation aimed to assess the elderly's physiological and perceptual responses to cooling through cold water ingestion (COLD) and L-menthol mouth rinse (MENT) during simulated activities of daily living in UK summer climatic conditions. It was hypothesized₁ that COLD would reduce physiological strain in comparison to CON and MENT interventions. Secondly, that MENT would have a perceptual cooling effect compared to CON, whilst having no effect on reducing physiological strain.

Methods

Ten (seven males and three females) habitually active participants (mean $\pm$ SD₂ age 69 ± 3 yrs, height 168 ± 10 cm, body mass 68.88 ± 13.72 kg) volunteered and provided written informed consent for the study. The experimental protocol was approved by the University's ethics committee (approval number: SSCREC17-30) and conducted in accordance with the principles of the revised Declaration of Helsinki.³²

Participants abstained from₃ alcohol (24 h), caffeine (12 h) and strenuous exercise (24 h)₄ prior to testing.³³ Participants arrived euhydrated, confirmed with a pre-experimental urine sample assessed for hydration status.

Preliminary trial

During preliminary testing, hydration, anthropometric, and baseline measures were collected, followed by a graded exercise test (GXT) and a familiarisation of the six-

minute walk test (6MWT) in an environmental chamber set to 35°C 50% relative humidity (RH). Detailed methods of the GXT are in Waddock and colleagues³⁰ but in brief, respiratory gas was collected at rest and at the end of each incremental stage (25W) to calculate individual resting 1 metabolic equivalent (MET) values and exercise intensities equating to 6 METs and 3.5W.kg⁻¹ metabolic heat production ($\dot{H}_{\text{prod}}$) to be used in the experimental trials.³⁰ The 6MWT was used as a test of functional capacity, with the aim to walk as far as possible in 6 minutes on a hard, flat surface without running or jogging.³⁴ The 6MWTs were completed on a treadmill (Woodway Pro, Germany) within experimental conditions. The coefficient of variation with an initial familiarisation and completed with an elderly population is 3.3%.³⁴

Experimental trials

Experimental trials (CON, COLD, MENT) were completed in a randomised order in 35°C, 50% (RH) and separated by at least seven days for participant recovery. Participants completed the simulated activities of daily living protocol, 40 min rest and 30 min recumbent cycling at 6 METs/ 3.5W.kg⁻¹ $\dot{H}_{\text{prod}}$, followed by the 6MWT. Skin temperature (T_{sk}), HR and T_{re} were recorded every 5 min and thermal sensation (TS)³⁵, thermal comfort (TC)³⁶, thirst sensation (ThS)³⁷ and rating of perceived exertion (RPE)³⁸ were recorded every 10 min. Whole body sweat rate (WBSR) was estimated from a pre and post nude body mass measurement.

During the COLD intervention participants drank 300 ml of water (4°C), every 10 min during rest (total of 1.2 L) and 100 ml of water (4°C), every 10 min, during exercise (total 300 ml)¹¹. Participants were given 2 min to drink each water intervention during rest and 1 min during exercise. The water temperature was checked prior to testing and consumption, using a thermometer (Fisher Scientific, Fisherbrand, red spirit filled partial immersion, UK). The MENT intervention was a 5 s, 25 µl L-menthol solution (0.01% concentration) mouth swill (every 10 min), expectorated into a bucket.³⁹ CON did not consume any fluids throughout the trial.

Statistical analyses

All data are presented as mean ± SD and were assessed for normality and sphericity prior to statistical analyses. When the assumption of sphericity was violated the Greenhouse-Geisser adjustment was used. One-way ANOVAs for baseline and peak

measurement comparison were completed when data was parametric (physiological variables) and Friedman's test when data was non-parametric (perceptual variables). Two-way repeated measures ANOVAs (time*intervention) were used to analyse time effects between interventions. Follow up Bonferroni-corrected post-hoc comparisons were completed if interaction and main effects were observed in parametric data and Wilcoxon signed rank test when data was non-parametric. Effect sizes were estimated using η_p^2 within statistical ANOVA analysis, to analyse the magnitude and trends of the intervention.⁴⁰ Effect sizes for t-tests and Wilcoxon ranked test were categorised as: small 0.2, moderate 0.5 and large 0.8 and are presented as d and r .⁴¹ Data were analysed using SPSS (version 22.0) with significance set at $p < 0.05$.

Results

Baseline measures and exercise intensity

Environmental conditions were not different ($p > 0.05$) between interventions for temperature, RH and WBGT. By research design there were no differences in the exercise intensity completed for METs and $\dot{V}_{\text{prod}}$. Likewise, there were no differences in physiological and perceptual measurements at baseline between interventions for HR, T_{re} , T_{sk} , RPE, TS, TC and ThS.

Physiological responses

There was a significant interaction between time and intervention for T_{re} ($p < 0.001$, $\eta_p^2 = 0.68$) (Fig 1, **panel A**). Likewise, there were significant interaction effect for the change in T_{re} (ΔT_{re}) and peak T_{re} from baseline to the end exercise ($p < 0.001$, $\eta_p^2 = 0.74$ and $p < 0.001$, $\eta_p^2 = 0.74$) (Table 1) with a decrease in T_{re} when drinking cold water from 20 min into rest until the end of exercise.

Insert figure 1 here

Similarly, there was a significant interaction between time and intervention for HR ($p < 0.001$, $\eta_p^2 = 0.34$) (Fig 2). Likewise, peak HR had a main effect of intervention ($p = 0.02$, $\eta_p^2 = 0.37$). However, pairwise comparison did not identify a significant reduction in HR in COLD compared to CON and MENT (Table 1).

Insert figure 2 here

1 Skin temperature was not different between interventions, across time ($p = 0.54$, $\eta_p^2 =$
2 0.85), or at peak ($p = 0.36$, $\eta_p^2 = 0.11$) (Table 1). However, due to the decrease in
3 peak T_{re} in the COLD intervention there was a significant main effect of peak core-to-
4 skin gradient between interventions ($p = 0.01$, $\eta_p^2 = 0.41$). Peak core-to-skin gradient
5 was significantly decreased in the COLD ($1.11 \pm 0.31^\circ\text{C}$) compared to the MENT (1.73
6 $\pm 0.47^\circ\text{C}$) trial, but not CON ($1.62 \pm 0.60^\circ\text{C}$) (Table 1).

8 There was a main effect of WBSR between trials ($p = 0.01$, $\eta_p^2 = 0.41$). Pairwise
9 comparison identified a significantly greater WBSR in the CON ($p = 0.02$, $d = 1.09$)
10 compared to COLD intervention, but no significant differences between COLD and
11 METH or CON and MENT (Table 1).

Insert table 1 here

13 *Perceptual responses*

14 There was no interaction for TS ($p = 0.21$, $\eta_p^2 = 0.14$) or TC ($p = 0.17$, $\eta_p^2 = 0.16$),
15 across time and intervention. However, there were main effects for intervention at the
16 end of rest for TS ($p = 0.01$) and TC ($p = 0.02$). Follow up Wilcoxon signed rank test
17 identified that TS was significantly lower at the end of rest in COLD compared to MENT
18 ($p = 0.01$, $r = -0.44$) and CON ($p = 0.05$, $r = 0.58$) (Fig. 3). Similarly, TC was significantly
19 lower at the end of rest in COLD compared to the MENT ($p = 0.02$, $r = -0.50$) but not
20 CON ($p = 0.059$, $r = 0.59$). There were no differences at the end of exercise for TS (p
21 $= 0.07$) or TC ($p = 0.26$) (Fig. 3). Therefore, participants at rest felt cooler and more
22 comfortable when drinking cold water compared to swilling menthol. Furthermore,
23 participants felt cooler at rest when drinking cold water compare to control.

Insert figure 3 here

26 There was an interaction for ThS ($p = 0.01$, $\eta_p^2 = 0.39$) across time and intervention.
27 Follow up analysis identified that participants felt significantly less thirsty in the COLD
28 trial compared to the CON trial throughout exercise and at the end of exercise
29 compared to the MENT (Table 2).

1 There was no significant interaction for RPE ($p = 0.78$, $\eta_p^2 = 0.04$) across time and
2 intervention. Likewise, there were no main effects of intervention at the end rest or
3 exercise for RPE (Table 2).

4
5 *Insert table 2 here*

Six-minute walking test (6MWT)

There were main effects for distance completed in the 6MWT ($p = 0.01$, $\eta_p^2 = 0.43$). Pairwise comparison identified a significantly greater distance covered in the COLD ($p = 0.01$, $d = 0.53$) compared to MENT intervention (+ 7.3 %), but no differences between COLD and CON (+ 6.2 %) or CON and MENT (+ 1.05 %) (Table 3). Likewise, there were main effects for intervention for pre 6MWT T_{re} ($p < 0.01$, $\eta_p^2 = 0.74$). Pairwise comparison identified a significantly lower pre 6MWT T_{re} in the COLD compared to MENT ($p = 0.001$, $d = 1.47$) and CON ($p < 0.001$, $d = 1.38$). Similarly, there were main effects for intervention for peak T_{re} in the 6MWT ($p = 0.04$, $\eta_p^2 = 0.30$). However, pairwise comparison identified no significant difference between interventions. Similarly, there were main effects for intervention for peak HR in the 6MWT ($p = 0.02$, $\eta_p^2 = 0.36$). Pairwise comparison identified a significantly reduced peak HR in the COLD ($p = 0.04$, $d = 0.38$) compared to CON intervention, but no significant differences between COLD and MENT or CON and MENT (Table 3). There were no significant main effects for peak perceptual variables in the 6MWT (Table 3).

Insert table 3 here

Discussion

This study investigated the effects of practical acute physical cooling, through cold water ingestion, and perceptual cooling, through L-menthol mouth rinse, on the elderly population while exercising in hot conditions. As hypothesised COLD reduced physiological strain, with significant reductions in peak T_{re} and ΔT_{re} and reductions in peak HR compared to CON and MENT. Furthermore, the COLD intervention significantly improved TS compared to CON and MENT and TC compared to MENT at the end of rest. Contrary to the second hypothesis, MENT had no effect on elderly people's thermal perception of the environment and was not different from CON during rest or exercise.

Physiological responses

This study demonstrated, that drinking 300 ml of 4°C water every 10 min during rest reduced T_{re} ~~by $-0.25 \pm 0.26^\circ\text{C}$ (Figure 1)~~. ~~This is less of a reduction reduction is less~~ than the $-0.5 \pm 0.1^\circ\text{C}$ reported in young adults (22 ± 4 yrs),¹¹ during the same rest period. However, in the current study the decrease was maintained throughout the trial and resulted in a lower peak T_{re} at end of the 6MWT compared to CON ($-0.21 \pm 0.24^\circ\text{C}$) and MENT ($-0.23 \pm 0.34^\circ\text{C}$) (Table 3). Similarly, Mündel and colleagues²² presented a -0.25°C difference in peak T_{re} in the cold water (4°C) compared to the CON trial, albeit in a young population (26 ± 7 yrs). The decrease in rectal temperature is attributed to the transfer of heat energy from the body to the cold water ingested.⁴¹ Heat energy transfers down a temperature gradient whereby, a high-temperature region increases the temperature of a cold-temperature region. Therefore, when internal body temperature is higher than fluid temperature, the body responds by heating the fluid via the temperature gradient created in the stomach.⁴¹ Consequently, the colder the fluid the greater the temperature gradient (*i.e.*, heat sink) created and the greater potential cooling effect the fluid can have on T_{re} .⁴¹ A high core temperature ($> 40^\circ\text{C}$) is a key contributor to the development of severe heat illness.⁴² Therefore, heat illness prevention strategies that reduce core temperature (*i.e.*, T_{re}) during rest and exercise, may prevent the onset of severe heat illness. Consequently, drinking cold water periodically has the potential to reduce thermal strain and prevent heat illness in an elderly population.

The study found that COLD reduced peak HR compared to CON ($-7 \pm 9 \text{ b.min}^{-1}$) and MENT ($-6 \pm 7 \text{ b.min}^{-1}$), albeit not significant reduction, it can be considered meaningful as it was a decrease above 5 b.min^{-1} . Similarly, Mündel and colleagues²² found a 5 b.min^{-1} reduction in peak HR compared to CON with younger adults ($26 \pm 7 \text{ yrs}$). Attenuating a progressive increase in HR is one of several cardiovascular related benefits from maintaining hydration including: preventing the decrease in plasma volume (PV), stroke volume (SV), cardiac output (Qc) and skin blood flow (SkBF).⁴³ After an initial decrease in PV at the onset of exercise, hydration that equates to fluid loss facilitates the maintenance of PV. Similarly, when euhydrated SV, Qc and SkBF are maintained, this allows for optimum thermoregulation.⁴³ Attenuating cardiovascular strain is essential, as an underlying cardiovascular deficiency is recorded as the primary cause of death in up to 94% excess mortality cases during periods of hot weather.⁴

There was a large effect of T_{sk} over-time, across all interventions, most likely due to increase in T_{sk} blood flow on the set of exercise, however it was not significant. Furthermore, peak T_{sk} ~~Skin temperature~~ was unchanged between interventions. This is of importance, as a rise in T_{sk} is an indicator of greater cutaneous vasodilation and blood flow to the skin, and thermoregulation depends on maintained SkBF as it facilitates sweat evaporation and increases heat loss via radiation.⁴⁵ The T_{sk} results are contrary to previous research with young adults where cold fluid ingestion reduced T_{sk} .¹¹ An age-related attenuation in cutaneous vasodilation may explain why there is no further decreases in elderly T_{sk} when drinking cold fluids. Jay & Morris⁴² found no difference in T_{sk} and SkBF between ice slurry ingestion and control trial in a young population and provide an alternative explanation. There may be thermoreceptors within the abdomen that independently effect thermoregulation, specifically heat loss via evaporation.⁴² Consequently, when cold fluids are ingested, T_{sk} and SkBF can be maintained compared to control trials, whilst there is a decrease in evaporative heat loss.

WBSR indicated a decrease in evaporative sweat loss in COLD compared to CON ($-0.33 \pm 0.28 \text{ L.h}^{-1}$) and MENT ($-0.18 \pm 0.24 \text{ L.h}^{-1}$) (Table 1). Jay & Morris⁴² explain that net heat loss is reduced when drinking ice slurry/cold drinks ($<10^{\circ}\text{C}$) under warm, dry and windy conditions, due to the heat loss gained from the cold fluid ingestion being

counter-balanced by the reduction in sweat production and evaporation. However, they further explain that net heat loss is dependent on the conditions and the population, for example athletes with an injury that decreases sweat output such as some spinal cord injuries and burn patients, may also have a net heat loss gained from cold fluid ingestion that outweighs the reduction in sweat evaporation. This theory was applied to the elderly population as they have a known reduced WBSR compared to younger individuals.^{4,46} Therefore, it was hypothesised that due to an already reduced WBSR, the effects of COLD would not further negatively affect WBSR and that cooling effect of the cold water ingestion would compensate for an age reduction in evaporative heat loss. Despite the negative consequence of COLD on WBSR, interventions that reduce physiological strain whilst preventing dehydration should be considered as a practical heat illness prevention strategy for the elderly.

Perceptual responses

Behavioural thermoregulation is the process of establishing the optimum conditions for heat exchange between the environment and the body, when a person feels hot they may remove excess clothing, seek a cooler environment or reduce activity levels.²⁹ Menthol can alter the perception of feeling hot and delay behavioural thermoregulatory responses, leading to improvements in athletic performance^{21,25,28} but could place vulnerable population, such as the elderly, at risk of heat illness via the delay in implementing behaviours that prevent the continual rise in core temperature.²⁸

L-menthol was administered as a mouth rinse as it is known to stimulate the greatest perceptual response in young people, when compared to topical applications which may also be a mild irritant when applied directly to the skin.⁴⁷ L-menthol elicits a cooling sensation by activating the TRPM-8 cold receptors and inhibits the calcium currents of neural membranes releasing a cooling sensation.^{21,27,47} Several studies have shown the perceptual benefits of L-menthol with athletes, with improvements in TS and RPE.^{26,48} This study found that L-menthol resulted in no improvements in TS, TC or RPE compared to CON at the end of rest or exercise in an elderly population. Furthermore, it was the COLD intervention that elicited a cooler sensation and the participants felt more comfortable compared to CON and MENT. This study provides

evidence that using L-menthol based cooling products may not elicit the proposed cooling sensation within the elderly. The lack of cooling sensation could be due to an age-related decrease in the sensitivity of the TRPM-8 in the oral cavity, similar to the age-related decrease in trigeminal sensitivity when exposed to L-menthol.³¹ This could explain why young populations experience a cooling sensation with L-menthol mouth swill and the elderly population in this study did not.

Additionally, participants only became slightly thirsty (3) in the control group. The elderly have an attenuated thirst response and reduced ability to maintain their fluid balance, due to reduced baroreceptor sensitivity to hypovolemia⁴⁹ and reduced renal function.⁵⁰ Consequently, the elderly may not feel the need to implement current hydration advice from PHE. The advice within '*Heatwave Plan for England*' and '*Beat the heat*' campaign states to provide regular cold drinks and monitor fluid intake, when caring for an elderly person, however, there is no guidance on temperature, volume or frequency of water or fluid intake.^{7,51} The combination of not feeling thirsty and unspecific advice from public health messages could be putting elderly people at unknowingly high risk of dehydration. Therefore, the '*Heatwave Plan for England*' would benefit from vulnerable population specific guidance in the form of: how much, when and at what temperature to drink fluids. This study can contribute to the elderly specific advice with evidence that suggests that drinking refrigerated water (4°C) periodically reduces thermoregulatory and cardiovascular strain during rest and exercise in the heat. More research is required into the volume of fluid to be drunk to reduce physiological strain during whole day and multiple day heat exposures with periods of rest and activity.

Six-minute walk test

The 6MWT is a validated, simple, safe and cost-effective measure of functional capacity in the elderly.³⁴ It assesses a person's capability of walking unaided, which is an essential activity for daily living and maintaining quality of life.³⁴ Findings suggest that when COLD is completed periodically during rest and cycling activity prior to the 6MWT, then performance, as defined by distance covered, was improved compared to CON and MENT (~~COLD; 610 ± 80 m, CON; 580 ± 90 m, MENT; 570 ± 80 m~~)(Table 3). Comparison with other studies is limited due to differences in pre 6MWT protocol,

exercise environment and treadmill vs. floor procedure. However, as an indication of the performance of other elderly people who are free from disease that would impact walking speed, Stotz and colleagues⁵² reported a median distance of 570 m covered when completing the 6WMT in a 30°C environment. Data from this study shows that the participants were able to cover a similar distance across all trials (Table 3). Furthermore, the distance covered was significantly further in COLD compared to MENT (+7.3 %) and higher in the CON trial (+6.2 %), which are both above the 3.3% CV previously reported for the 6MWT completed by the elderly.³⁴

Additionally, physiological strain, T_{re} and HR, were decreased in the COLD at the end of the 6MWT compared to CON (~~$-0.21 \pm 0.24^{\circ}\text{C}$ and $-7 \pm 8 \text{ b}\cdot\text{min}^{-1}$~~) and MENT (~~$-0.23 \pm 0.34^{\circ}\text{C}$ and $-4 \pm 7 \text{ b}\cdot\text{min}^{-1}$~~). HR was decreased in nine out of ten participants in the COLD trial compared to both CON and MENT, albeit the decrease was only significant between COLD and MENT. Similarly, T_{re} decreased in eight out of ten participants in the COLD trial compared to CON and six out of ten participants in the MENT.

The 6MWT results indicate that functional capacity, can be improved during 35°C, 50% RH when periodically drinking cold water (4°C). Additionally, even with the greater distance covered, the markers of heat illness and cardiovascular strain are reduced compared to MENT and CON.

Limitations and future considerations

This study is not without its limitations. By research design each trial had a different level of hydration. Maintaining hydration through fluid ingestion during exercise in healthy athletes has the physiological benefit of reducing the rise in T_{re} .⁴⁴ The rise in T_{re} is attenuated when fluid intake matches sweat rate.⁴⁴ Therefore, it could be argued that the decrease in peak T_{re} , reduction in the change T_{re} and reduced HR in the COLD trials are a result of hydration differences between the trials as opposed to a direct cooling effect of the water temperature. However, the lack of fluid replacement was intentional for the CON and MENT trials. It is well established that the elderly are at an increased risk of dehydration during periods of hot weather.⁵⁰ Findings from this study suggest that the elderly only became slightly thirsty in the CON trial during

exercise. Therefore, in a real-world scenario they are not likely to take on fluid replacement, especially as the current guideline is to drink to thirst.⁵¹ Also, it was not our intention to investigate equivalent hydration strategies, as drinking 37°C (often used as a control temperature to match body temperature and avoid a 'heat sink') water or fluids is not a normal fluid intake preference and therefore would not ~~be~~ have had practical relevance-applications. Lastly, the wetness of the mouth is considered an important aspect of the menthol intervention,²¹ therefore to control for this in the CON trial no fluid was given to participants. Consequently, the physiological differences between the trials may be partly attributed to the differences in hydration, however, this does not diminish the key physiological findings in the COLD trial, when the overarching aim is to provide strategies for the prevention of heat illness within the elderly population.

It could also be considered a limitation that the experimenter had control of the intervention and intensity of exercise. By controlling when the fluid was given to the participants and how hard they needed to work, the behavioural thermoregulation component of implementing a heat illness prevention strategy was omitted. Consequently, with participants only feeling slightly thirsty at the end of exercise in the CON group, elderly people may not implement a drinking-based heat illness prevention strategy. Therefore, with the understanding that COLD can reduce physiological strain in the elderly population, future research should investigate elderly people's behavioural thermoregulation by allowing them to drink cold water *ad libitum* during rest and exercise. Furthermore, with L-menthol having a known influence on work rate in younger populations, it is unknown how L-menthol would have impacted self-paced exercise and if it would have increased the risk of hyperthermia.

Thirdly, the results for this study suggest that L-menthol had no perceptual benefit on the elderly during rest or exercise. However, it could be considered a limitation that the elderly participants had a maximum change in T_{re} of 1.08°C and maximum thermal sensation score of 6.5 (between 'hot' and 'very hot') during the MENT and CON trial. Consequently, the thermal strain may not have been sufficient enough to elicit a change in thermal sensation with L-menthol. Stevens and colleagues²¹ found significant improvements in thermal sensation, using the same scale (CON: 7, MENT: 6.5,

values read off a figure), with L-menthol in young adults that had a change in T_{re} of 2-2.5°C. Similarly, Flood and colleagues⁴⁸ found significant improvements in thermal sensation when using L-menthol compared to control. The participants within the study had an average rectal temperature >38°C, T_{re} did not reach 38°C in the present study. Although, there may not have been sufficient thermal strain to elicit a cooling sensation effect with L-menthol in the elderly, the purpose of this study was to replicate activities of daily living, and by doing so the L-menthol had no effect on thermal sensation.

Future research should consider matching the length of cooling exposure. This study took guidance from the literature on the standard exposure times for L-menthol mouth swill³⁹ and appropriate consumption time of 300 ml and 100 ml of cold-water.¹¹ However, the significant time difference in intervention exposure may contribute to the differences in thermal sensation at the end of exercise between the COLD, CON and MENT interventions. This is because the COLD trial had longer to stimulate a greater number of receptors to elicit a cooling sensation in comparison to the MENT trial. Therefore, the length of intervention exposure time, in addition to a possible age-related decrease in the sensitivity of the TRPM-8 in the oral cavity, may explain the lack of cooling sensation in MENT trial.

The elderly population in this study and in future studies needs consideration. This research is most applicable to the active and healthy elderly population who are able to complete activities of daily living unassisted. Due to the novelty of this type of research in an elderly population it provides findings in which to build on to further help the most vulnerable elderly populations. Therefore, more acute heat illness prevention research is warranted with elderly people that are at even greater risk of heat illness (e.g., elderly people in care homes and those with cardiovascular issues). A future consideration for research using more vulnerable elderly people is the type of test used to assess functional capacity, a 6MWT could be inappropriate, however, a get up and go test where the participant could be aided through the movements could provide a suitable alternative.

Future research needs to also consider the duration of heat and exercise exposure. This study provides evidence for heat illness prevention during acute and intense heat and exercise exposure however, in reality, periods of hot weather could last several

1 days and weeks, leading to accumulation in heat storage and greater risk of heat
2 illness. Therefore, future research should consider longer heat exposure with elderly
3 participants and the implementation of cooling strategies.

4 **Conclusion**

5 It is essential that elderly maintain their ability to complete activities of daily living
6 during periods of hot weather for their mental and physical well-being whilst posing a
7 minimal risk of developing a heat-illness. This study provides evidence that drinking
8 refrigerated water (4°C) periodically reduces physiological strain (T_{re} and HR) in
9 elderly people completing activities of daily living in hot UK climatic conditions. The
10 study indicated no perceptual or functional benefits from MENT in an elderly
11 population. Furthermore, the elderly's end exercise perception (TS and TC) of the hot
12 environment did not differ between CON, COLD and MENT. Consequently, the elderly
13 could still be at risk of heat illness, because they do not feel hot and uncomfortable
14 enough to implement physiological strain reducing strategies such as cold-water
15 ingestion. ~~Therefore, education of when to implement these strategies without~~
16 ~~perceptual cues is warranted.~~

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Ethical approval

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Competing interests

There were no competing interests

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Table 1: Peak physiological variables for the interventions and the differences between interventions. The data is presented as mean ± standard deviation.

Physiological Variable	CON	COLD	MENT	Difference CON-MENT	Difference COLD-CON	Difference COLD-MENT
ΔT_{re} (°C)	0.53 ± 0.18*	0.15 ± 0.25 #†	0.68 ± 0.27	-0.16 ± 0.15	-0.38 ± 0.26	-0.53 ± 0.30
Peak T_{re} (°C)	37.66 ± 0.30	37.32 ± 0.67#†	37.68 ± 0.36	-0.02 ± 0.17	-0.34 ± 0.16	-0.36 ± 0.20
Peak HR (b.min ⁻¹)	112 ± 14	105 ± 15	111 ± 15	2 ± 6	-7 ± 9	-6 ± 7
Peak T_{sk} (°C)	36.04 ± 0.70	36.21 ± 0.30	35.99 ± 0.58	0.09 ± 0.63	0.17 ± 0.64	0.27 ± 0.46
Peak core-to-skin gradient (°C)	1.62 ± 0.60	1.11 ± 0.31§	1.73 ± 0.47	-0.11 ± 0.64	-0.51 ± 0.68	-0.62 ± 0.44
WBSR (L.h ⁻¹)	0.94 ± 0.26	0.62 ± 0.26#	0.80 ± 0.24	0.15 ± 0.36	-0.33 ± 0.28	-0.18 ± 0.24

Abbreviations: CON; control, COLD; cold water ingestion, MENT; L-menthol mouth rinse; Δ; change, Tre; rectal temperature, HR; heart rate, Tsk; skin temperature, WBSR; whole body sweat rate. * denotes a significant (p < 0.05) difference between CON and MENT. # denotes a significant (p < 0.05) difference between COLD and CON. † denotes a significant (p < 0.05) difference between COLD and MENT.

Table 2: End rest and exercise for the perceptual variables. The data is presented as mean ± standard deviation.

Perceptual Variable	CON	COLD	MENT
End rest ThS	2 ± 1	1 ± 0	1 ± 1
End exercise ThS	3 ± 2	1 ± 0#†	2 ± 1
End rest RPE	6 ± 1	6 ± 0	6 ± 0
End exercise RPE	13 ± 3	13 ± 2	13 ± 2

Abbreviations: CON; control, COLD; cold water ingestion, MENT; L-menthol mouth rinse, ThS; thirst sensation, RPE; rating of perceived exertion. # denotes a significant ($p < 0.05$) difference between COLD and CON. † denotes a significant ($p < 0.05$) difference between COLD and MENT.

Table 3: Performance, physiological and perceptual variables during the 6MWT. The data is presented as mean ± standard deviation.

6MWT variables	CON	COLD	MENT	Difference CON-MENT	Difference COLD-CON	Difference COLD-MENT
Distance (m)	580 ± 90	610 ± 80§	570 ± 80	10 ± 40	40 ± 40	40 ± 30
Pre 6MWT T _{re} (°C)	37.66 ± 0.30	37.32 ± 0.24#†	37.68 ± 0.36	-0.02 ± 0.17	-0.34 ± 0.16	-0.36 ± 0.20
Peak T _{re} (°C)	37.87 ± 0.36	37.56 ± 0.29	37.88 ± 0.42	-0.02 ± 0.26	-0.21 ± 0.24	-0.23 ± 0.34
Peak HR (b.min ⁻¹)	129 ± 21	121 ± 21#	126 ± 21	3 ± 8	-7 ± 8	-4 ± 7
Peak TS	6.4 ± 0.7	6.2 ± 0.8	6.3 ± 0.6	0.1 ± 0.6	-0.2 ± 0.7	-0.1 ± 0.7
Peak TC	4 ± 1	4 ± 1	4 ± 1	0 ± 1	0 ± 1	0 ± 1
Peak RPE	14 ± 2	14 ± 2	14 ± 2	1 ± 1	0 ± 2	1 ± 2

Abbreviations: 6MWT; six-minute walk test, CON; control, COLD; cold water ingestion, MENT; L-menthol mouth rinse, T_{re}; rectal temperature, HR; heart rate, TS; thermal sensation, TC; thermal comfort, RPE; rating of perceived exertion. # denotes a significant (*p* < 0.05) difference between COLD and CON. † denotes a significant (*p* < 0.05) difference between COLD and MENT.

Figure 1: The mean $\pm$ standard deviation of T_{re} across time and interventions; CON (circles), COLD (squares) and MENT (triangles). *denotes a significant difference ($p < 0.05$) between CON and MENT. # denotes a significant difference ($p < 0.05$) between CON and COLD. † denotes a significant difference ($p < 0.05$) between COLD and MENT. SD bars omitted from MENT for figure clarity.

Figure 2: The mean $\pm$ standard deviation of HR across time and interventions; CON (circles), COLD (squares) and MENT (triangles). *denotes a significant difference ($p < 0.05$) between COLD and MENT. SD bars omitted from CON for figure clarity.

Figure 3: Thermal sensation (A) and thermal comfort (B) at the end of rest and exercise. Bars represent the mean and the circles represent the individual participant data point (n =10). * denotes that COLD was significantly ($p < 0.05$) lower than MENT. # denotes that COLD was significantly ($p < 0.05$) lower than CON.