

# Occupational heat stress and the role of wearable cooling interventions: A systematic review and meta-analysis of physiological and perceptual outcomes

by Ankit Sheth, MBBS, MD, Ankit Viramgami, MBBS, MD, Mahendra Thakor, MBBS, MD, Bhavesh Modi, MBBS, MD, Bhavanishankara Bagepally, MBBS, PhD, Ananya Kar, MSc, Ekta Ram, MPH, Anuj Dave, MPH, Rakesh Balachandar, MBBS, PhD

Correspondence to: Rakesh Balachandar, MBBS, PhD, Scientist-, ICMR-Regional Occupational Health Centre, Bengaluru-562110, India. [E-mail: rakesh.bal@icmr.gov.in; balachandar.rakesh@gmail.com]. ORCID: <https://orcid.org/0000-0002-9940-4878>

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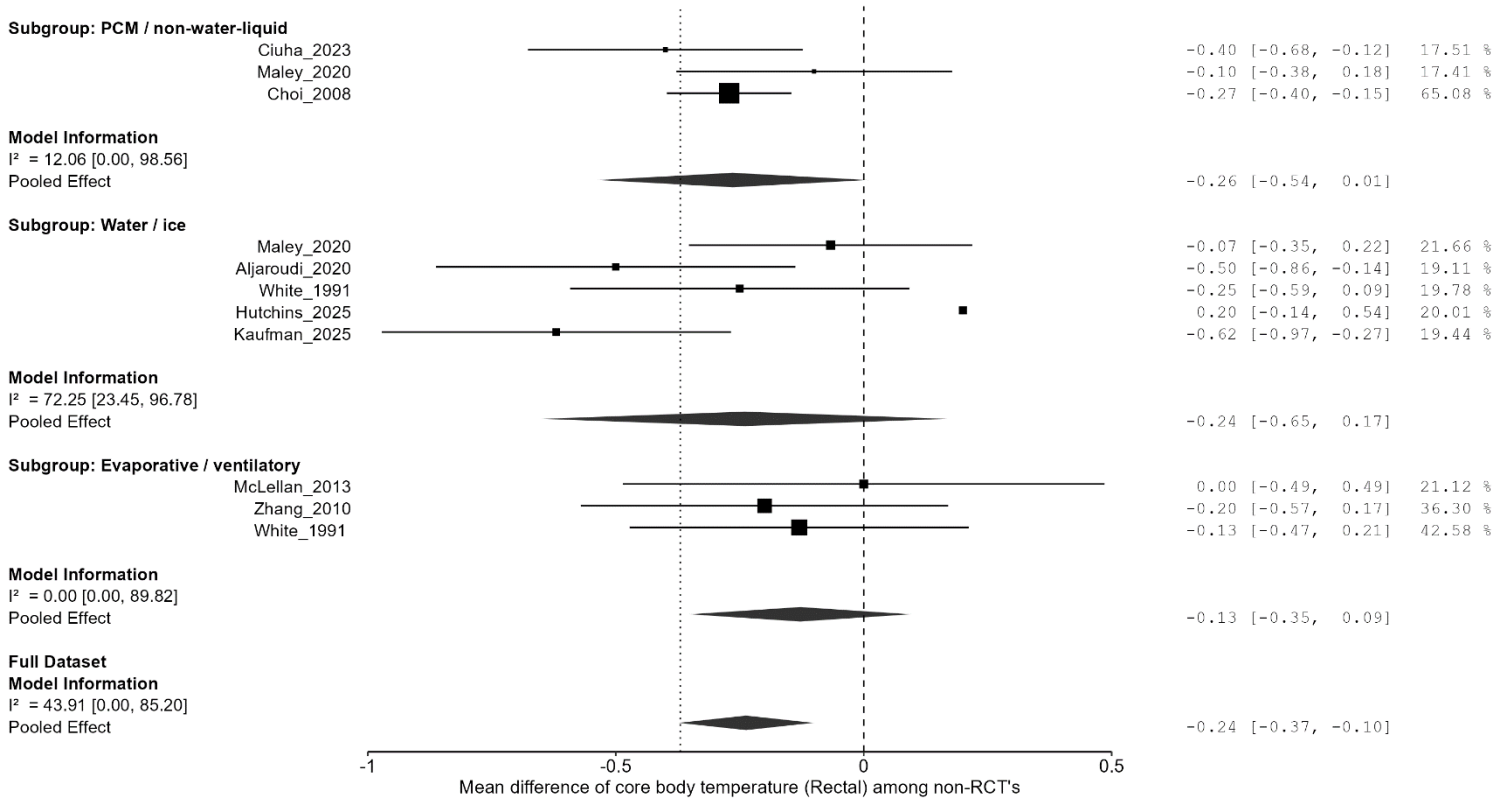
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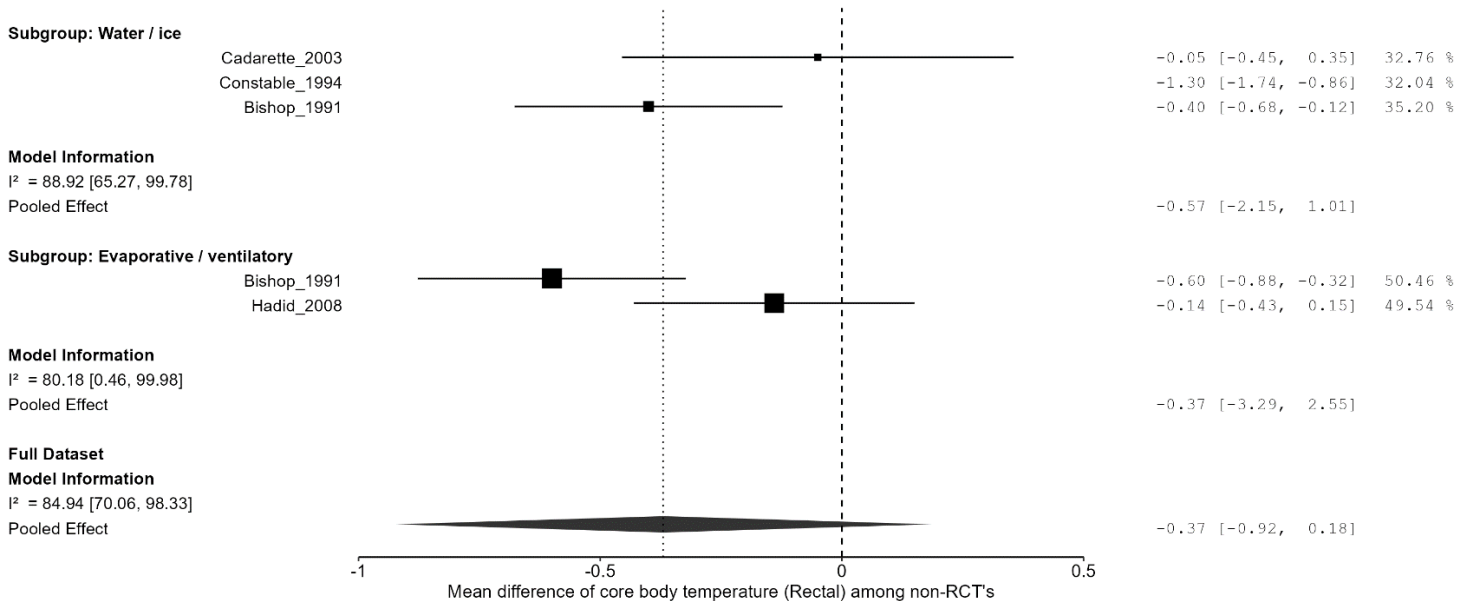
## Supplement figures:

Supplement figure 1: Forest plot analysis of rectal temperature for post intervention comparison:

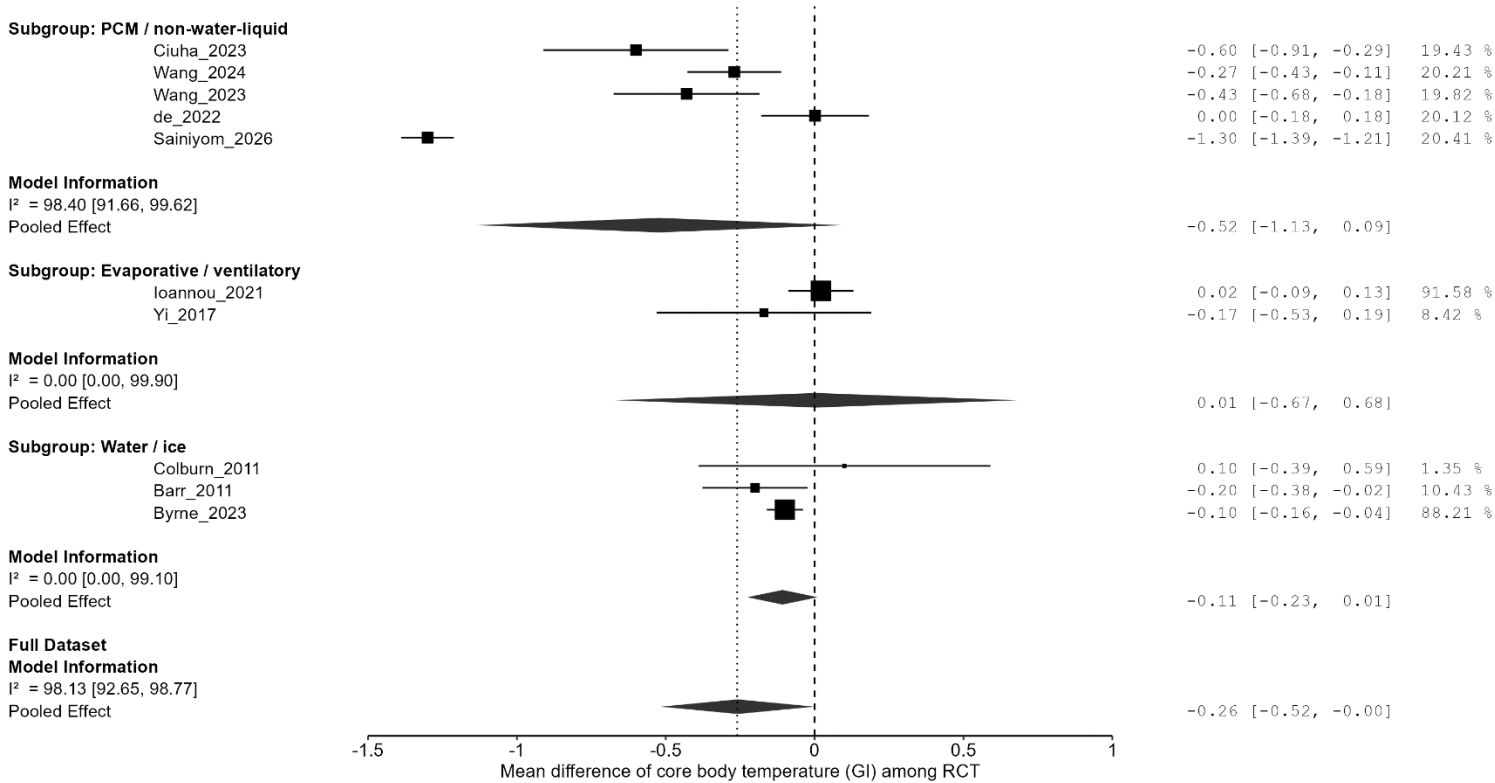
### 1a: RCT



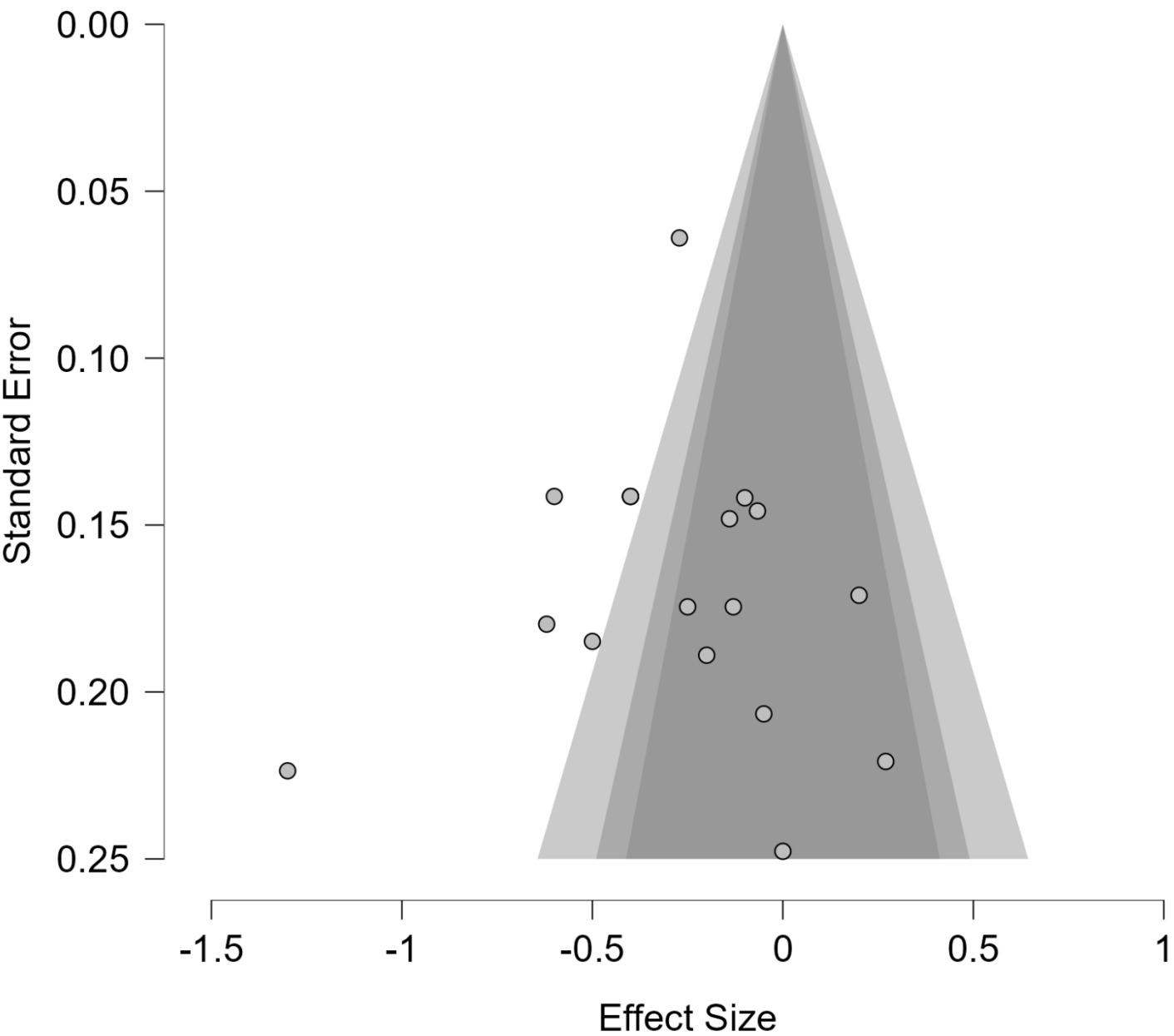
### 1b: non-RCT



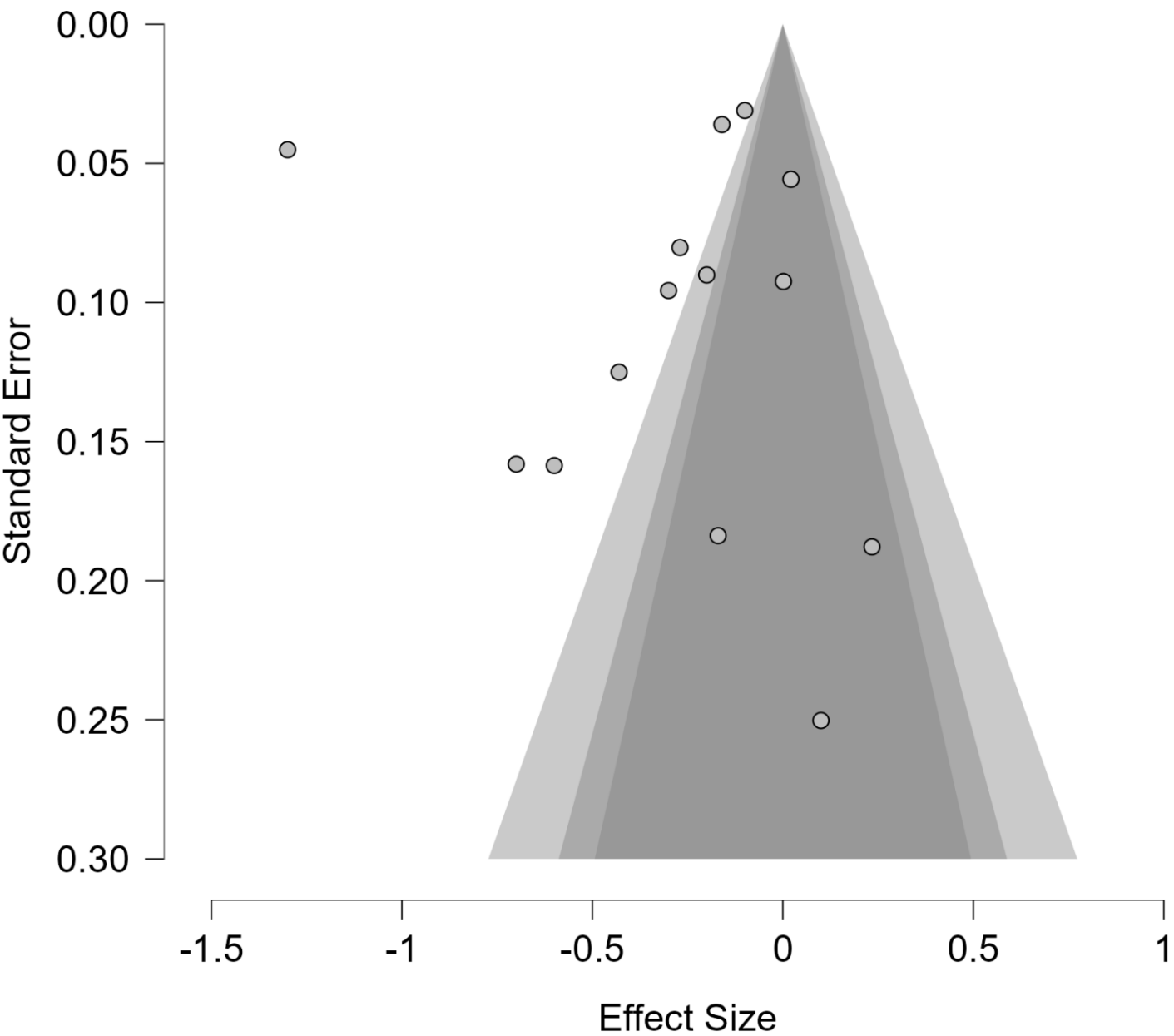
Supplement figure 2 Forest plot analysis of GI temperature for post intervention comparison:



Supplement figure 3 Funnel plot analysis of rectal temperature for post intervention comparison:

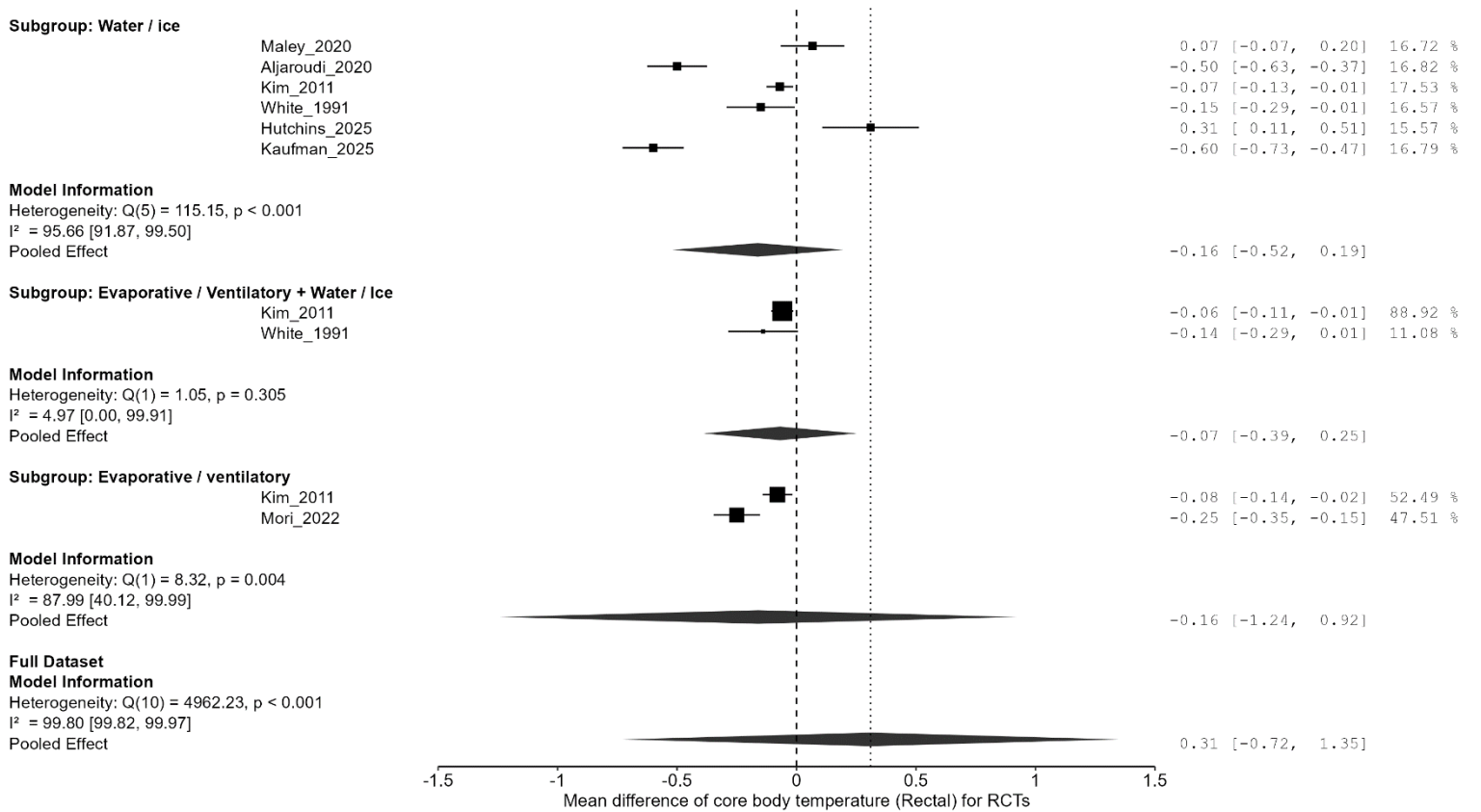


Supplement figure 4: Funnel plot analysis of GI temperature for post intervention comparison:

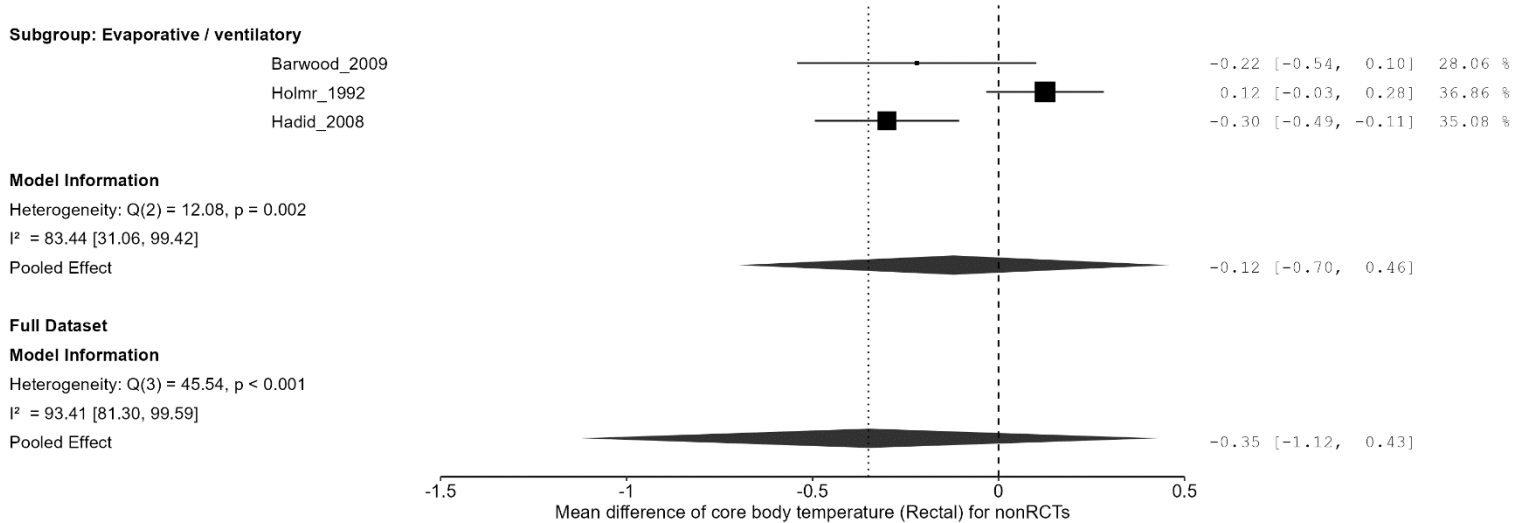


Supplement figure 5: Forest plot analysis of rectal temperature for within-group change comparison

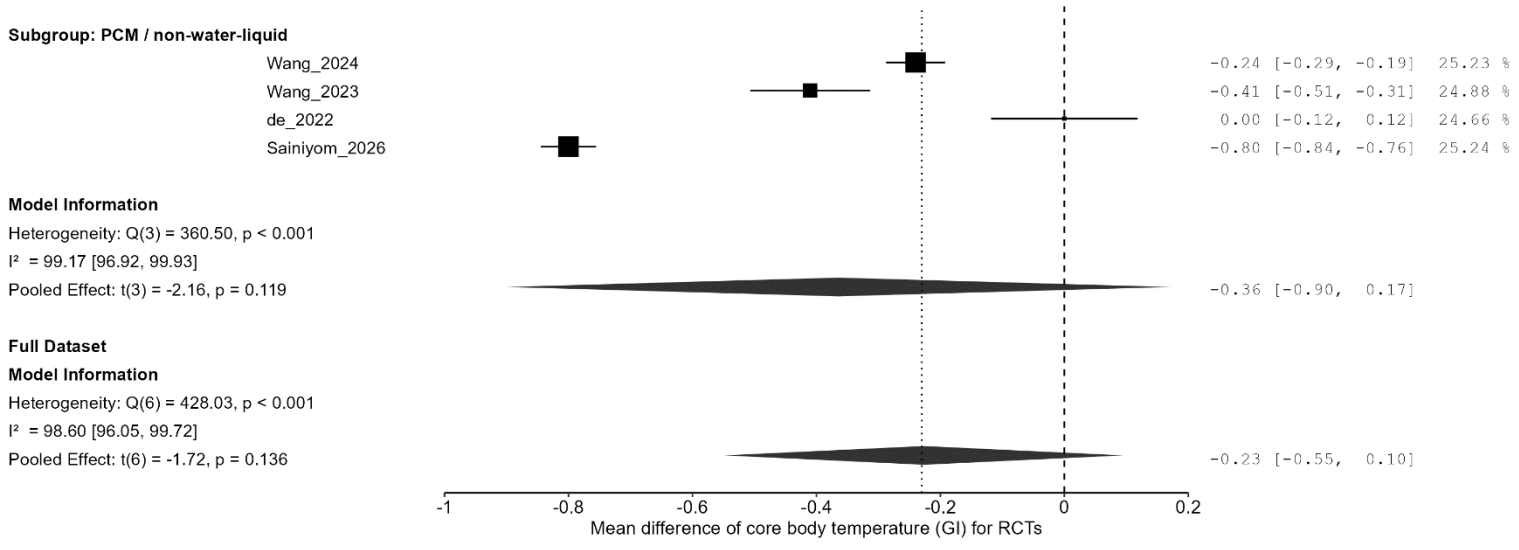
5a: RCT



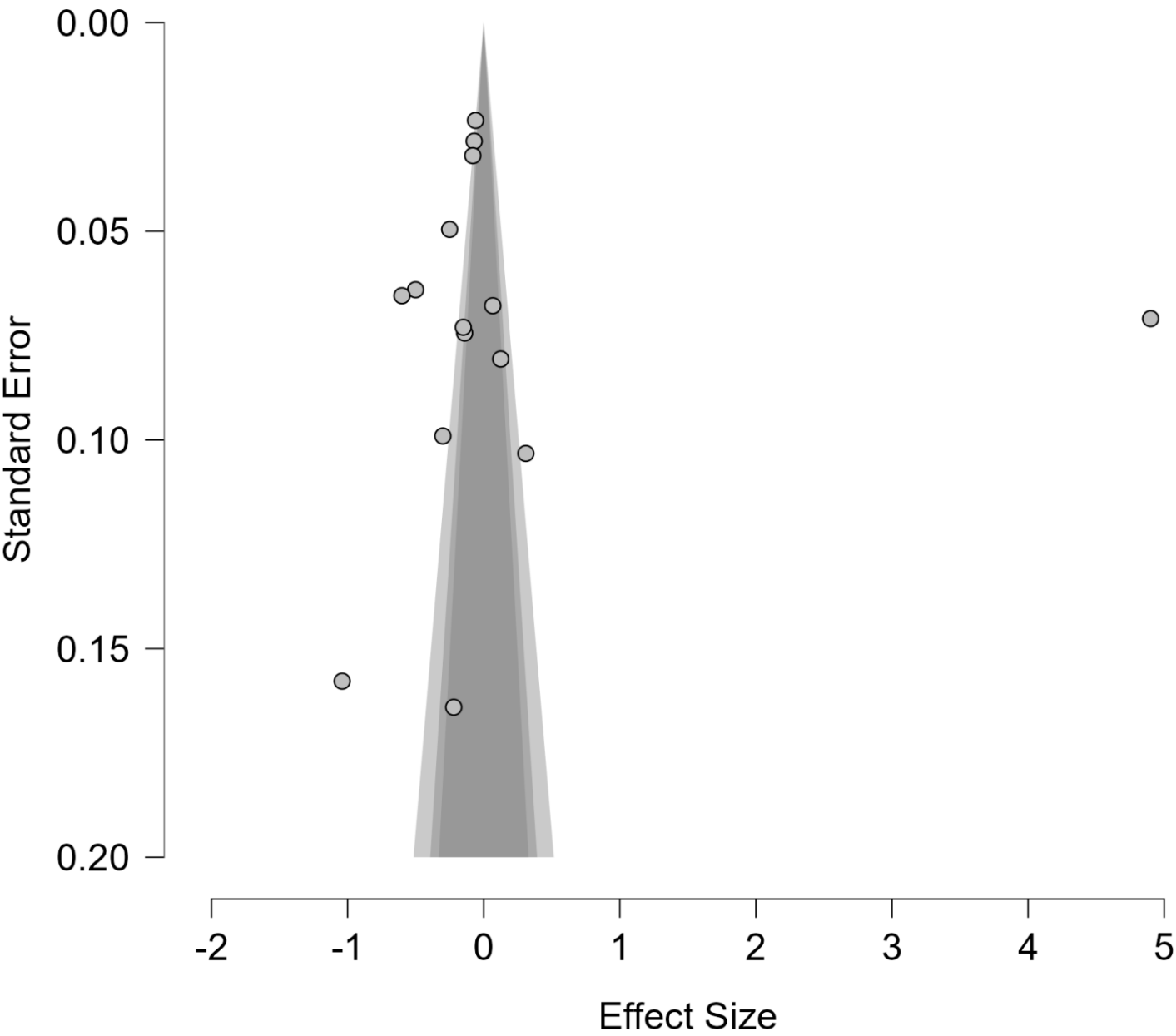
5b: Non-RCT



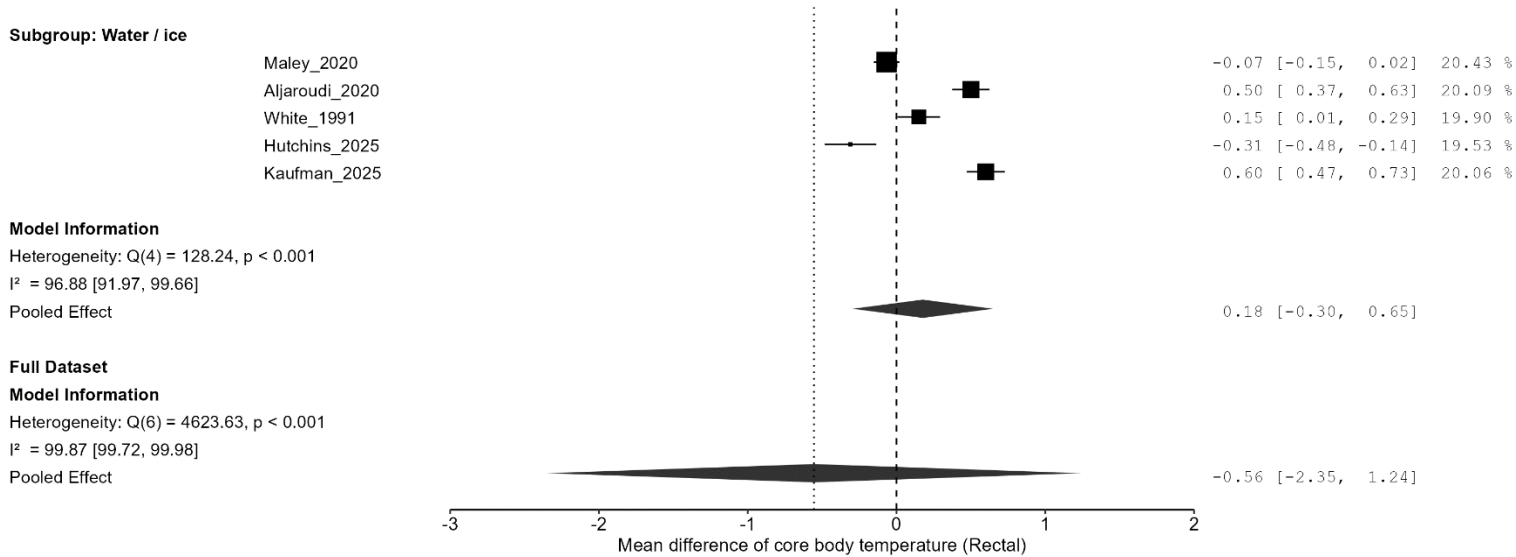
Supplement figure 6: Forest plot analysis of GI temperature for within-group change comparison



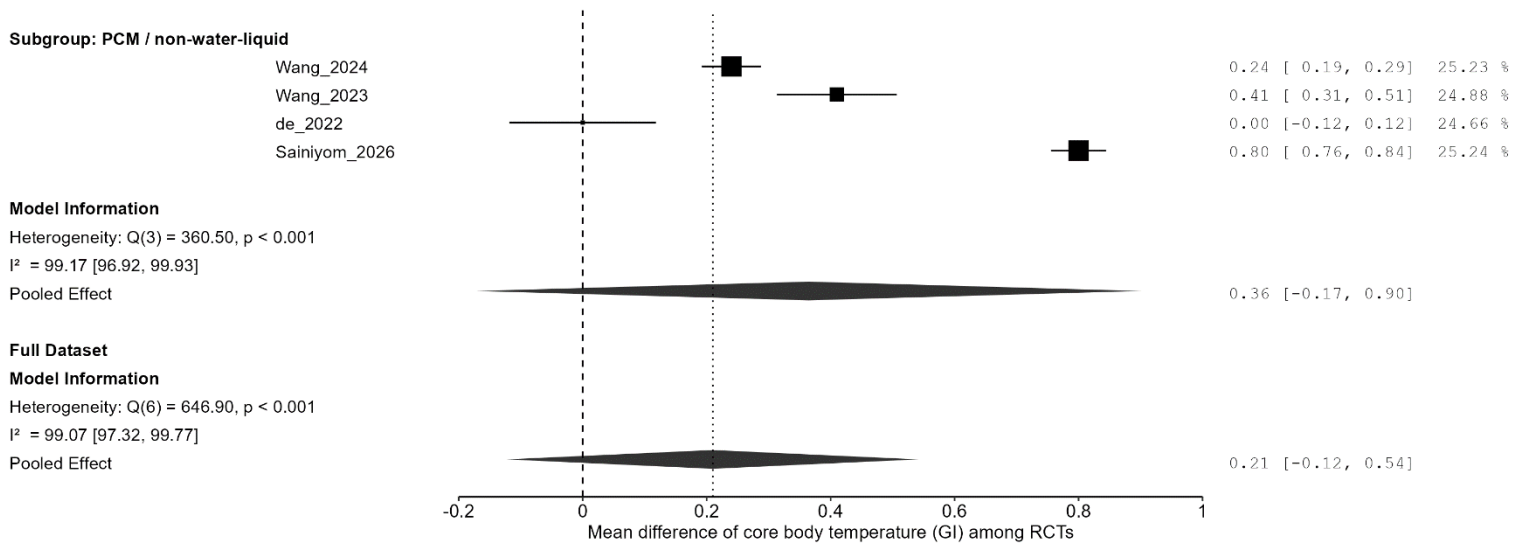
Supplement figure 7: Funnel plot analysis of rectal temperature for within-group change comparison



Supplement figure 8: Forest plot analysis of rectal temperature for change in between-group differences over time

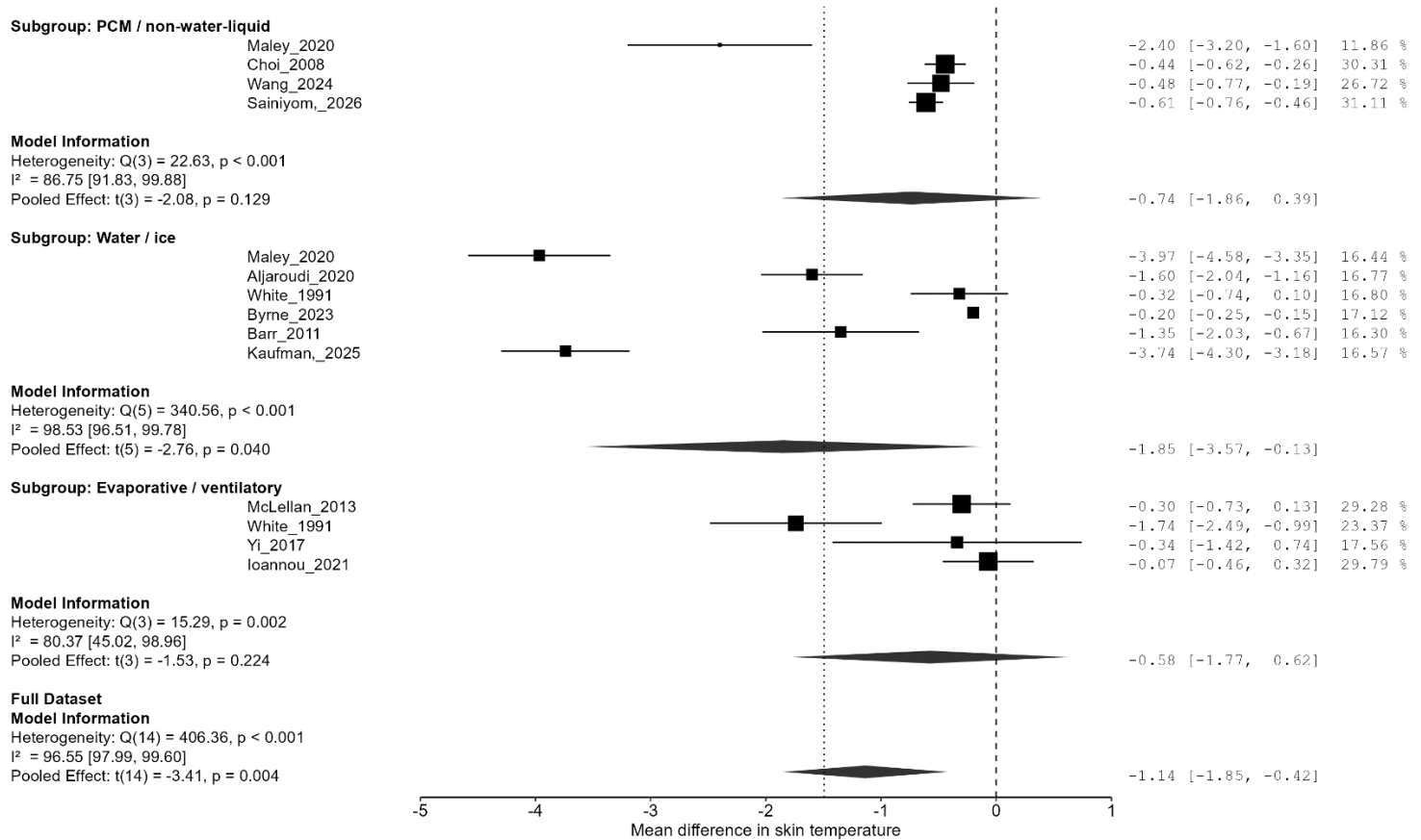


Supplement figure 9: Forest plot analysis of GI temperature for change in between-group differences over time

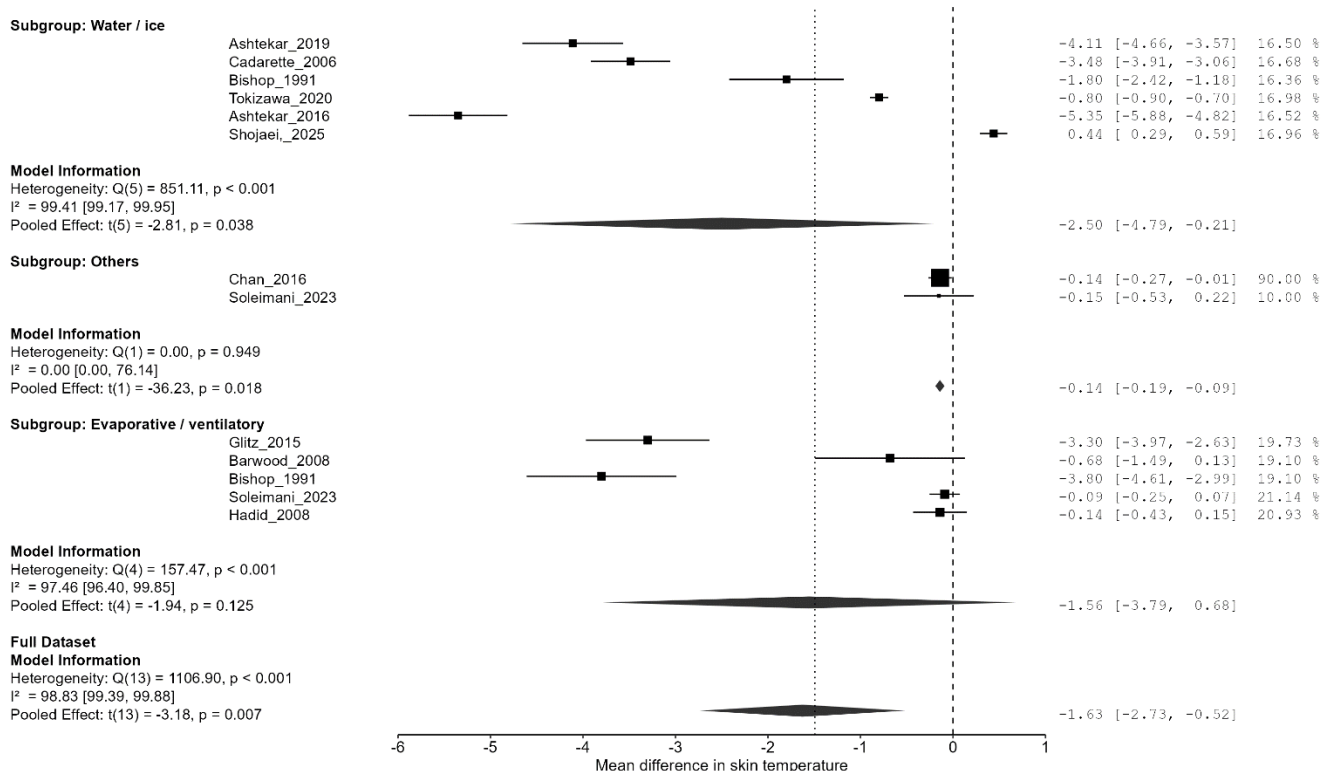


## Supplement figure 10: Forest plot analysis of skin temperature for post intervention comparison

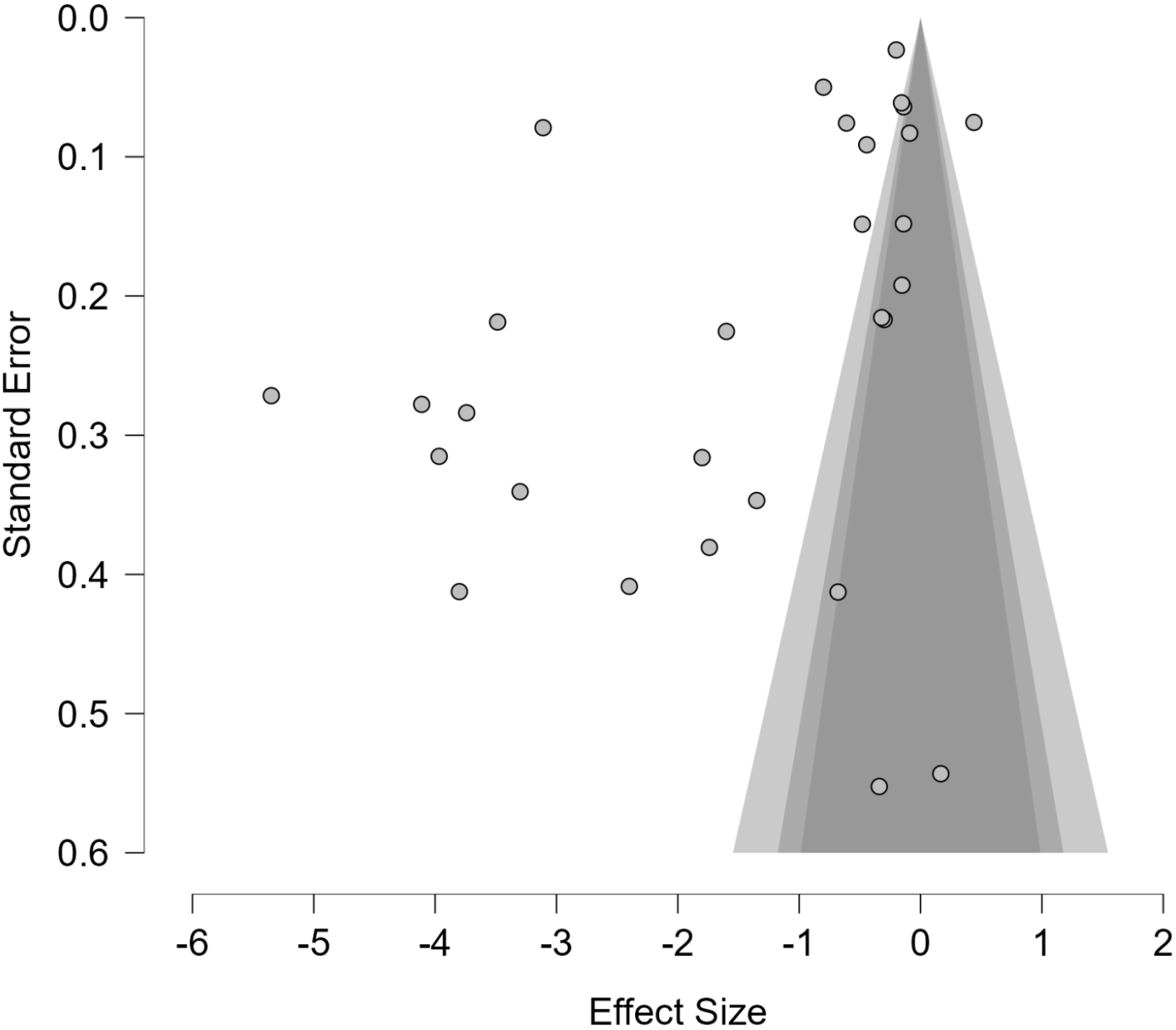
### 10a: RCT



### 10b: Non-RCT

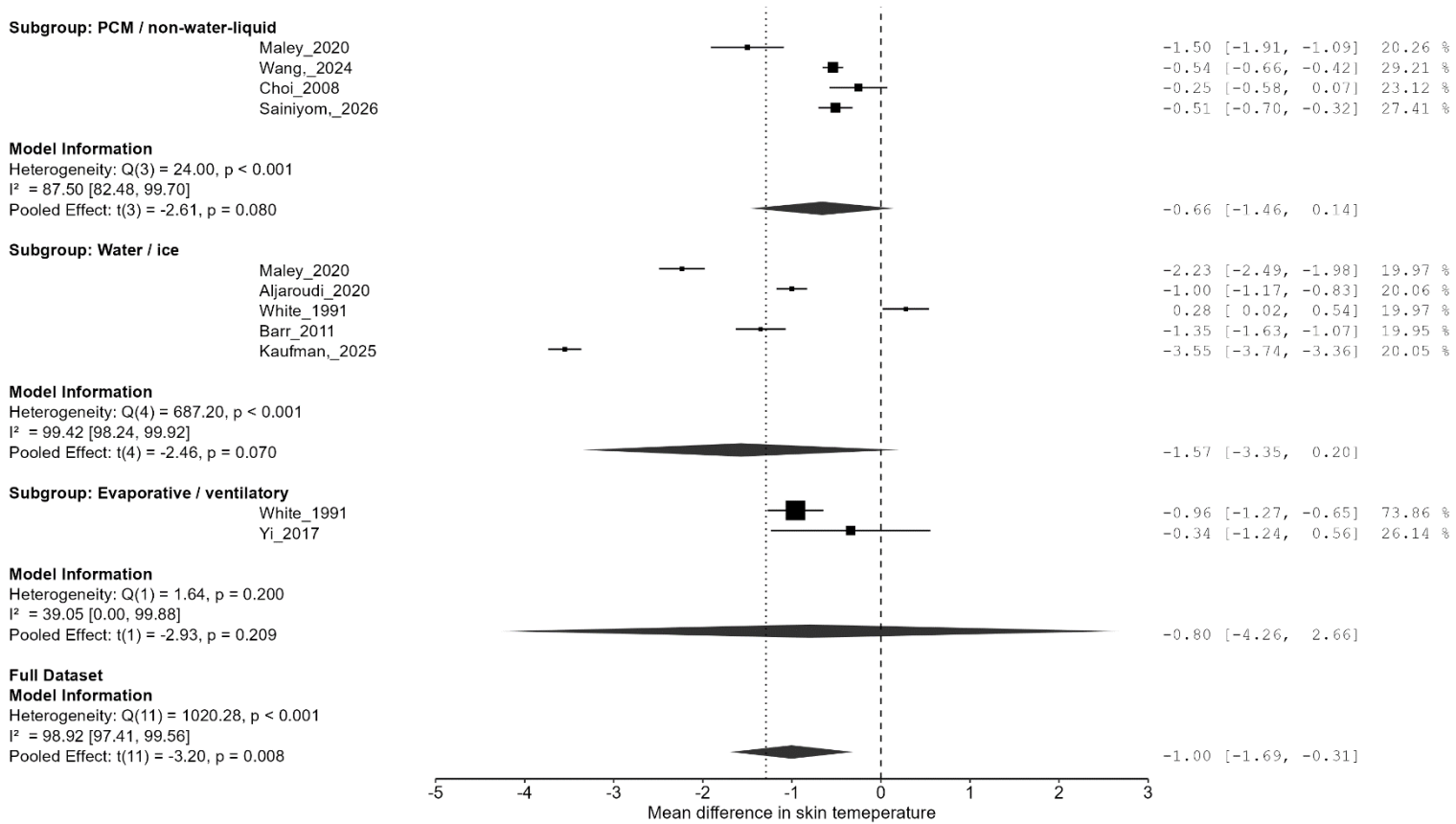


Supplement figure 11: Funnel plot analysis of skin temperature for post intervention comparison

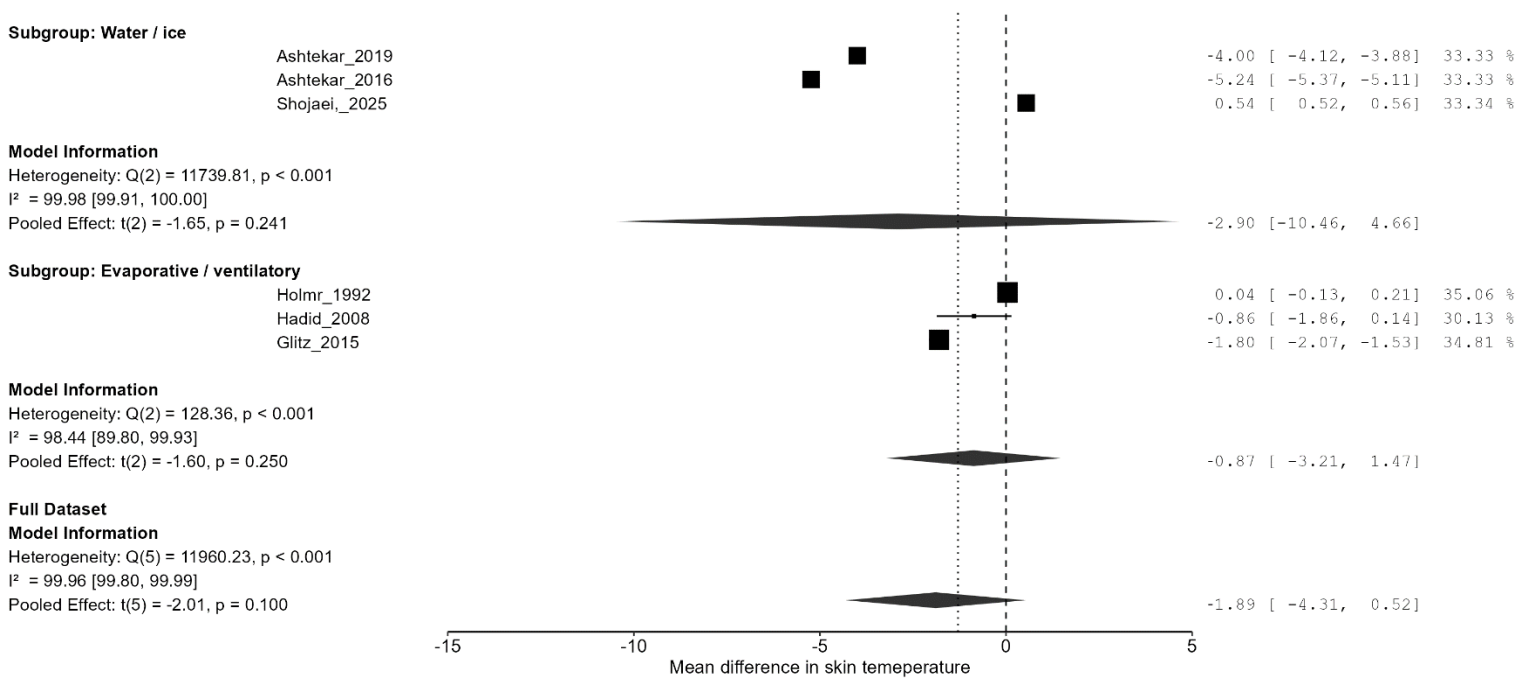


Supplement figure 12: Forest plot analysis of skin temperature for within-group change comparison

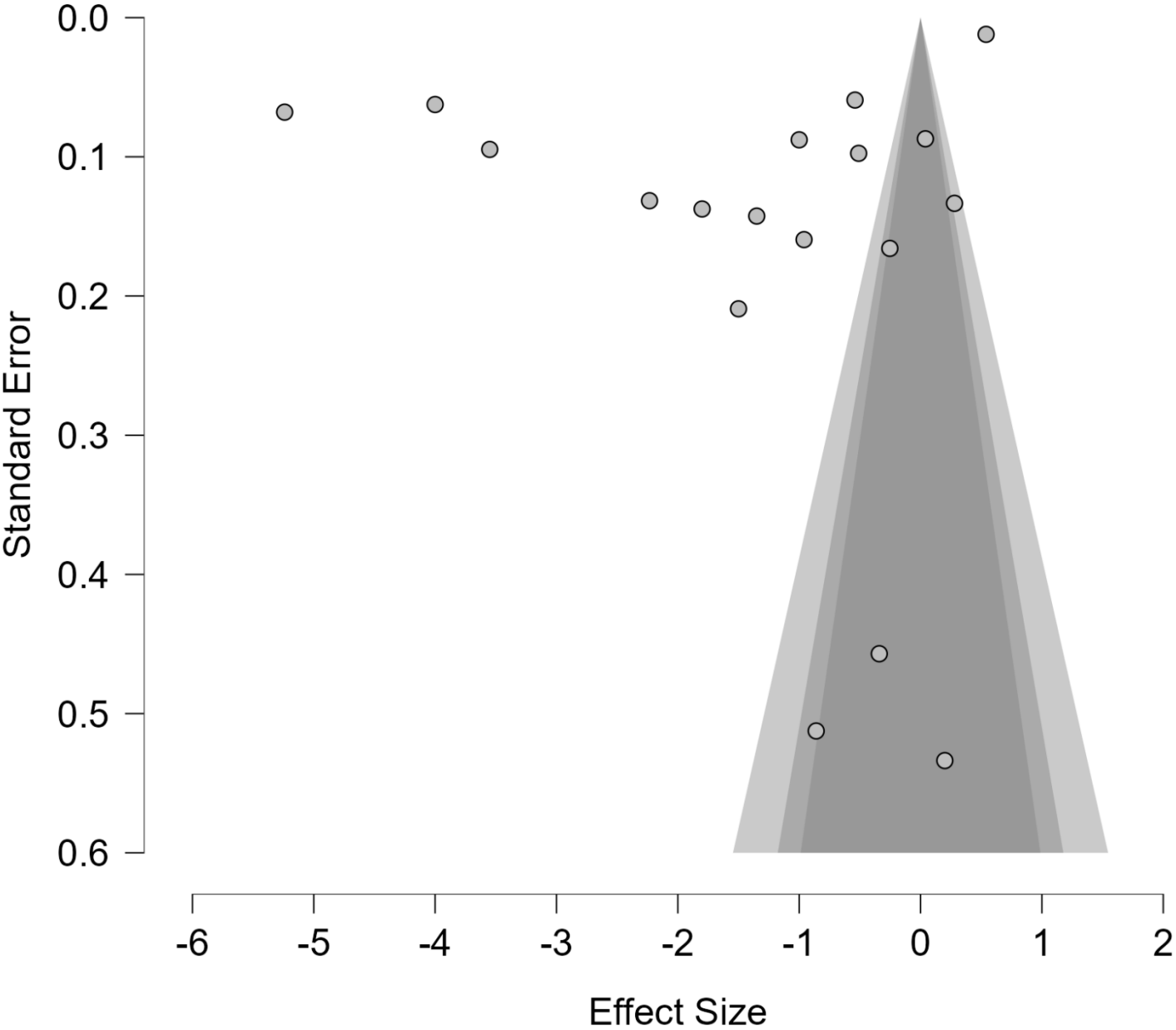
12a: RCT



12b: Non-RCT

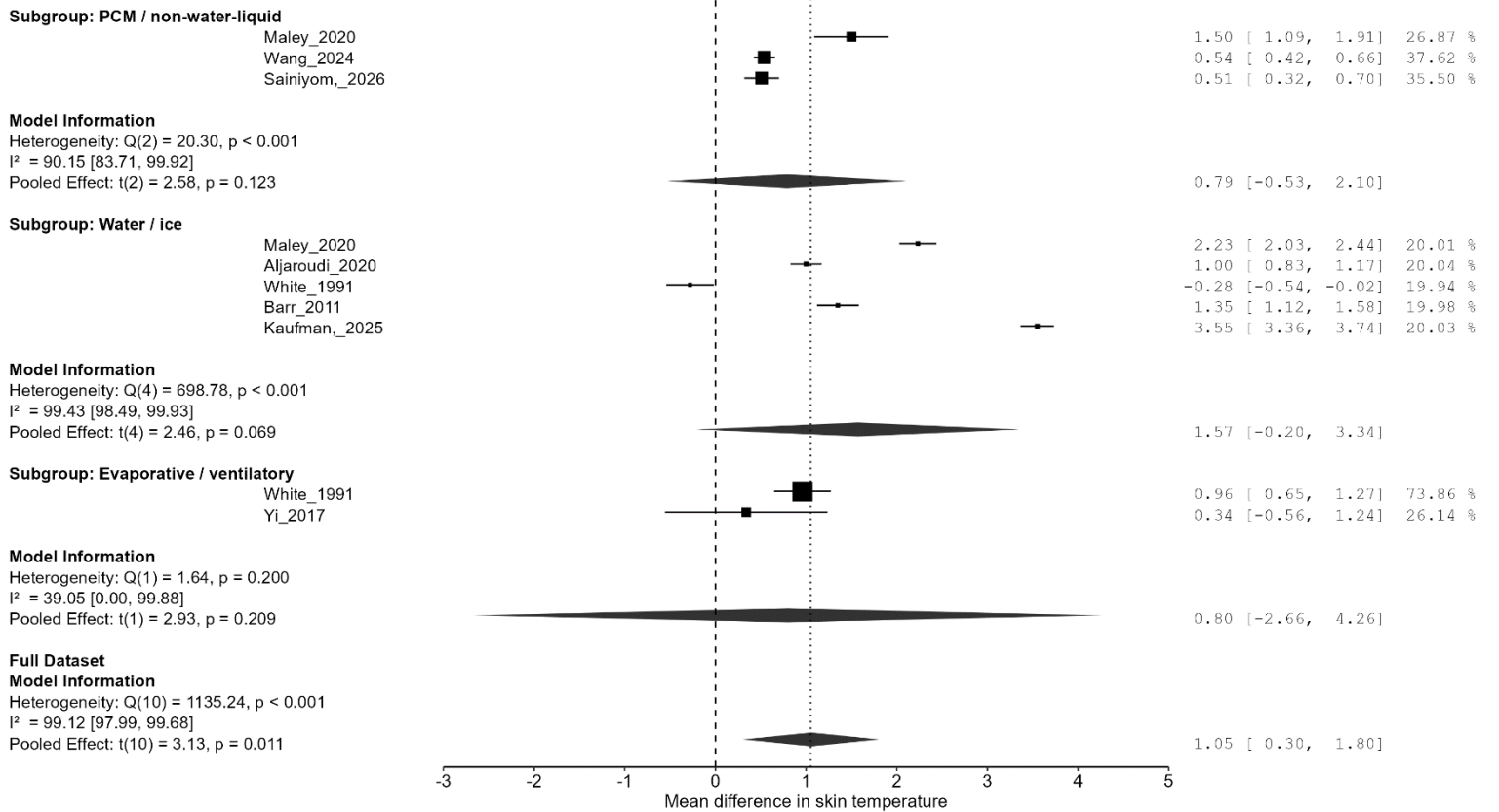


Supplement figure 13: Funnel plot analysis of skin temperature for within-group change comparison

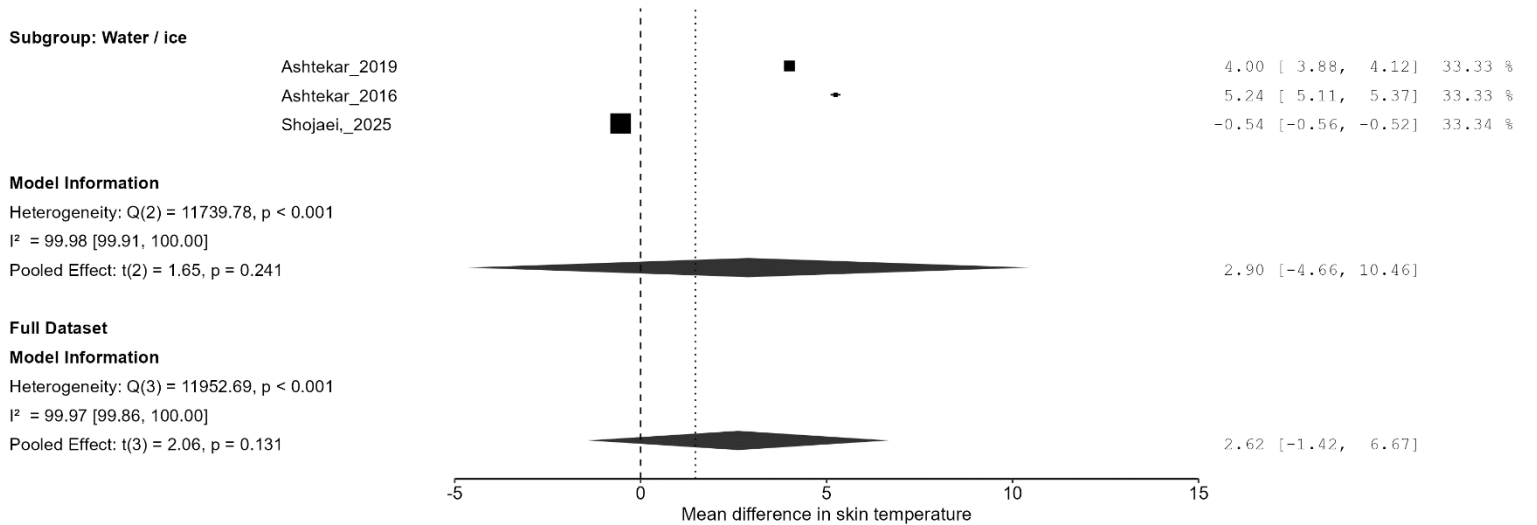


Supplement figure 14: Forest plot analysis of skin temperature for change in between-group differences over time

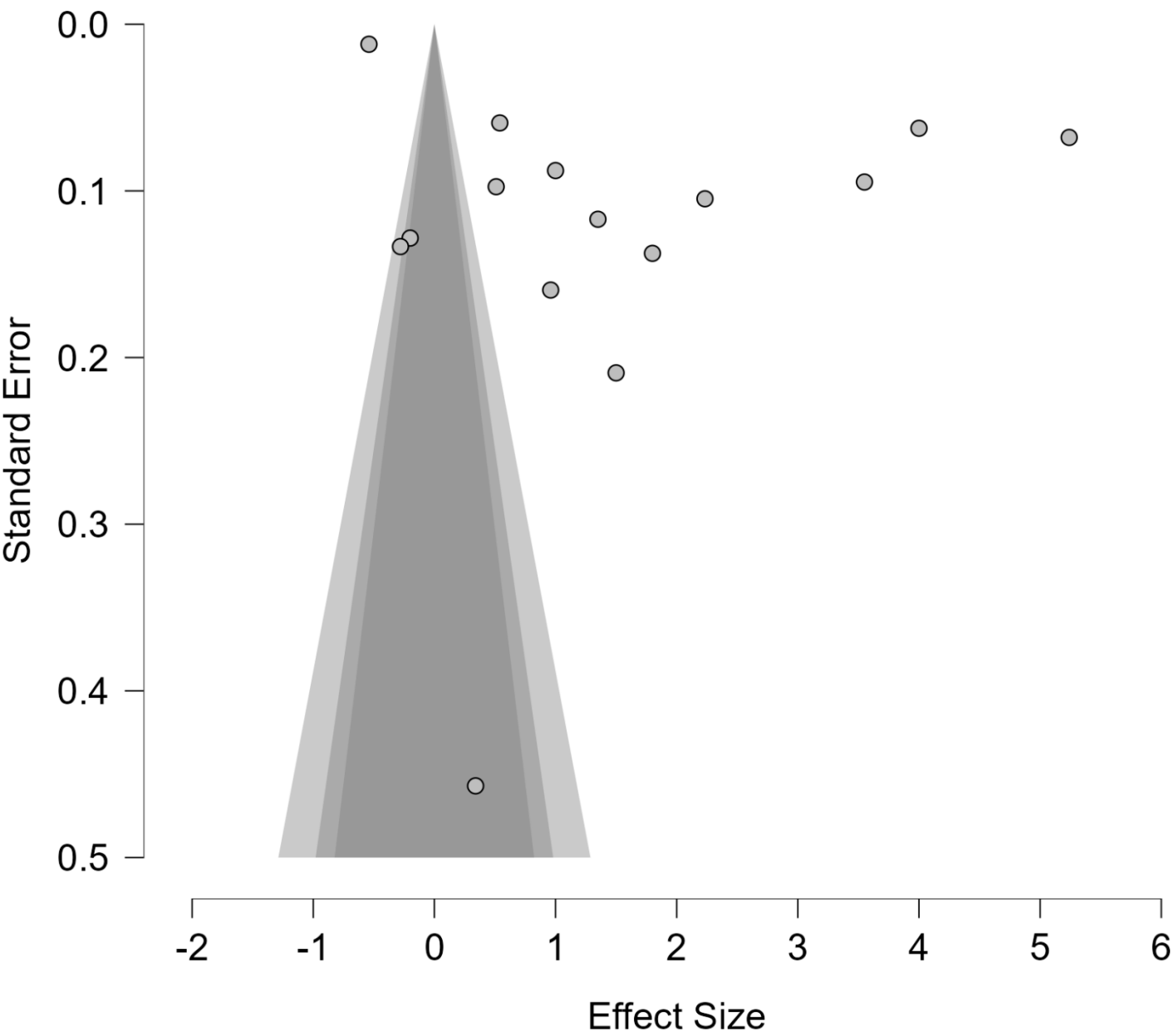
14a: RCT



14b: Non-RCT

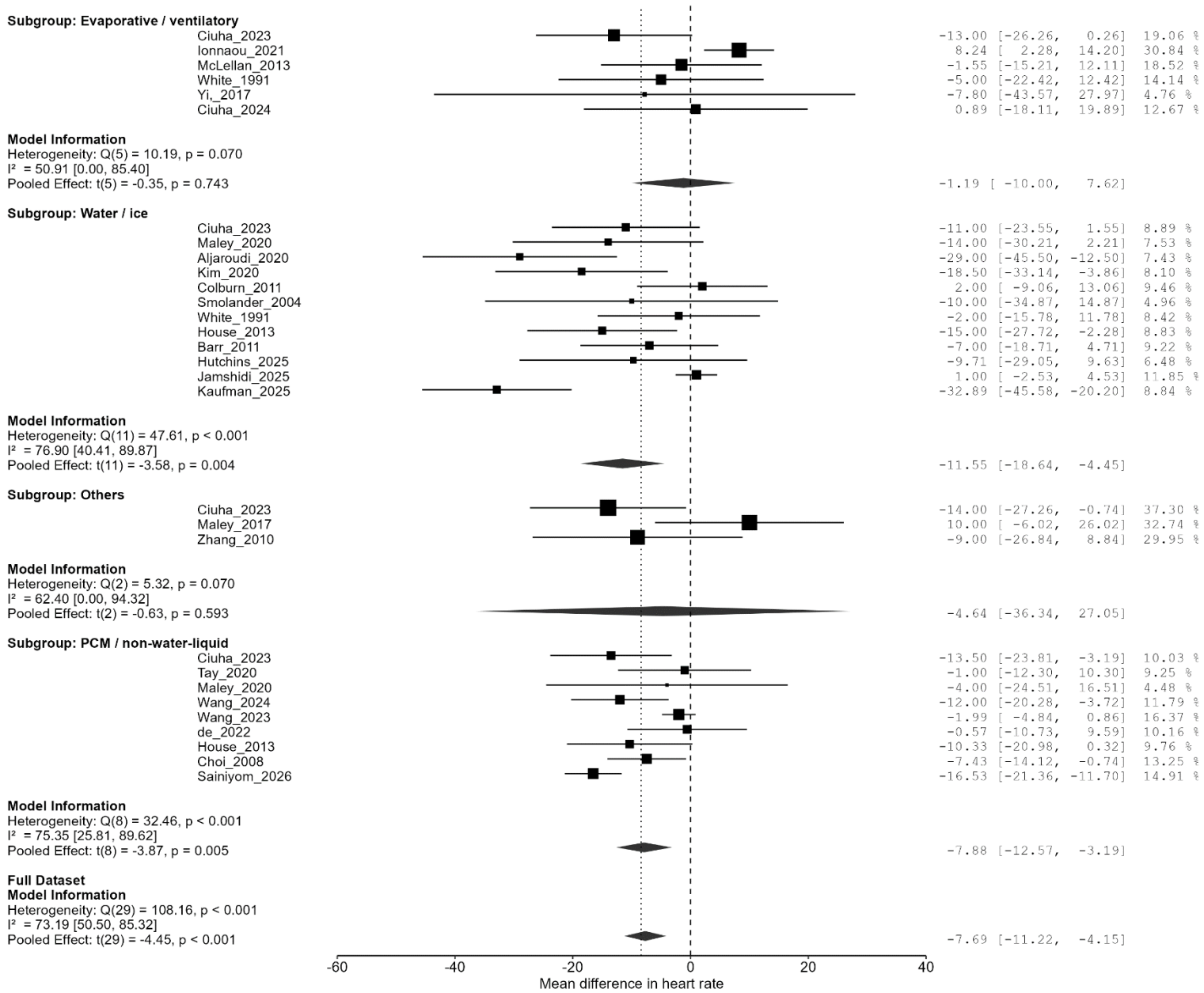


Supplement figure 15: Funnel plot analysis of skin temperature for change in between-group differences over time



Supplement figure 16: Forest plot analysis of heart rate for post intervention comparison

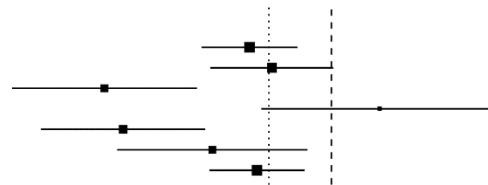
16a: RCT



## 16b: Non-RCT

### Subgroup: Water / ice

Ashtekar\_2019  
Ashtekar\_2016  
Cadarette\_2006  
Cadarette\_2003  
Constable\_1994  
Bishop\_1991  
Tokizawa\_2020



-11.00 [-17.44, -4.56] 17.57 %  
-8.00 [-16.25, 0.25] 16.08 %  
-30.50 [-42.94, -18.06] 12.60 %  
6.50 [-9.42, 22.42] 10.11 %  
-28.00 [-39.04, -16.96] 13.72 %  
-16.00 [-28.79, -3.21] 12.32 %  
-10.00 [-16.39, -3.61] 17.61 %

### Model Information

Heterogeneity:  $Q(6) = 23.28$ ,  $p < 0.001$

$I^2 = 74.23$  [50.09, 96.64]

Pooled Effect:  $t(6) = -3.20$ ,  $p = 0.019$

### Subgroup: PCM / non-water-liquid

Jovanovi\_2014  
Wickwire\_2009



-4.75 [-25.74, 16.24] 38.82 %  
-1.98 [-18.70, 14.74] 61.18 %

### Model Information

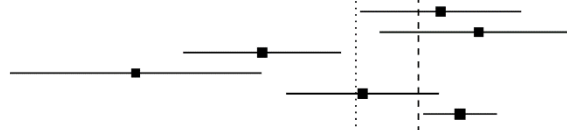
Heterogeneity:  $Q(1) = 0.04$ ,  $p = 0.840$

$I^2 = 0.00$  [0.00, 51.62]

Pooled Effect:  $t(1) = -2.26$ ,  $p = 0.265$

### Subgroup: Evaporative / ventilatory

Barwood\_2000  
Holmr\_1992  
Bishop\_1991  
Glitz\_2015  
Hadid\_2008  
Soleimani\_2023



3.00 [-7.82, 13.82] 16.92 %  
8.11 [-5.22, 21.44] 15.80 %  
-21.00 [-31.61, -10.39] 17.01 %  
-38.00 [-54.92, -21.08] 14.12 %  
-7.50 [-17.77, 2.77] 17.16 %  
5.60 [0.64, 10.56] 18.99 %

### Model Information

Heterogeneity:  $Q(5) = 42.69$ ,  $p < 0.001$

$I^2 = 88.29$  [75.33, 98.69]

Pooled Effect:  $t(5) = -1.04$ ,  $p = 0.347$

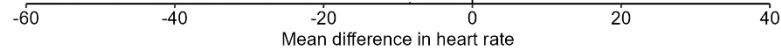
### Full Dataset

#### Model Information

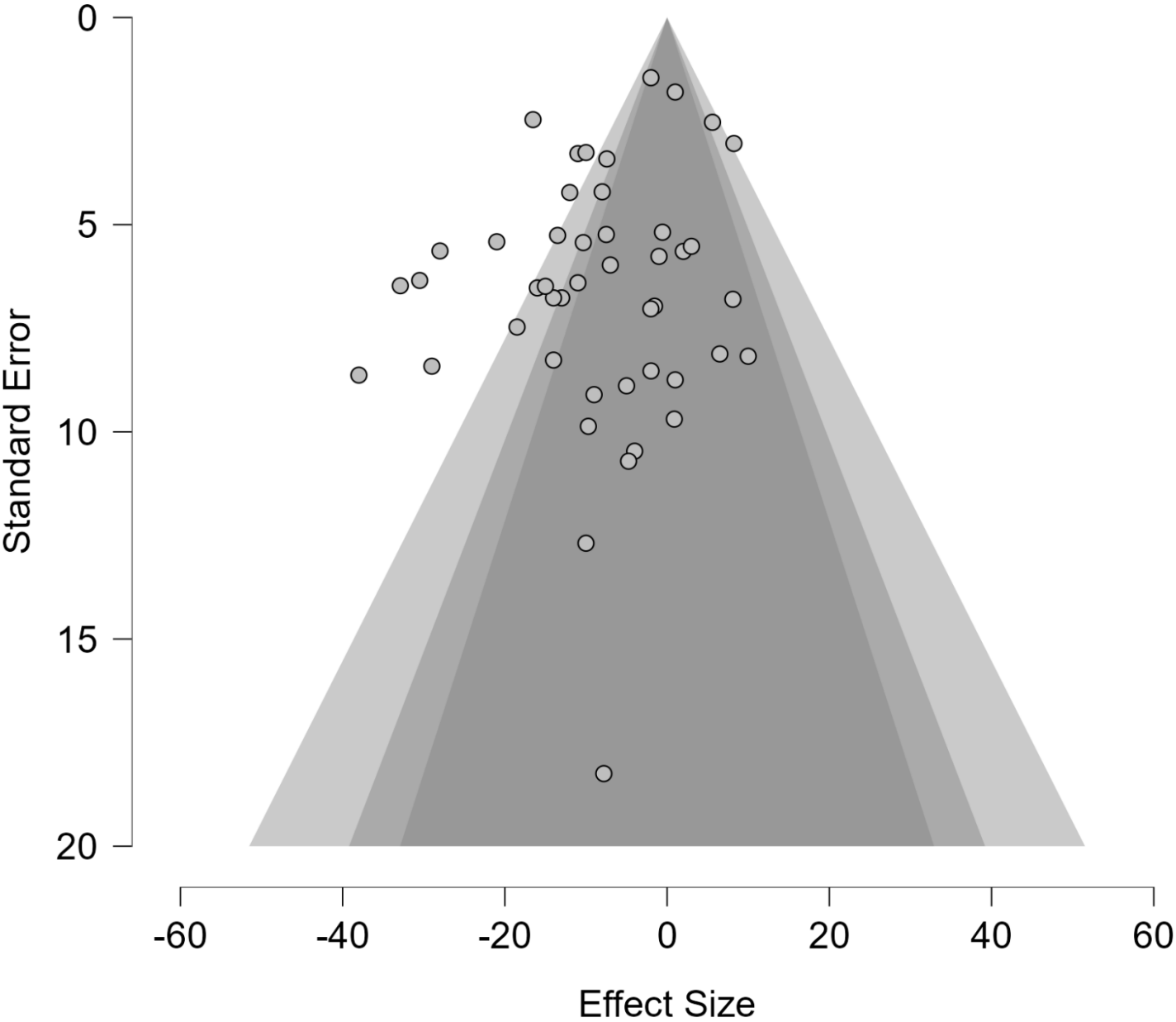
Heterogeneity:  $Q(15) = 88.50$ ,  $p < 0.001$

$I^2 = 83.05$  [70.45, 94.25]

Pooled Effect:  $t(15) = -2.80$ ,  $p = 0.014$

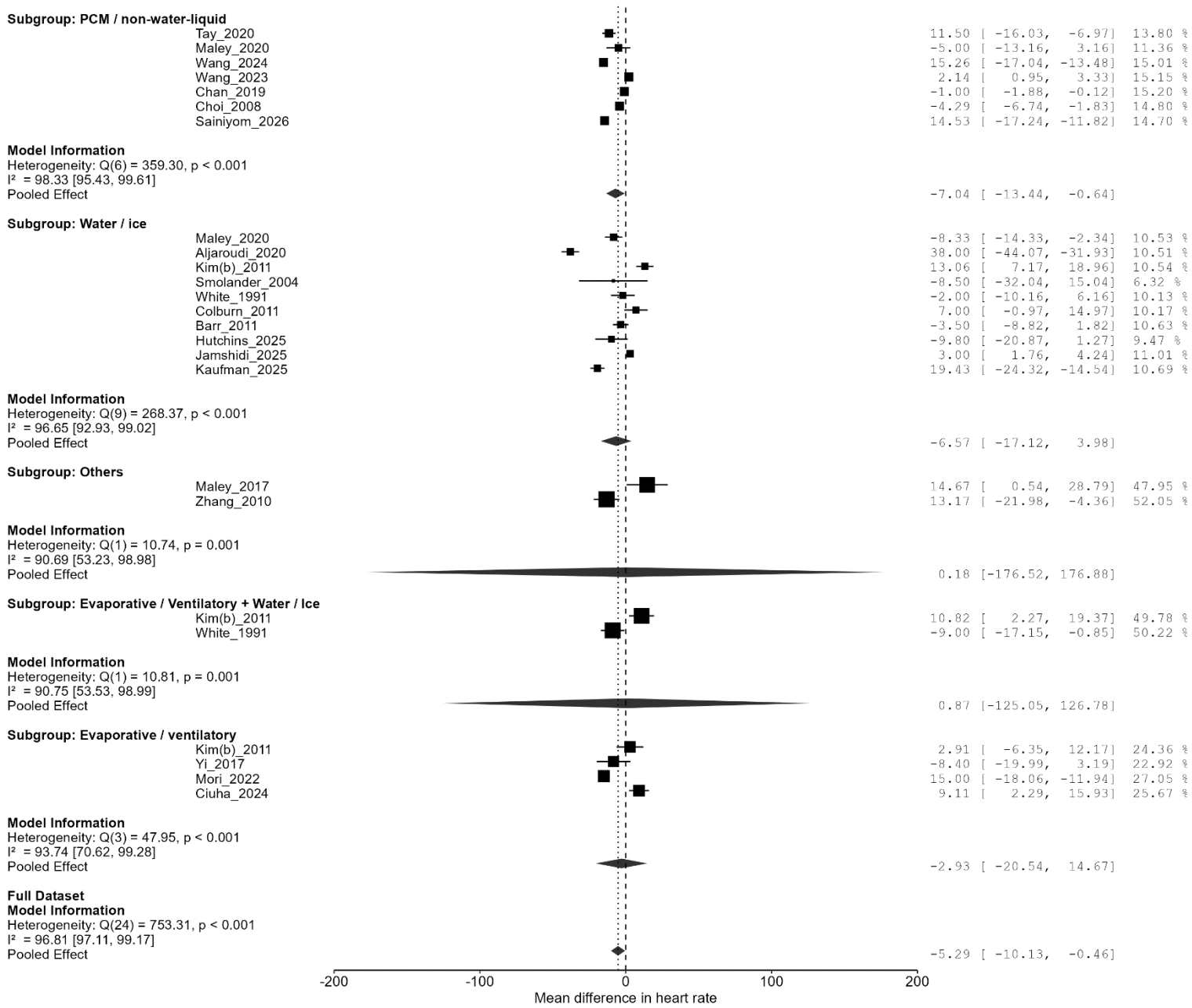


Supplement figure 17: Funnel plot analysis of heart rate for post intervention comparison

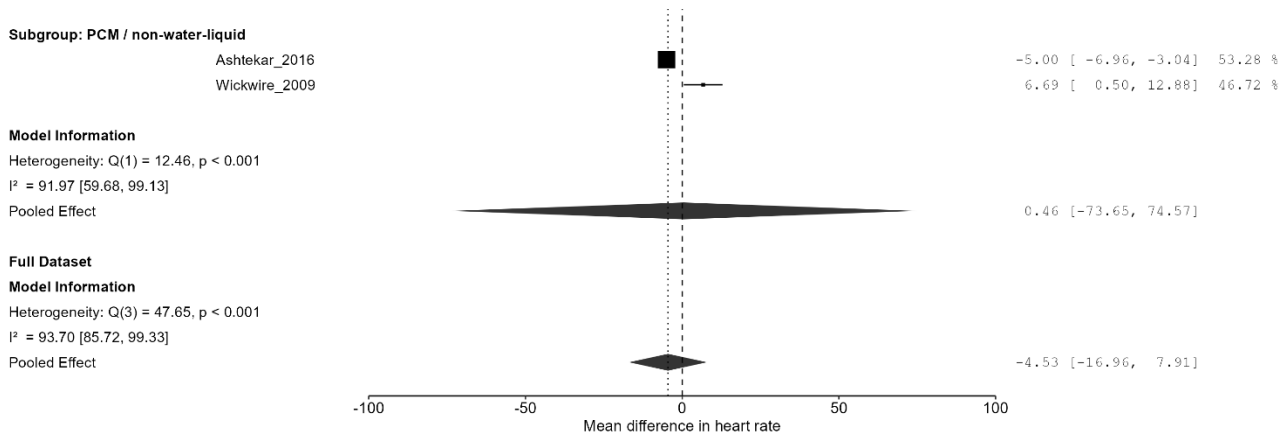


Supplement figure 18: Forest plot analysis of heart rate for within-group change comparison

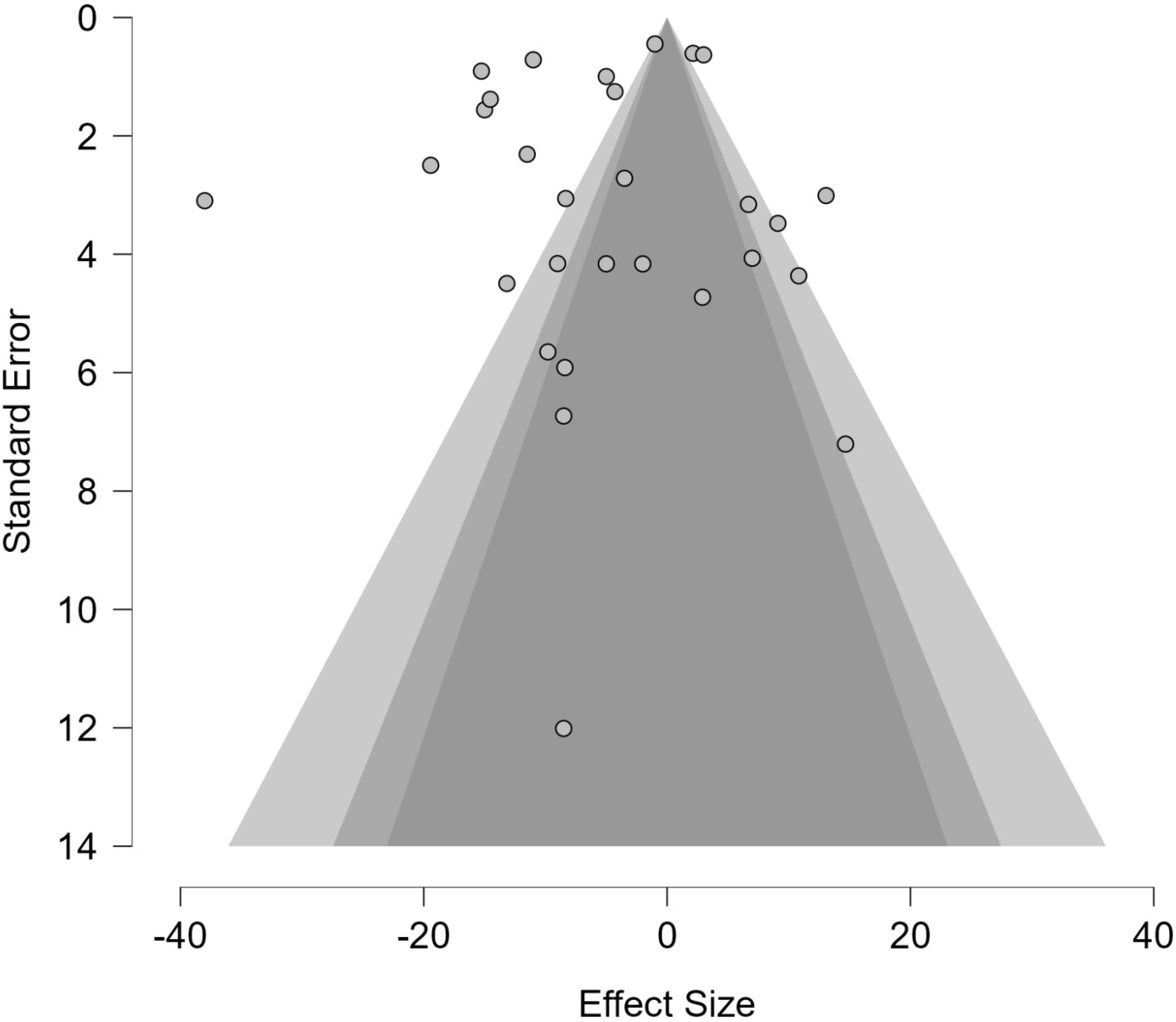
18a: RCT



18b: Non-RCT

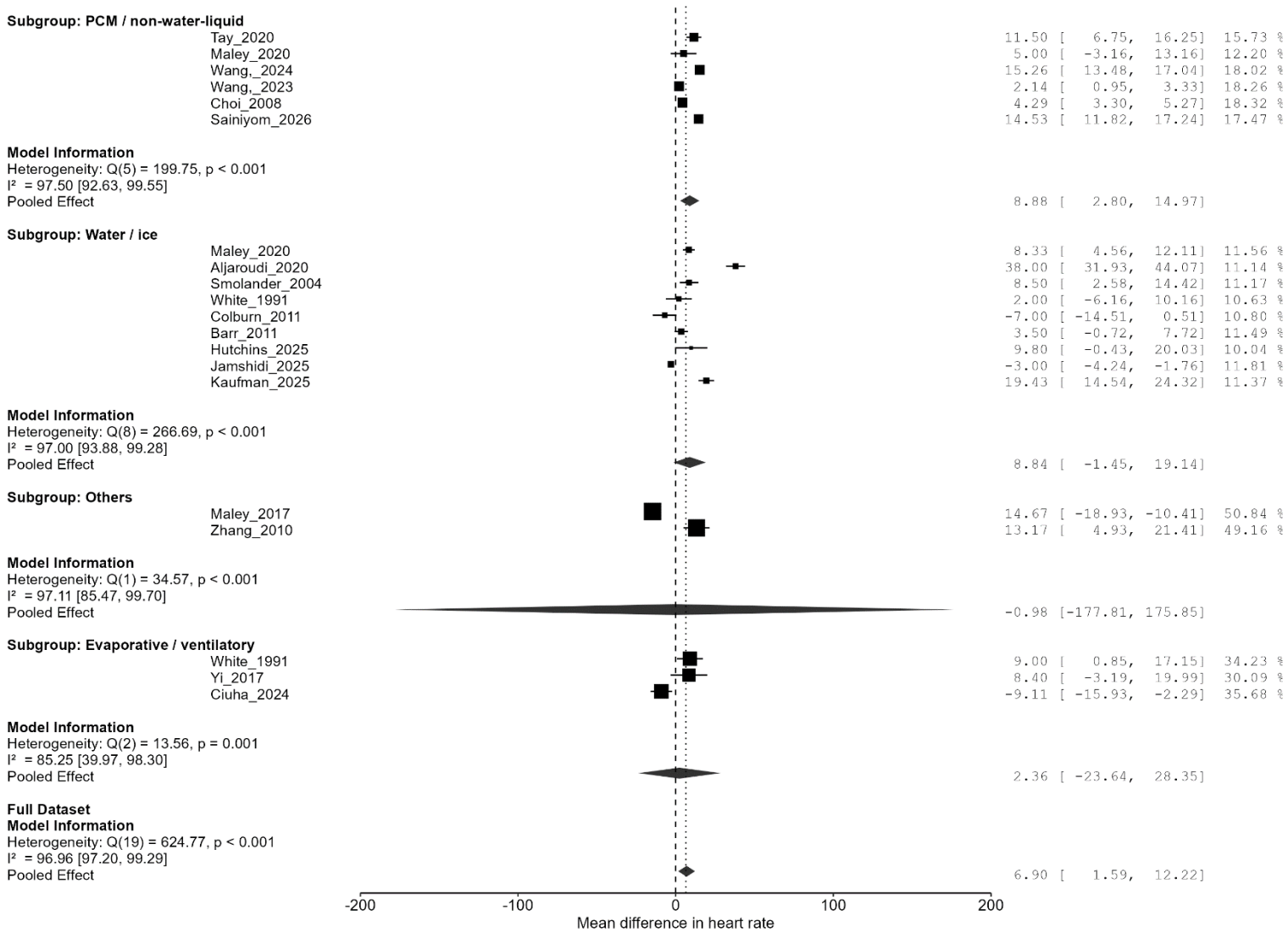


Supplement figure 19: Funnel plot analysis of heart rate for within-group change comparison

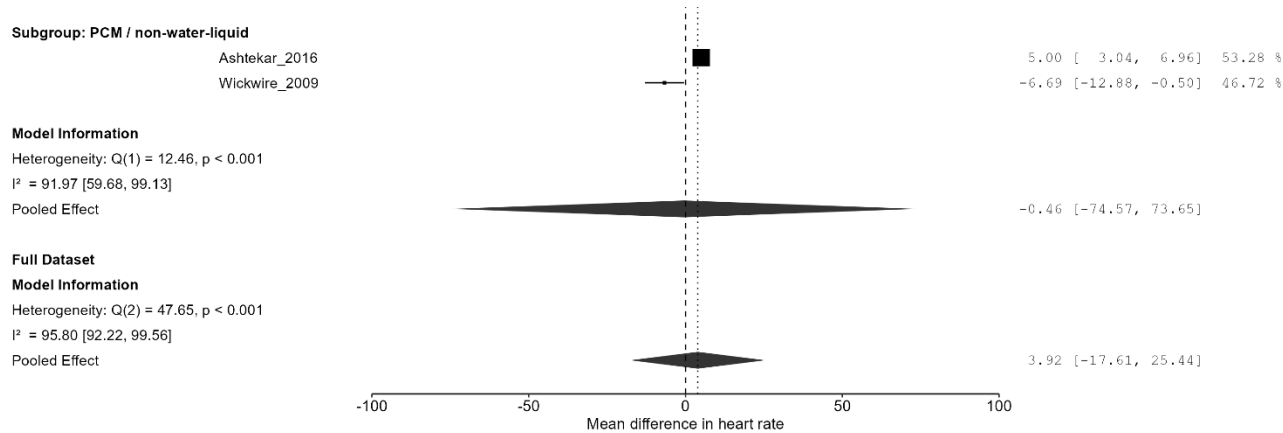


Supplement figure 20: Forest analysis of heart rate for change in between-group differences over time

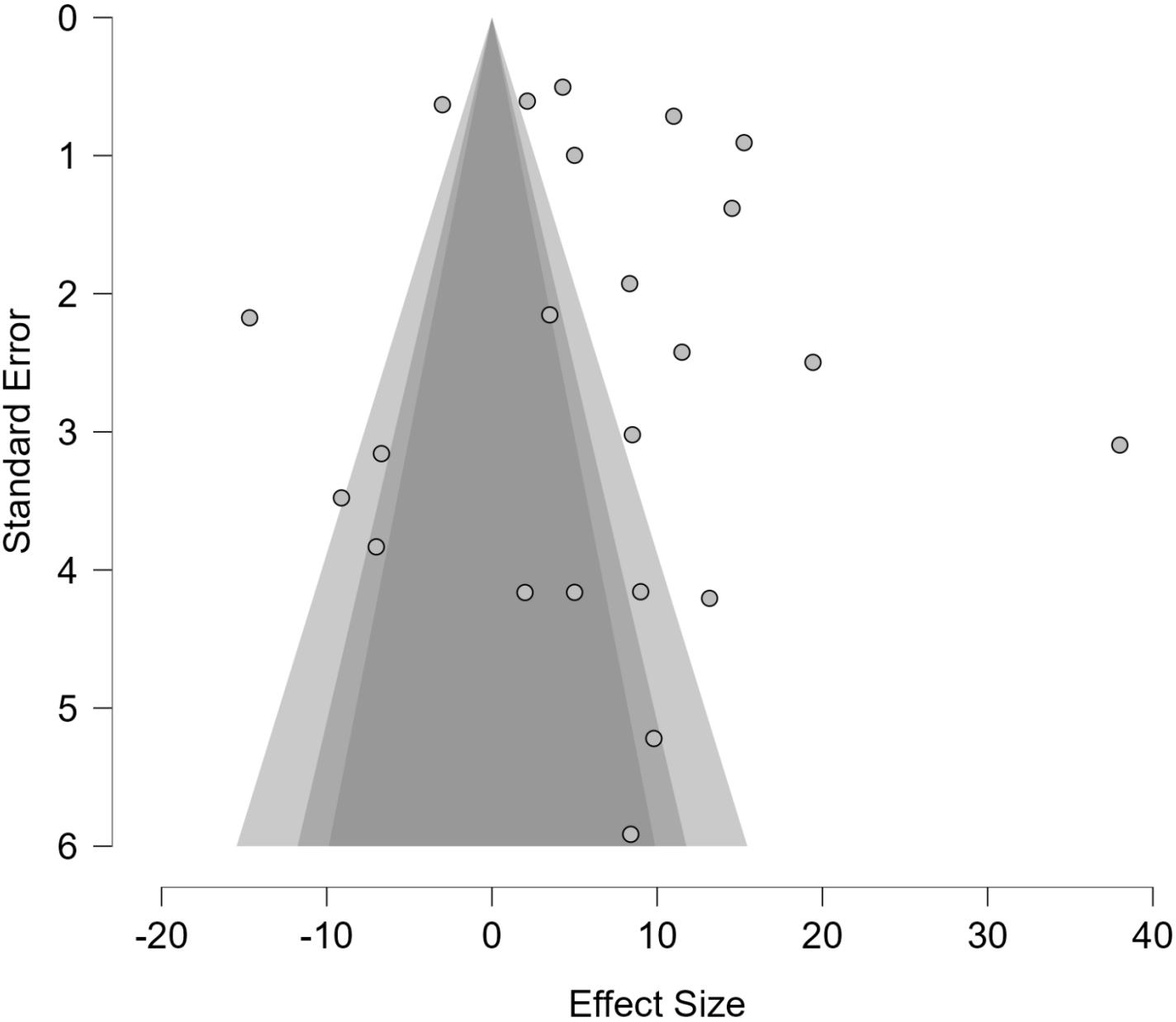
20a: RCT



20b: Non-RCT

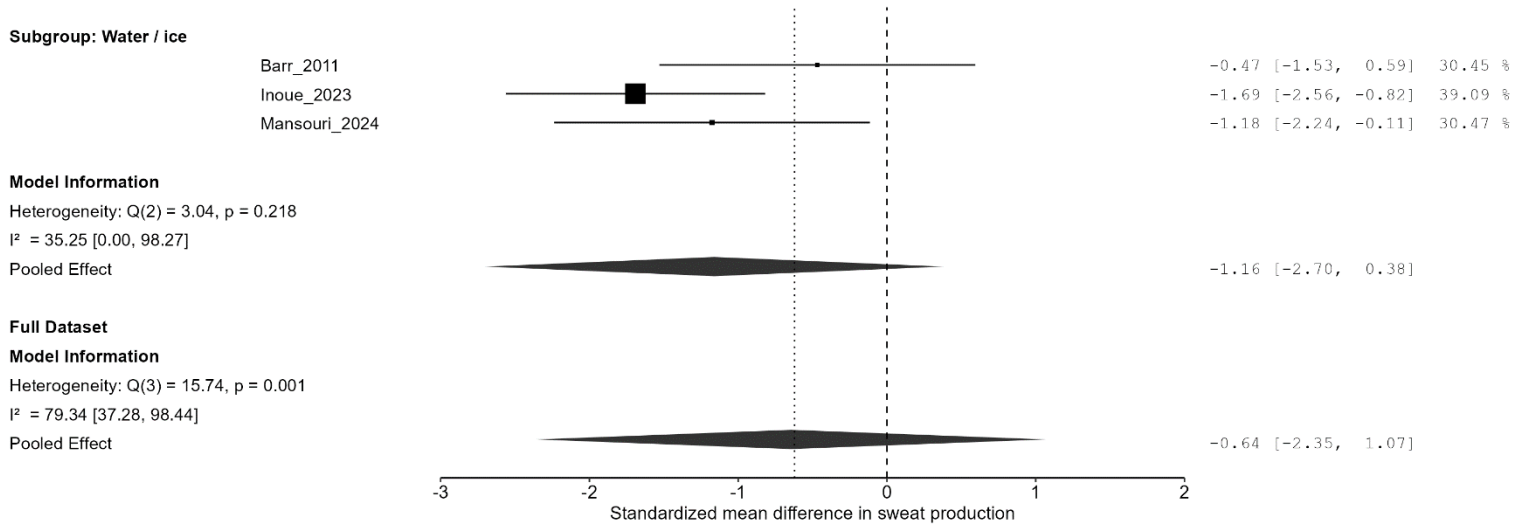


Supplement figure 21: Funnel analysis of heart rate for change in between-group differences over time

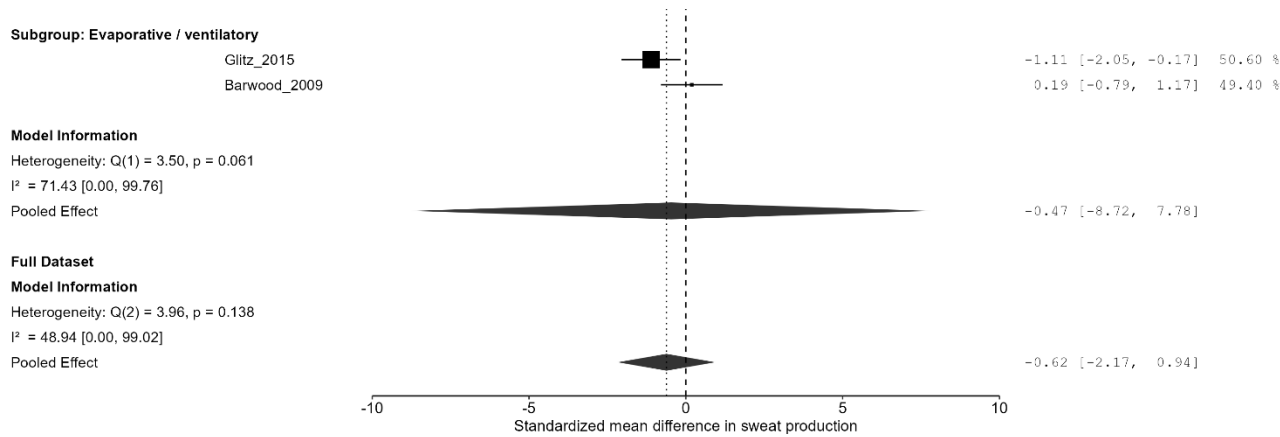


Supplement figure 22: Forest plot analysis of sweat production for post intervention comparison

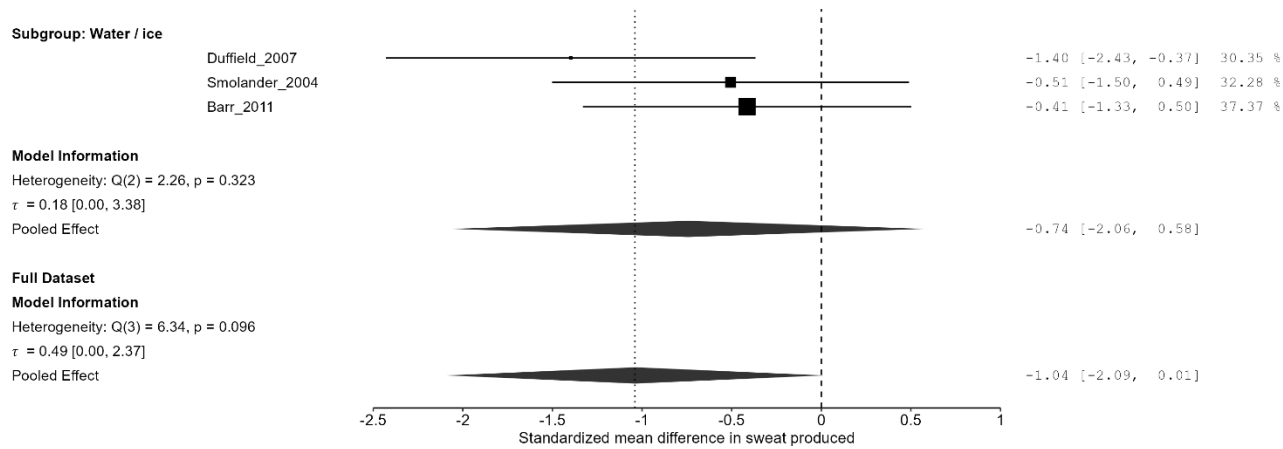
22a: RCT



22b: Non-RCT

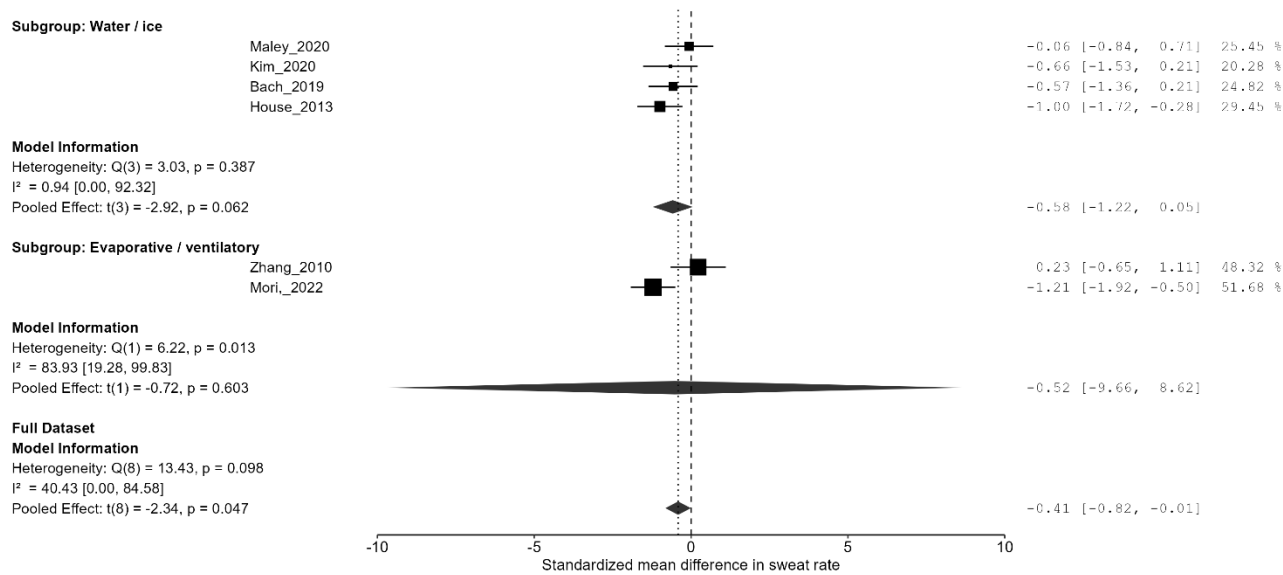


Supplement figure 23: Forest plot analysis of sweat production for within-group change comparison

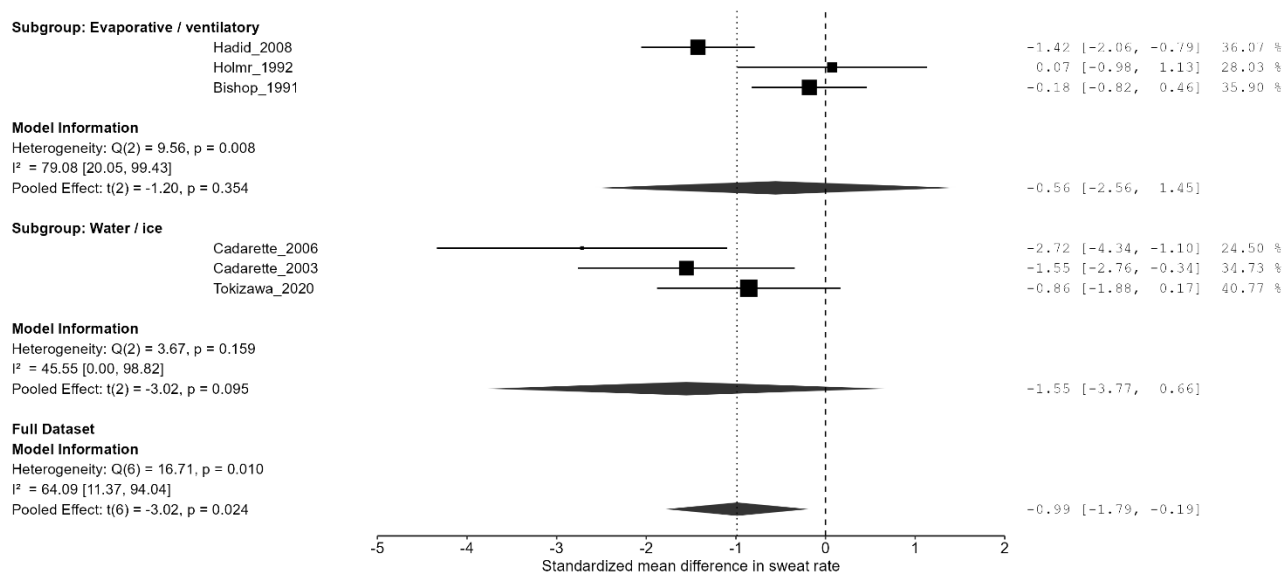


Supplement figure 24: Forest plot analysis of sweat rate for post intervention comparison

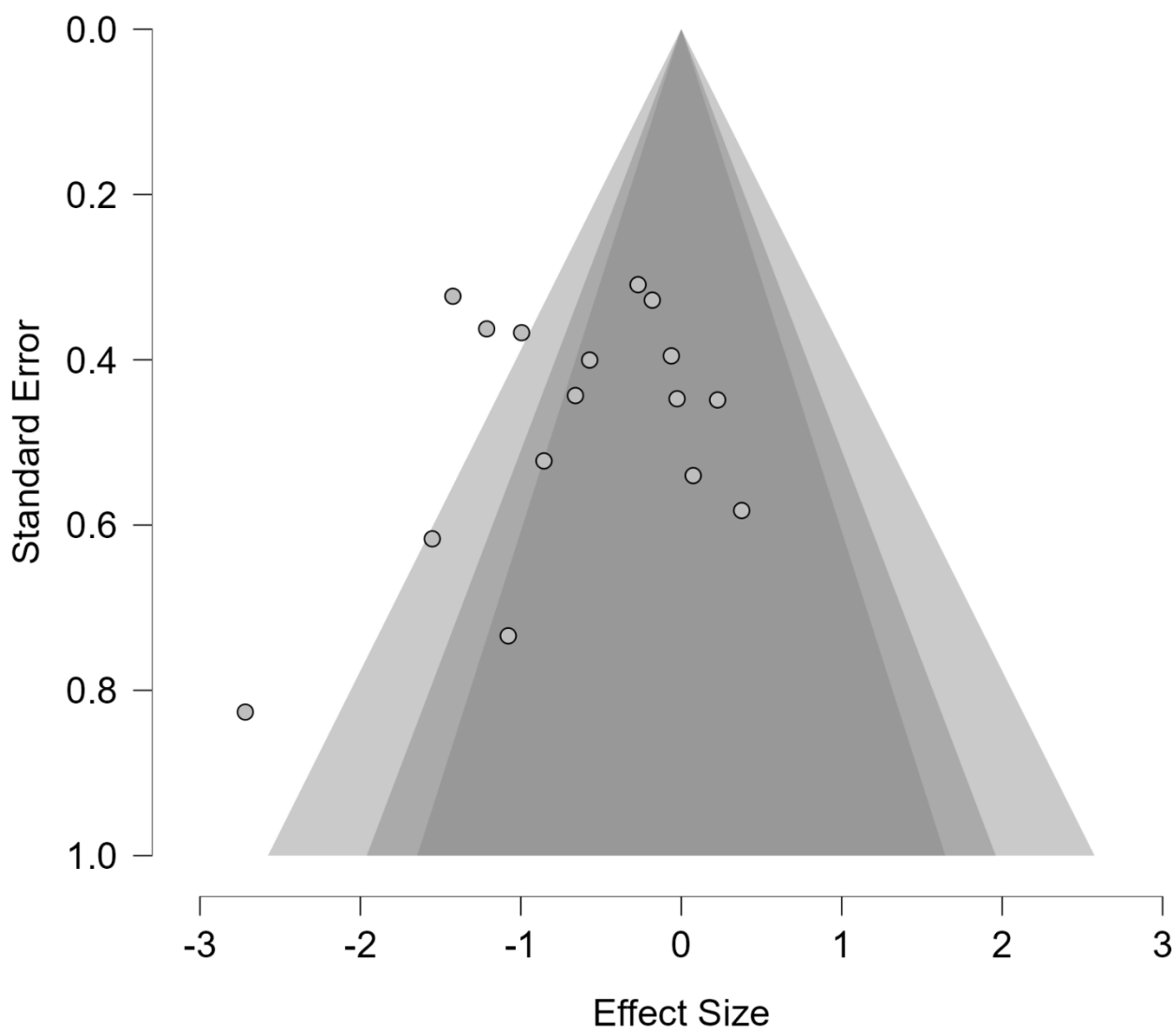
24a: RCT



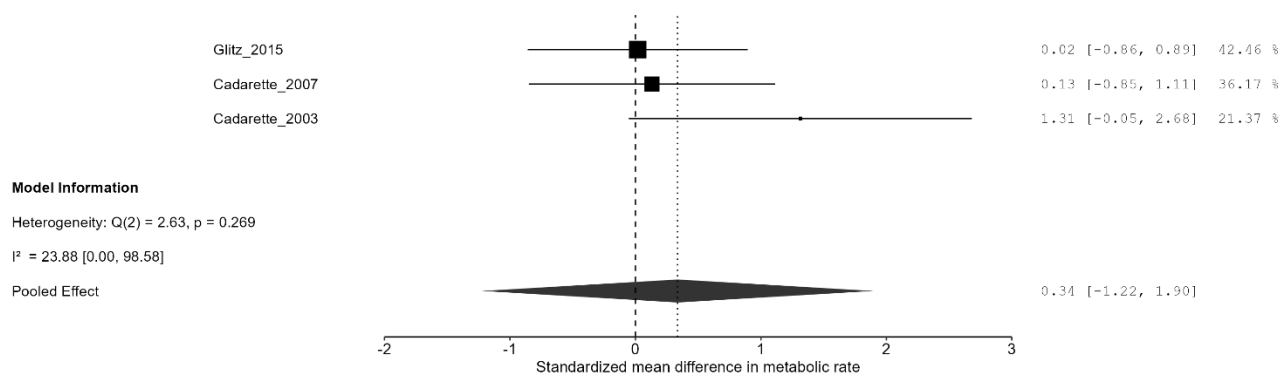
24b: Non-RCT



Supplement figure 25: Funnel plot analysis of sweat rate for post intervention comparison

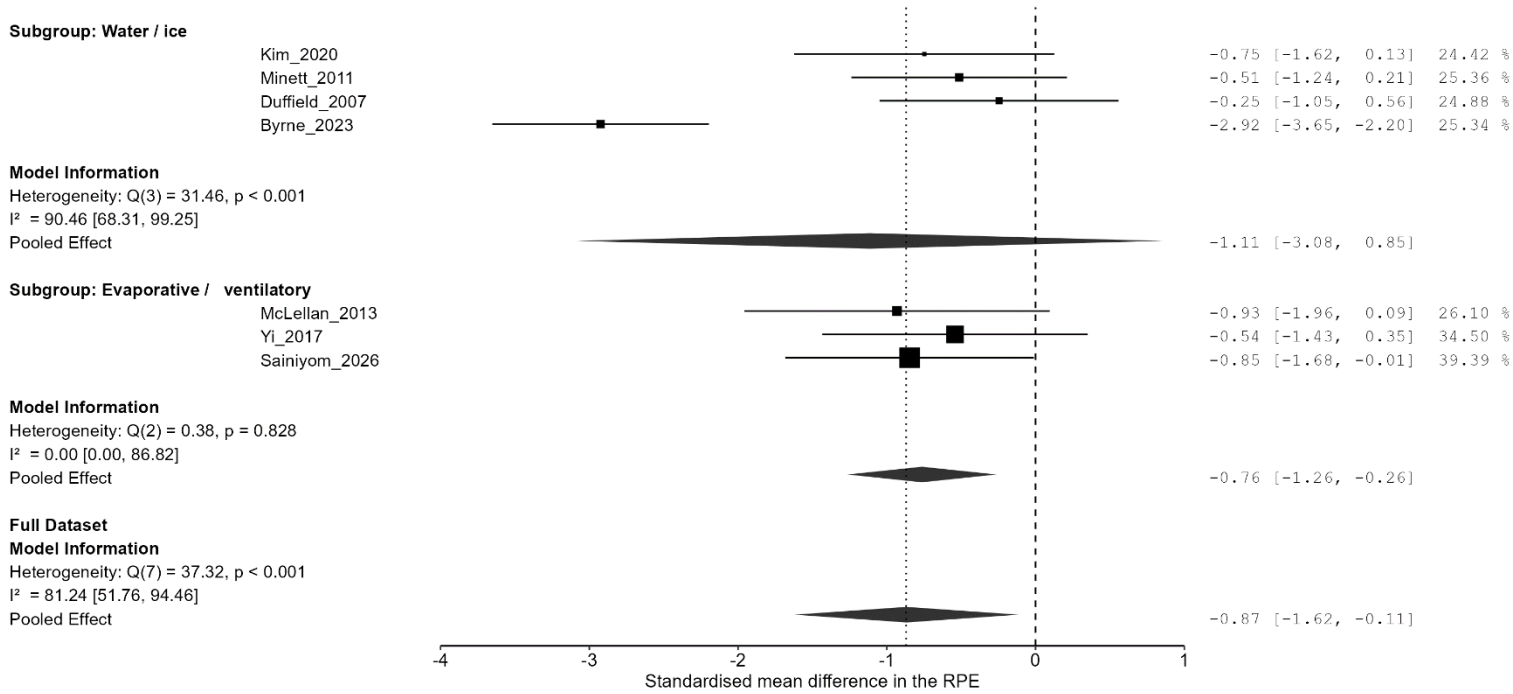


Supplement figure 26: Forest plot analysis of metabolic rate for post intervention comparison

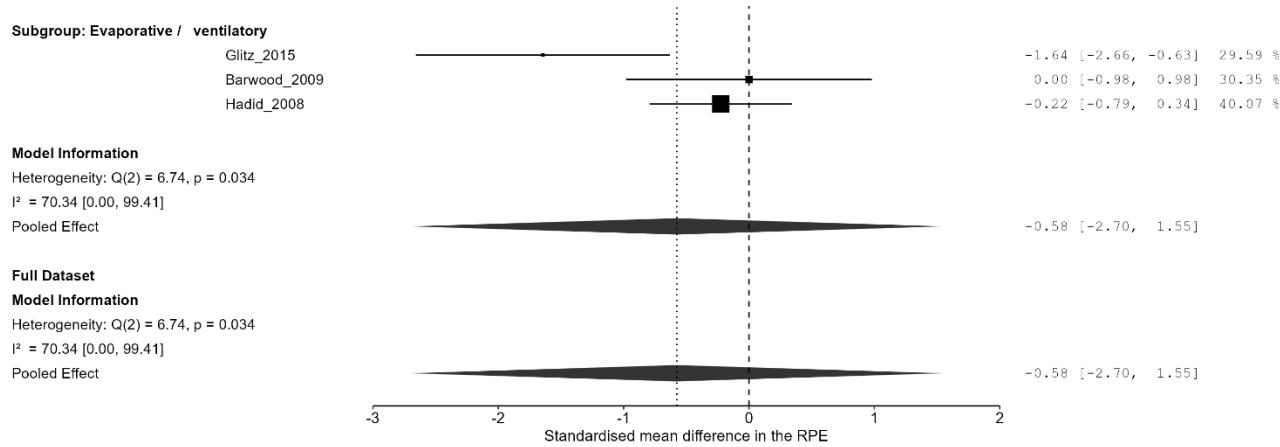


Supplement figure 27: Forest plot analysis of rating of perceived exertion (RPE) for post intervention comparison

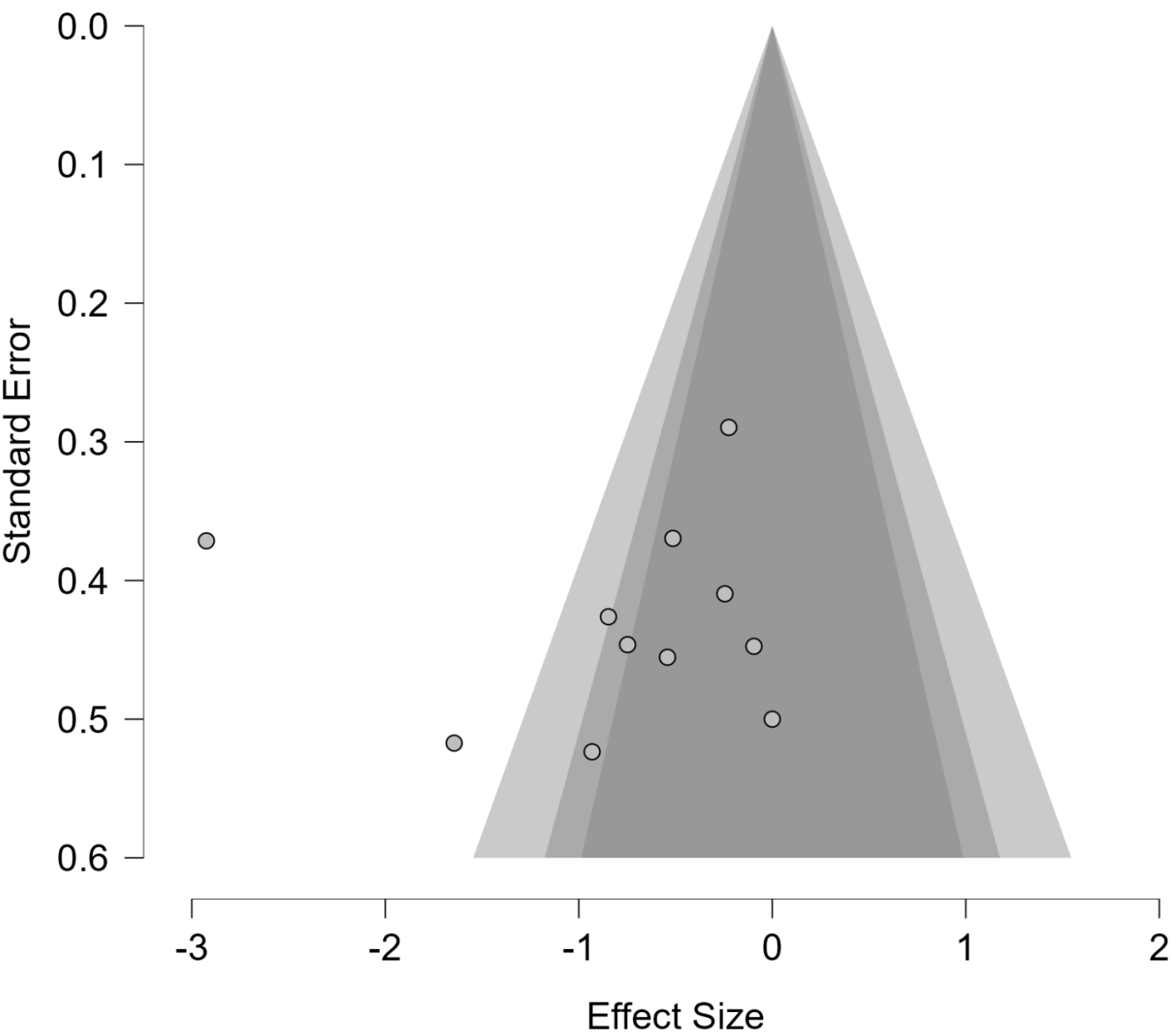
27a: RCT



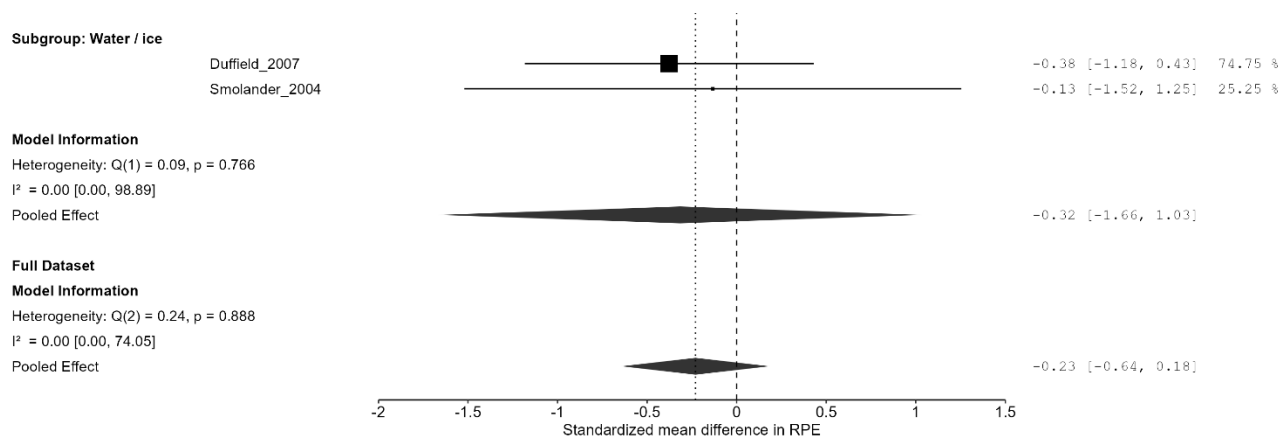
27b: Non-RCT



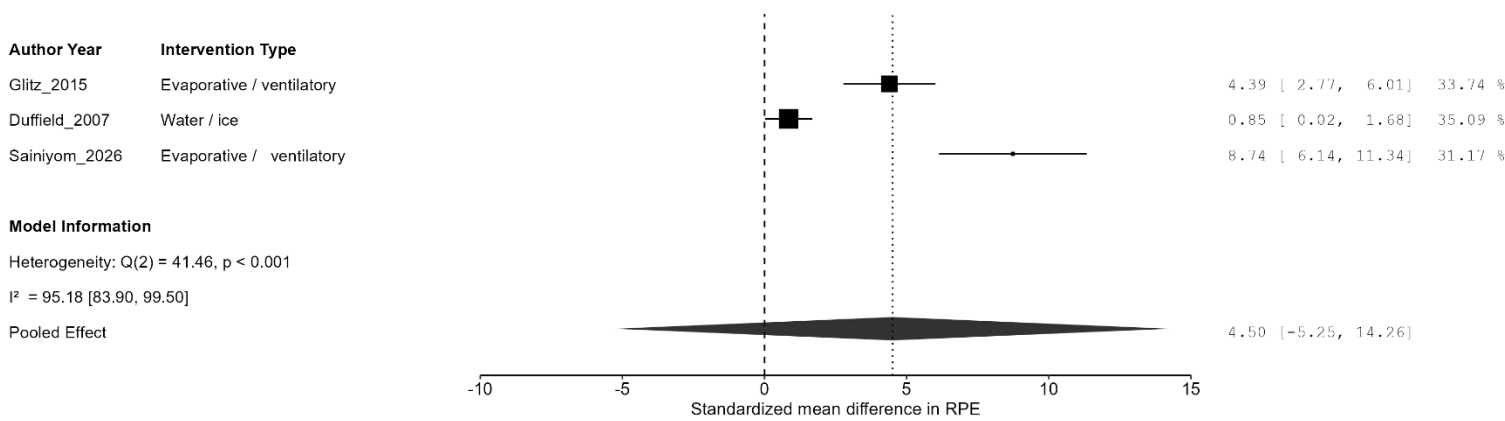
Supplement figure 28: Funnel plot analysis of rating of perceived exertion (RPE) for post intervention comparison



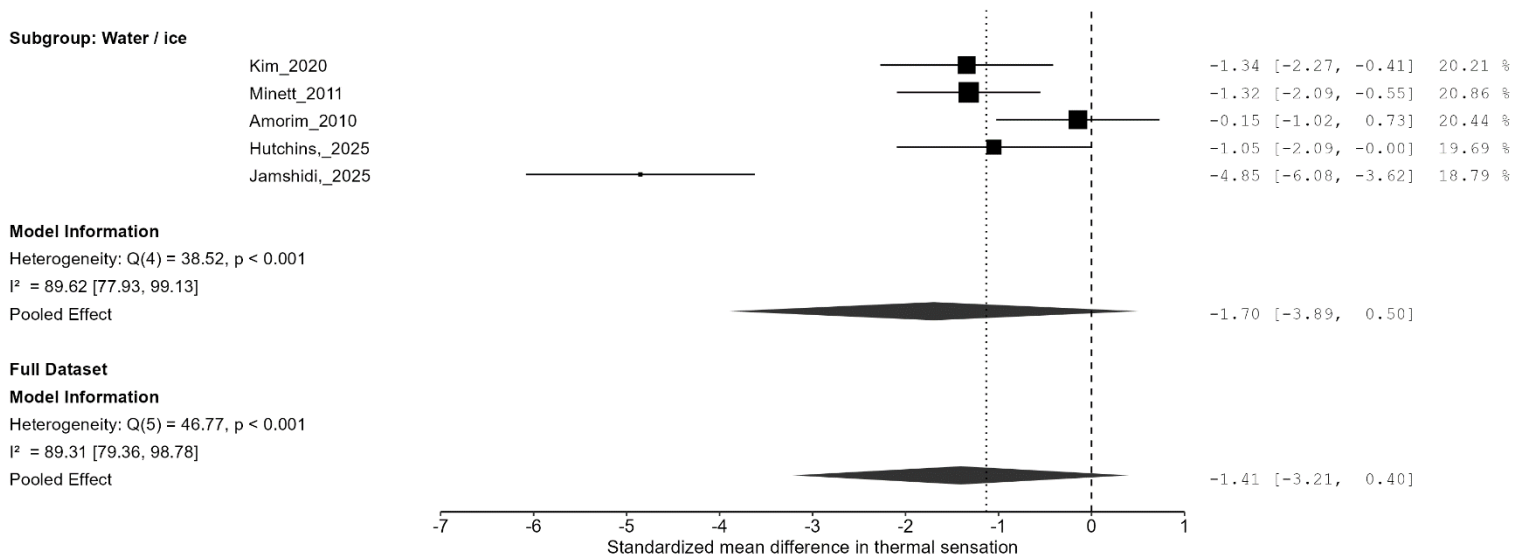
Supplement figure 29: Forest plot analysis of RPE for within-group change comparison



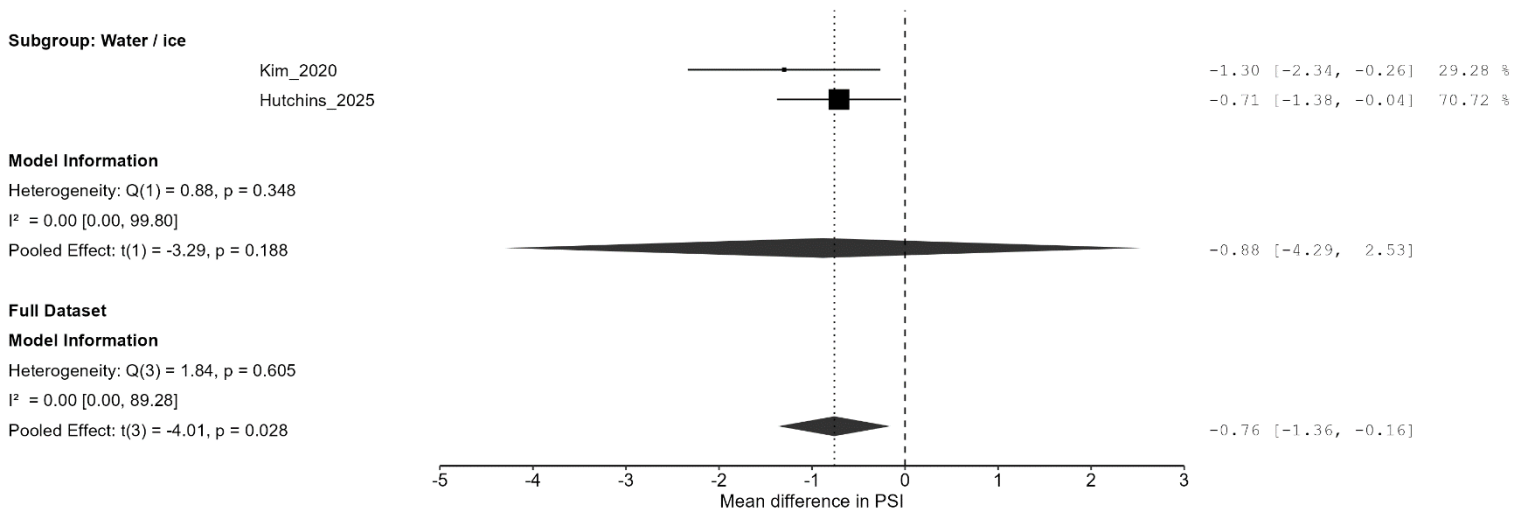
Supplement figure 30: Forest plot analysis of RPE for Change in between-Group differences over time



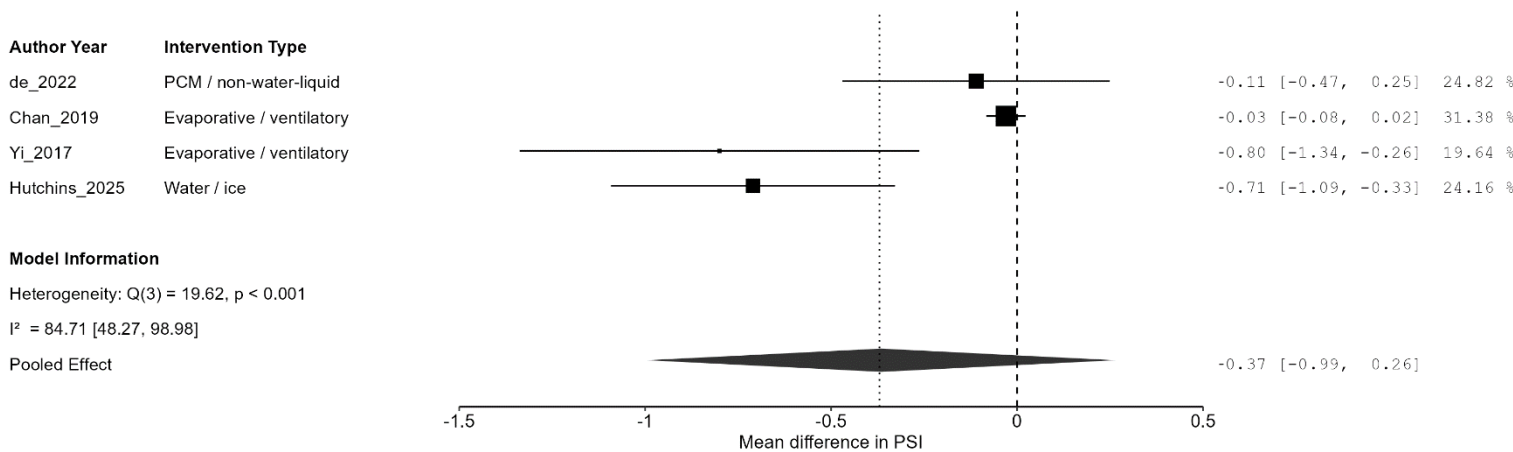
Supplement figure 31: Forest plot analysis of thermal sensation for post intervention comparison (RCT)



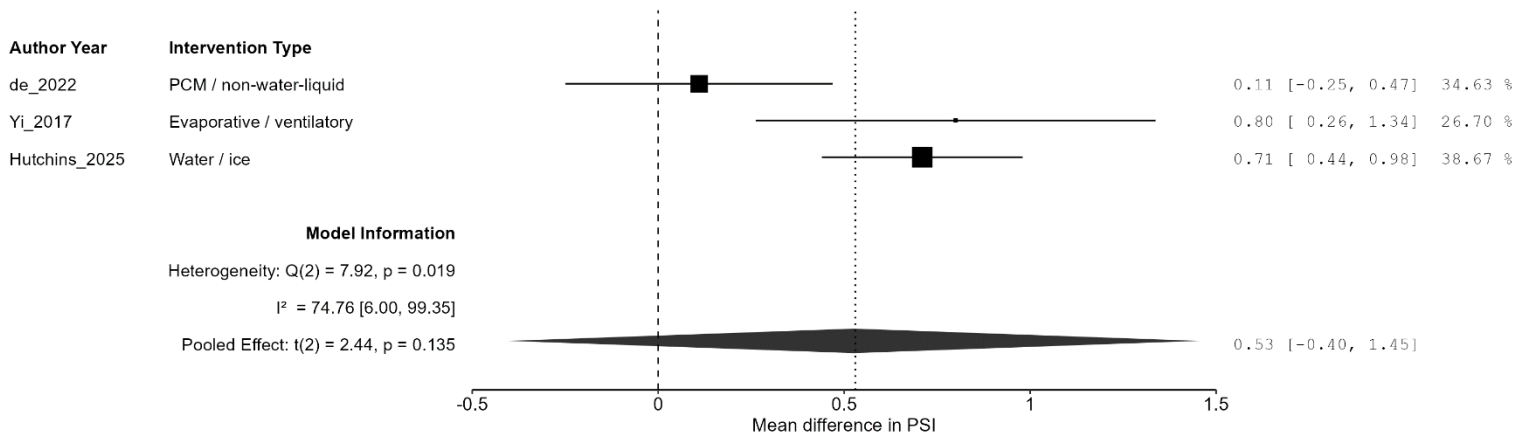
Supplement figure 32: Forest plot analysis of Physiological Strain Index (PSI) for post intervention comparison (RCT)



Supplement figure 33: Forest plot analysis of PSI for within-group (Difference of difference) comparison:



Supplement figure 34: Forest plot analysis of PSI for within-group (Difference of difference) comparison:



Supplement tables:

Supplement table 1a: Search strategy at pubmed medline digital library

| Search        | Pubmed                                                                                                                                                                                                                                                                                      | Results   |         |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|---------|
|               |                                                                                                                                                                                                                                                                                             | A*        | B*      |
| 1             | Laborer OR Worker                                                                                                                                                                                                                                                                           | 2,958,987 | 680,975 |
| 2             | (Heat stress) OR Heat                                                                                                                                                                                                                                                                       | 379,837   | 36,268  |
| 3             | Airing OR ventilation OR aeration OR (air circulation) OR (rest break) OR (work rest) OR hydration or (water drinking) OR shade OR shelter OR (cooling intervention) OR (cooling garment) OR (protective garment) OR (cooling device)                                                       | 486,041   | 48,383  |
| 1 AND 2 AND 3 | (Airing OR ventilation OR aeration OR (air circulation) OR (rest break) OR (work rest) OR hydration or (water drinking) OR shade OR shelter OR (cooling intervention) OR (cooling garment) OR (protective garment) OR (cooling device)) AND (laborer OR worker) AND ((heat stress) OR heat) | 2,753     | 733     |

Supplement table 1b: Search strategy at scopus digital library

| Search                                                                                          | Scopus                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Results   |           |
|-------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|-----------|
|                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | A*        | B*        |
| 1                                                                                               | Laborer OR Worker                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1,666,651 | 731,629   |
| 2                                                                                               | (Heat stress) OR Heat                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 4,685,308 | 2,264,671 |
| 3                                                                                               | Airing OR ventilation OR aeration OR (air circulation) OR (rest break) OR (work rest) OR hydration or (water drinking) OR shade OR shelter OR (cooling intervention) OR (cooling garment) OR (protective garment) OR (cooling device)                                                                                                                                                                                                                                      | 2,811,584 | 800,301   |
| 1 AND 2 AND 3                                                                                   | (Airing OR ventilation OR aeration OR (air circulation) OR (rest break) OR (work rest) OR hydration or (water drinking) OR shade OR shelter OR (cooling intervention) OR (cooling garment) OR (protective garment) OR (cooling device)) AND (laborer OR worker) AND ((heat stress) OR heat)                                                                                                                                                                                | 13322     | 865       |
| 1 AND 2 AND 3 with filters (excluding review, book, book chapter), (limit to human and English) | ( airing OR ventilation OR aeration OR ( air AND circulation ) OR ( rest AND break ) OR ( work AND rest ) OR hydration OR ( water AND drinking ) OR shade OR shelter OR ( cooling AND intervention ) OR ( cooling AND garment ) OR ( protective AND garment ) OR ( cooling AND device ) ) AND ( laborer OR worker ) AND ( ( heat AND stress ) OR heat ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) ) AND ( LIMIT-TO ( EXACTKEYWORD , "Human" ) ) AND ( LIMIT-TO ( SRCTYPE , "j" ) ) | 2847      | 314       |

Supplement table 1c: Search strategy at Embase digital library

| Search | Embase                | Results |        |
|--------|-----------------------|---------|--------|
|        |                       | A*      | B*     |
| 1      | Laborer OR Worker     | 160,534 | 22,543 |
| 2      | (Heat stress) OR Heat | 397,457 | 49,410 |
| 3      | 1 AND 2               | 1,538   | 406    |

\* The systematic search was undertaken during May 14, 2026 (A), subsequently the search is updated as Feb 24, 2026 (B)

Supplement table 2 Description of the individual studies

| Citation, Country                | Participant description                                                                                                          | Intervention                                                                                                                                                                                                                                                                                                                                                              | Heat stress exposure                                                                                                                                                                                                                                                                                                                      | Outcome variables                                                                                                                                                           | Study design, additional remarks |
|----------------------------------|----------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| Bach et al (2024), Thailand (21) | Total participants: 12 sawmill workers<br>Sex distribution: 58.3% male<br>Mean age: 33 ± 7 years                                 | Type: Phase Change Material (PCM)–based cooling vest (non-ice-based)<br>recharged using ~2 °C ice water<br>Timing of use: Worn during the work shift<br>Body coverage: Torso (vest)                                                                                                                                                                                       | Saw mill                                                                                                                                                                                                                                                                                                                                  | ↓Core body temperature (GI),<br>↓heart rate and ↓self-reported heat symptoms.                                                                                               | RCT cross over design.           |
| Ciuha et al (2023), Slovenia (9) | Total participants: 10 men<br>Mean age: 22 ± 4 years                                                                             | Type: Cooling vests with five different technologies<br>• Compressed air<br>• Ice & cold water,<br>• Soaked in room water temperature (evaporative)<br>• Phase changing material recharged by placing in freezer for 24 hours<br>• Hybrid: evaporative and phase changing material.<br>Timing of use: Worn during heat stress trials<br>Body coverage: Upper torso (vest) | Environment: Simulated industrial setting: 35°C and 50% relative humidity with low air flow.<br>Heat stress trial: participants were seated for 30 min to induce passive heating.<br>Participants donned the cooling vest and started a 150 minute walk on a treadmill at a speed of 4.5 km/h with the treadmill set at an incline of 1 % | ↓Core body temperature (GI* & rectal*), ↓Torso skin temperature*, ↓heart rate*, ↓sweat secretion, ↓sweat evaporation*, ↑Thermal comfort, Rating of perceived exertion (RPE) | RCT crossover design             |
| Bonell et al (2021), Gambia(8)   | Total participants: 12 healthcare workers from COVID wards<br>Sex distribution: 58.3% male<br>Mean age (males): 29.4 ± 2.6 years | Pre-cooling method: Ice slurry consumed over 15 minutes before donning PPE<br>Type: Ice vest<br>Timing of use: Worn during ~2-hour patient                                                                                                                                                                                                                                | COVID wards                                                                                                                                                                                                                                                                                                                               | Tympanic temperature, heart rate, blood pressure, urine specific gravity, ↑thermal comfort*, ↑thermal sensation*, ↓thirst                                                   | RCT cross over design            |

| Citation, Country                         | Participant description                                                                                                                                                                                                   | Intervention                                                                                                                                                                                                                                                                                                                                     | Heat stress exposure                    | Outcome variables                                                                                                                              | Study design, additional remarks |
|-------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                           | Mean age (females):<br>36.5 ± 12.2 years                                                                                                                                                                                  | care services<br>Body coverage: Torso (vest), worn over PPE kit                                                                                                                                                                                                                                                                                  |                                         | sensation*                                                                                                                                     |                                  |
| Ioannou et al (2021), Cyprus & Qatar (43) | Cyprus<br>Participants: 6 farmers<br>Mean age: 39.2 ± 11.8 years<br><br>Qatar<br>Participants: Farmers: 12<br>Mean age: 35.3 ± 8.5 years<br>Construction workers: 32<br>Mean age: 35.9 ± 7.8 years                        | Ventilated<br>Type: electric fans<br>Body coverage: torso<br>Timing of use: During work activities<br>Evaporative<br>Type: electric fans<br>Body coverage: full body<br>Timing of use: During work activities                                                                                                                                    | Construction site and agriculture farms | Core body temperature (GI),<br>↓skin temperature*,<br>↑heart rate                                                                              | RCT crossover design             |
| Chicas et al (2021), Florida, USA (22)    | Participants:<br>Control group: 17 farmers<br>Bandana group: 20 farmers (45% male)<br>Vest group: 20 farmers (48% male)<br>Combined (Bandana + Vest) group: 21 farmers (40% male)<br>Mean age (all groups): 42 ± 24 years | Type:<br>• Cooling bandana – Specialized cloth wrapped around head or neck<br>• Cooling vest – PCM-based vest covering the torso<br>• Combined – Both cooling bandana and cooling vest worn together<br>• Cooling method: Phase Changing Material (PCM)<br>Timing of use: Worn during farming activities<br>Body coverage:<br>Bandana: Head/neck | Agriculture farms                       | Total duration for which participants' core body temperature (GI) exceeded 38.0°C, and frequency of self-reported health-related illness (HRI) | RCT parallel design              |

| Citation, Country                              | Participant description                                                                                                                                                                                                                                              | Intervention                                                                                                                                                                                                                                                                                                                                            | Heat stress exposure                                                                                                                                                                                                   | Outcome variables                                                                                              | Study design, additional remarks |
|------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                                |                                                                                                                                                                                                                                                                      | Vest: Torso                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                        |                                                                                                                |                                  |
| Tay et al (2020), Singapore (46)               | <p>Control Group<br/>Participants: 13<br/>medical personnel<br/>Sex: 42.6% male<br/>Mean age: <math>35.5 \pm 7.8</math> years</p> <p>Intervention Group<br/>Participants: 10<br/>medical personnel<br/>Sex: 60% male<br/>Mean age: <math>30 \pm 6.2</math> years</p> | <p>Type: Sleeveless Carbon Cool vest (neoprene + TPU) worn over T-shirt and under PPE<br/>Cooling method: 12 graphite–water MPad inserts (15× more thermally conductive than ice)<br/>Timing: During heat stress trial<br/>Body coverage: Torso</p>                                                                                                     | Participants donned PPE for 55 minutes during physical activity in training exercise (HAZMAT operation and training)                                                                                                   | <p>↓Heart rate, blood pressure (systolic), ↓core body temperature (tympanic), ↑safety, ↑comfort, ↑mobility</p> | RCT Parallel design              |
| Maley et al (2020), Queensland, Australia (24) | <p>Total participants: 8<br/>Men<br/>Mean age: <math>24 \pm 4</math> years</p>                                                                                                                                                                                       | <ul style="list-style-type: none"> <li>Ice-based cooling vest<br/>Coverage: Torso<br/>Additional methods: With or without ice slush ingestion (pre- and per-cooling)</li> <li>PCM-based cooling vest<br/>Coverage: Torso<br/>Battery-operated water-perfused suit<br/>Coverage: Full body (jacket, trousers, hood), excluding feet and hands</li> </ul> | <p>Environment: air temperature and RH maintained at <math>35^{\circ}\text{C}</math>, 50%<br/>Heat stress trial: Walking with the chemical, biological, radiological, nuclear ensemble on a treadmill, 1% gradient</p> | <p>↓Core body temperature (rectal)*, ↓heart rate*, ↓skin temperature*, sweat rate</p>                          | RCT with Cross over design       |
| Aljaroudi et al (2020), USA (27)               | <p>Total participants: 12 men<br/>Mean age: <math>24 \pm 3.2</math> years</p>                                                                                                                                                                                        | <p>Type: Liquid cooling garment with integrated tubing<br/>Cooling method: Continuously infused with <math>18^{\circ}\text{C}</math> water<br/>Body coverage: Head, torso, forearms, and thighs</p>                                                                                                                                                     | <p>Environment: Simulated chamber at warm (<math>30^{\circ}\text{C}</math>) and humid (70% RH) condition<br/>Heat stress trial: Treadmill exercise inducing 40% <math>\text{VO}_2</math> max for 40 min</p>            | <p>↓Heart rate*, ↓core body temperature(rectal)*, ↓skin temperature*</p>                                       | RCT with cross over design       |

| Citation, Country                             | Participant description                                 | Intervention                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Heat stress exposure                                                                                                                                                              | Outcome variables                                                                                                                                                                                                              | Study design, additional remarks |
|-----------------------------------------------|---------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                               |                                                         | Timing: Worn during heat exposure trials                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                   |                                                                                                                                                                                                                                |                                  |
| Kim et al (2020), Seoul, South Korea (11)     | Total participants: 8 men<br>Mean age: 23±2.5 years     | <p>Cooling Vest Variants during Heat Stress Trial</p> <ul style="list-style-type: none"> <li>Do:<br/>Type: Vest with non-frozen sports drink<br/>Cooling method: Participants drank sports drink every 5 minutes</li> <li>Co:<br/>Type: Vest with non-frozen cooling liquid<br/>Cooling method: Passive cooling via liquid in vest</li> <li>CD:<br/>Type: Vest with frozen sports drink<br/>Cooling method: Participants drank the sports drink every 5 minutes once frozen packs melted (~10 min into exercise)<br/>Body coverage: Torso</li> </ul> | Environment: Simulated chamber with ambient air temperature of 30°C and RH of 50% while wearing the firefighting clothes.<br>Heat stress trial: Exercised for 30 min at 5.5 km/hr | <p>↓Core body temperature (rectal)*, ↓skin temperature*, ↓heart rate*, ↓blood pressure, sweat rate, ↓thermal sensation*, ↓thermal comfort*, ↓thirst sensation*, ↓urine specific gravity, ↓physiological strain index(PSI)*</p> | RCT cross over design            |
| Bach et al (2019), Queensland, Australia (20) | Total participants: 8 men<br>Mean age: 23.6 ± 3.9 years | <p>Participants underwent one of the following during the heat stress trial</p> <ul style="list-style-type: none"> <li>IV<br/>Type: Ice vest stored in - 20°C<br/>Body coverage: torso,</li> <li>PCM<br/>Type: Phase change vest with melting temperature at</li> </ul>                                                                                                                                                                                                                                                                              | Environment: simulated chamber (35.2°C, 49%RH) wearing personal protective clothing.<br>Heat stress trial: Continuous walking at 4.5km/h on a treadmill for up to 120 min         | <p>↓Core body temperature(rectal)*, ↓skin temperature*, ↓heart rate*, ↓rating of perceived exertion*, ↓thermal sensation*, ↓thermal comfort*, ↓sweat rate*,</p>                                                                | RCT cross over design            |

| Citation, Country                            | Participant description                                                  | Intervention                                                                                                                                                                                                                                                                                                                              | Heat stress exposure                                                                                                           | Outcome variables                                                                                                                                                                    | Study design, additional remarks |
|----------------------------------------------|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                              |                                                                          | 14°C<br>Body coverage: torso<br>• WS<br>Water-perfused with tubes<br>Body coverage: whole body<br>• Combination of IV + slurry<br>Type: ice vest and ingestion of 7.5 g / kg body weight of ice slurry                                                                                                                                    |                                                                                                                                |                                                                                                                                                                                      |                                  |
| Udayraj et al (2019), Hong Kong (25)         | Total participants: 8 men<br>Mean age: 22.7±1.8 years                    | Type:<br>• Meshed fabric cloth with phase changing material (PCM)<br>• PCM clothing with layer of insulation (PCM+Ins)<br>• PCM clothing with entilation fans (Hyb)<br>• PCM clothing with layer of insulation and ventilation fans (Hyb+Ins)<br>Body coverage: torso, upper and lower limbs<br>Timing: Worn during the heat stress trial | Environment: Simulated chamber with 36°C, RH=59%<br>Heat stress trial: Walking at 4.5 km/h on a motorized treadmill for 70 min | ↓Mean Skin temperature*, ↓Upper torso temperature, ↓core body temperature (GI)*, heart rate, physiological strain index (PSI), sweat production*                                     | RCT cross over design            |
| Ashtekar et al (2019), Ahmedabad, India (39) | Total participants: 29 Male construction workers<br>Mean age: 23±4 years | Type: Ice cold water based personal cooling garment vest<br>Body coverage: torso<br>Timing: Worn during the construction activity                                                                                                                                                                                                         | Construction site                                                                                                              | ↑Oral temperature*, ↓heart rate*, ↓weighted skin temperature*, ↓chest temperature, ↓back temperature, ↓torso temperature, ↓sweat loss, ↑subjective evaluation of comfort*, ↓ thermal | Non RCT crossover design         |

| Citation, Country                              | Participant description                                                        | Intervention                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Heat stress exposure                                                                                                                                                                                                | Outcome variables                                                                                   | Study design, additional remarks |
|------------------------------------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|----------------------------------|
|                                                |                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                     | sensation*,<br>↓sweating response*                                                                  |                                  |
| McQuerry et al (2018), Florida USA (75)        | Total participants: 8 male professional firefighters<br>Mean age: 35±5.7 years | Four structural turnout suits <ul style="list-style-type: none"> <li>• Modular, single layer outer shell system without moisture barrier and thermal liner</li> <li>• Active ventilation design (ventilating)</li> <li>• Suit with stretch material panels (stretch)</li> <li>• Combination suit with venting, stretch, and reduced thermal liner layers (revolutionary)</li> </ul> Body coverage: Whole body except head, feet and hands<br>Timing: worn during heat stress trial: | Environment: Simulated conditions of 24°C and 50% RH<br>Heat stress trial: Walked on a treadmill at 5.6 km/h at a 3% incline. The protocol included four cycles of alternating walking (20 min) and resting (5 min) | ↓Core temperature (GI)*, ↓skin temperature*, ↓heart rate, ↓physiological strain index*              | RCT with crossover design        |
| Zhao et al (2018), Hong Kong (26)              | Total participants: 14 Male construction workers<br>Mean age: 29 ± 3.2 years   | Type: Hybrid cooling vest composed of phase changing material (PCM) packs and ventilation fans<br>Body coverage: covering torso<br>Timing: Worn during construction activity                                                                                                                                                                                                                                                                                                        | Construction site (steel bar fixing work)                                                                                                                                                                           | ↓Core temperature*(Tympa nic), ↓thermal sensation*, ↓heart rate*, ↓rate of perceived exertion(RPE)* | Non RCT crossover design         |
| Maley et al (2017), Queensland, Australia (59) | Total participants: 8 men<br>Mean age: 23 ± 3 years                            | Type: Chemical protective clothing system with: Reduced trapped air layers and                                                                                                                                                                                                                                                                                                                                                                                                      | Environment: Simulated chamber at wet bulb globe temperature (WBGT), dry temperature (DT) and relative humidity (RH)                                                                                                | ↑Heart rate, ↑core body temperature(GI)*, ↑mean skin temperature*,                                  | RCT with crossover design        |

| Citation, Country                            | Participant description                                                        | Intervention                                                                                                                                                         | Heat stress exposure                                                                                                                                                                                                                                | Outcome variables                                                                                                                                    | Study design, additional remarks |
|----------------------------------------------|--------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                              |                                                                                | Improved water vapor permeability<br>Compared against traditional chemical protective ensembles<br>Body coverage: Full body<br>Timing: Worn during heat stress trial | respectively<br>Neutral: 21°C WGBT, 24°C DT & 50% RH<br>Warm wet: 30°C WGBT, 32°C DT & 60% RH and<br>Hot dry: 37°C WGBT, 48°C DT & 20% RH<br>Heat stress trial: Walking for up to 120 min on a motorized treadmill at 4 km/h and 1% gradient inside | ↓thermal sensation, ↑thermal comfort, ↑rating of perceived exertion*                                                                                 |                                  |
| Chan et al (2017), Hong Kong (30)            | Total participants: 140 male construction workers<br>Mean age: 32.1±9.1 years  | Type: Hybrid cooling vest, combination of phase change materials and air ventilation fans<br>Body coverage torso,<br>Timing: Worn during construction activity       | Construction industry, tested under<br>15 minutes rest in the forenoon and<br>30 minutes rest in the afternoon                                                                                                                                      | ↓Heart rate*, ↓thermal sensation*, ↑thermal comfort*, ↓rate of perceived exertion(RPE)*, ↓perceptual heat strain index(PeSI)*.                       | Non RCT cross over design        |
| Ashtekar et al (2016), Ahmedabad, India (45) | Total participants: 24 male iron foundry workers<br>Mean age: 30.92 ±6.9 years | Type: Personal cooling garments, cooled by ice-chilled liquid<br>Body coverage: torso<br>Timing: worn during the activity                                            | Iron foundry worksite                                                                                                                                                                                                                               | ↓Heart rate, ↓Weighted skin temperature*, ↓oral temperature, ↓chest temperature*, ↓back temperature, ↓sweat loss*, ↑thermal comfort*, blood pressure | Non RCT cross over design        |
| Sefton et al (2016), USA (32)                | Total participants: 35 men<br>Mean age 28.3±4.23 years.                        | Type: Cooling towel<br>Body coverage: placed on neck and shoulders<br>Timing: After 10 minutes of exercise.                                                          | Environment: Simulated chamber for the control group Temperature 32.04°C ± 0.54°C. Relative humidity 75.15% ±2.7%.<br>For intervention trial: Temperature 32.04°C ±                                                                                 | Core temperature (rectal), ↓heart rate*, blood pressure, thermal comfort, perceived temperature, perceived wetness                                   | RCT with crossover design        |

| Citation, Country                    | Participant description                                                                                        | Intervention                                                                                                                                                                                         | Heat stress exposure                                                                                                                                                                                                                  | Outcome variables                                                                                                                 | Study design, additional remarks |
|--------------------------------------|----------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                      |                                                                                                                |                                                                                                                                                                                                      | 0.64°C. Relative humidity 75.91% ±2.4%<br>Heat stress trial: Participants ran at 60% VO <sub>2</sub> max until core temperature was either 1.5 °C above the baseline measurement or 39°C.                                             |                                                                                                                                   |                                  |
| Bartkowiak et al (2017), Poland (71) | Total participants: 6<br>Male volunteers<br>Mean age of 24.7 ± 1.2 years                                       | Type: Liquid cooling garments with circulating cold water, within knitted fabric<br>Body coverage: Torso, both arms<br>Timing: worn during the heat stress trial                                     | Environment: Simulated chamber at air temperature: 30.0±0.4°C, relative humidity 40.0±0.2%<br>Heat stress trial: Standing (10 min), walking at 2.5 km/h (15 min) & 3.5 km/h (15 min), standing (10 min) and walking 2.5 km/h (10 min) | Heart rate, skin temperature*, ↓core body temperature (tympanic temperature)*, skin wetness, ↓thermal sensation, Sweat production | Non RCT crossover design         |
| O'Hara et al (2016), USA (80)        | Total participants: 12<br>army men<br>Mean age: 25.42 ± 2.84 years                                             | Type: Cooling garment: made from moisture-wicking fabric with flame-resistant cryotherapy inserts<br>Body coverage: chest and back (covering the torso)<br>Timing: Worn during the heat stress trial | Environment: Simulated dry heat conditions at 35°C and 50% relative humidity.<br>Heat stress trial: Walked for 60-minute on treadmill with 2% inclination wearing a 50-pound vest                                                     | ↓Core body temperature (GI)*, heart rate, subjective rate of perceived exertion, capillary blood lactate                          | RCT cross over design            |
| Chan et al (2016), Hong Kong (54)    | Total participants: 12<br>Construction workers<br>Sex distribution: 96.2% males<br>Mean age: 34.3 ± 10.3 Years | Type: Thin, vapor-permeable, and breathable fabrics with good sweating, transfer function and protection (UV protection),<br>Body coverage: Whole body Uniform (except                               | Environment: Simulated at 34.5 °C and 75% RH. Heat stress trial: Resting phase for 30 min seated<br>Warm-up by walking for 3 mins each at 6, 8 and 6 km/h<br>Work simulation by walking                                               | ↓Core temperature (GI)*, ↓skin temperature*, skin relative humidity, sweat rate                                                   | RCT with crossover design        |

| Citation, Country                                      | Participant description                                | Intervention                                                                                                                                                                                                                                                                | Heat stress exposure                                                                                                                                                                                                                         | Outcome variables                                                                                                                                 | Study design, additional remarks |
|--------------------------------------------------------|--------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                                        |                                                        | head, forearms, hand and feet)<br>Timing: Worn during the heat stress trial                                                                                                                                                                                                 | at 8.5 & 5 km/h alternatively until core body temperature is 38.6 and max heart rate for corresponding age & sex.<br>Active recovery by walking for 3 min each at 3.5 and 2 km/h alternatively<br>Passive recovery by 30 min seated on chair |                                                                                                                                                   |                                  |
| Glitz et al (2015), Rhineland-Palatinate, Germany (35) | Total participants: 10 men<br>Mean age: 25.3±7.3 years | Type: Air-diffusing garment (suit) that includes a three-dimensional space knitted fabric with a stellate tube system for dry air ventilation<br>Body coverage: Whole body (chest, back, upper arms, forearms, thighs and calves)<br>Timing: Worn during heat stress trial. | Environment: Simulated at 25 °C (air temperature), 50% relative humidity, and 0.2 m/s wind speed<br>Heat stress trial: Alternate marching for 30 min at 3 km/h at 5% inclination and rested for 10 min, for 3 cycles                         | ↓Core body temperature (GI)*, ↓skin temperature*, ↑metabolic rate, ↓sweat loss*, ↓self-perceived heat burden*, evaporated heat loss*, ↓heart rate | Non RCT cross over design        |
| Teunissen et al (2014), Netherlands (76)               | Total participants: 9 men<br>Mean age 31 ±11 years     | Type: Vest with<br>• Cooling pads soaked in water<br>• tubed vest, connected to a backpack with two frozen bottles<br>Body coverage: torso<br>Timing: Worn during the heat stress trial                                                                                     | Environment: Simulation at 30 °C, 50% relative humidity. Heat stress trial: Participants habituated for 30 minutes, and walked for 30 min at 6km/h on treadmill followed by rest for 10 minutes                                              | ↓Core body temperature (rectal), ↓skin temperature*, ↓heart rate, rate of perceived exertion, ↓thermal sensation, ↓thermal comfort                | Randomized cross over design     |
| Jovanovi et al (2014), Serbia                          | Total participants: 10 male soldiers Mean              | Type: Four types of cooling systems                                                                                                                                                                                                                                         | Environment: Simulated at 40°C, relative humidity 30 ±                                                                                                                                                                                       | ↓Core body temperature                                                                                                                            | Non-random cross over trial      |

| Citation, Country                       | Participant description                                 | Intervention                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Heat stress exposure                                                                                         | Outcome variables                                                                                                                     | Study design, additional remarks |
|-----------------------------------------|---------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| (73)                                    | age: 25.8±2.4 years                                     | <ul style="list-style-type: none"> <li>• Phase change material (A): Vest with crystal balls which swell into biodegradable viscose, when soaking in water.</li> <li>• Phase change material- (T): Vest with cooling packs with the ability to freeze at 18.3°C.</li> <li>• Phase change material (S): Vest with mixture sealed in aluminium wrapper activated at 28°C</li> <li>• Cooling underwear (O): Made of non-toxic paraffin microcapsules wrapped by melamine-formaldehyde polymer</li> </ul> Body coverage: worn under protective clothing<br>Timing: During walking on treadmill | 3%.<br>Heat stress trial: Participants walked on treadmill at 5.5 km.h speed.                                | (tympanic)*, ↓skin temperature*, ↓heart rate, ↓sweat rate*                                                                            |                                  |
| McLellan et al (2013), Canada (34)      | Total participants: 6 men<br>Mean age: 26.8±4.4         | Type: Protective assault uniform (PTAU) with two different fabrics (details unavailable) <ul style="list-style-type: none"> <li>• PTAU-A</li> <li>• PTAU-B</li> </ul> Body coverage: full body<br>Timing: During walking on treadmill                                                                                                                                                                                                                                                                                                                                                     | Environment: Simulated at 35.8°C, 30% relative humidity. Heat stress trial: Participants walked for 90 mins. | ↓Core body temperature(rectal)*<br>↓heart rate*, ↓skin temperature*, ↓rate of perceived exertion(RPE)*, ↑thermal comfort*, Sweat rate | RCT cross over design            |
| House et al (2013), United kingdom (23) | Total participants: 10 men<br>Mean age 28.8 ± 6.9 years | Type: 4 types of Vests <ul style="list-style-type: none"> <li>• Ice</li> <li>• PCM: that melts at 10°C</li> <li>• PCM: that melts at 20°C</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                      | Environment: Simulated at 40°C dry bulb and 29.5°C wet bulb and 46 % relative humidity (RH)                  | ↓Core body temperature (rectal), ↓skin temperature (abdomen, chest),                                                                  | RCT cross over design            |

| Citation, Country                     | Participant description                                               | Intervention                                                                                                                                                                                                                                                                                                                                                                                 | Heat stress exposure                                                                                                                                                                                                                                                | Outcome variables                                                                                                                                                      | Study design, additional remarks |
|---------------------------------------|-----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                       |                                                                       | <ul style="list-style-type: none"> <li>PCM: that melts at 30°C</li> </ul> Body coverage: Torso-tabard style<br>Timing: Wore during heat stress trial                                                                                                                                                                                                                                         | Heat stress trial:<br>Participants stepping on a 2.5 cm box at a rate of 12 complete steps per minute for 45 min                                                                                                                                                    | ↓VO <sub>2</sub> , ↓Heart rate(HR)*, ↓skin blood flow, ↓body heat storage*, ↓sweat production, ↓sweat evaporation                                                      |                                  |
| Kim et al (2011), Pittsburg, USA (28) | Total participants: 6 men<br>Mean age 30.5 ± 6.8 years                | Type: 2 variants of Liquid cooling garments, cooled by circulating cold water<br>Top Cooling Gear (TCG): Cooled water circulates through head and forearm sections<br>Short Cooling Gear (SCG): Extends coverage to torso (chest, back, side abdomen) and thighs<br>Body coverage: TCG: Head and forearms<br>SCG: Head, forearms, torso, and thighs<br>Timing: Worn during heat stress trial | Environment: Simulated at air temperature of 35.8°C and relative humidity 50%.<br>Heat stress trial: Participants stabilized, warmed up (2 min) and performed alternative exercises on treadmill at 75% VO <sub>2</sub> Max(15 min) and rest for 10 min. (3 cycles) | Body core temperature (rectal), mean skin temperature*, heart rate, physiological strain index*, thermal comfort*, heat perception*, fatigue, overall body discomfort* | RCT cross over design            |
| Kim et al (2011), Pittsburg, USA(29)  | Total participants: 6 male firefighters<br>Mean age: 30.5 ± 6.8 years | Type and body coverage: The liquid cooling garments are cooled by circulating cold water (CG)<br>Air ventilation using the SCBA air exhaust system (AV) <ul style="list-style-type: none"> <li>Top cooling garment (TCG): Covers head and forearm</li> <li>TCG + AV</li> <li>Short Cooling Garment</li> </ul>                                                                                | Environment: Simulated at air temperature of 35.8°C and relative humidity 50%.<br>Heat stress trial: Participants stabilized, warmed up (2 min) and performed alternative exercises on treadmill at 75% VO <sub>2</sub> Max(15 min) and rest for 10 min. (3 cycles) | ↓Core body temperature (rectal)*, skin temperature, ↓heart rate*, ↓sweat rate*, performance time*, ↓subjective heat perception*, subjective fatigue                    | RCT cross over design            |

| Citation, Country                               | Participant description                                                                                                                     | Intervention                                                                                                                                                                                                                                                                                                                                                                        | Heat stress exposure                                                                                                                                                                                                     | Outcome variables                                                                                                              | Study design, additional remarks |
|-------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                                 |                                                                                                                                             | (SCG): additionally covers torso (chest, back, side abdomen) and thigh<br>• SCG+AV<br>Timing: During the heat stress trial.                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                          |                                                                                                                                |                                  |
| Minett et al (2011), Queensland, Australia (31) | Total participants: 10 male sports athletes<br>Mean age: 20.9 ± 2.6 years                                                                   | Type and body coverage:<br>• Head and neck (H) is cooled using towel soaked in cold water (5.0°C ± 0.5°C)<br>• Head and Hand (HH): Participants in addition to H dipped hand in cold water 9.0°C ± 0.5°C (HH)<br>• Whole body (WB): Additional to HH participants wore ice vest and cooled quadriceps using ice packs<br>Timing: Before heat stress trial and during recovery phase | Environment: Simulated hot condition of 33.0°C to 0.7°C and 33.3% to 3.9% relative humidity. Heat stress trial: Participants performed 2 spells of sprint on a 20 m running track separated by a 15 min recovery period. | ↓Core body temperature (GI)*, ↓skin temperature*, ↓heart rate*, ↓rate of perceptual exertion*, ↓thermal sensation*, sweat loss | RCT cross over design            |
| Colburn et al (2011), Pittsburgh, USA (33)      | Total participants: 9 Firefighters in control and 11 in the intervention group.<br>Sex distribution: 92% male<br>Mean age: 30.6 ± 6.4 years | Type: Ice water-soaked cooling vest<br>Body coverage: Torso and partially the arms<br>Timing: After heat stress trial                                                                                                                                                                                                                                                               | Live fire training evolution lasting approximately 20 minutes                                                                                                                                                            | Core temperature* (GI), heart rate*, mean skin temperature, rate of perceived exertion, and perceptions of thermal sensation   | RCT parallel design              |
| Barr et al (2011),                              | Total participants: 7                                                                                                                       | Type and body coverage:                                                                                                                                                                                                                                                                                                                                                             | Environment: Simulated at                                                                                                                                                                                                | ↓Core body                                                                                                                     | RCT cross                        |

| Citation, Country                     | Participant description                                                                                 | Intervention                                                                                                                                                                                                             | Heat stress exposure                                                                                                                                                                                                                                                                                                                                                                                              | Outcome variables                                                                                                                                                                          | Study design, additional remarks |
|---------------------------------------|---------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| UK (47)                               | male firefighters<br>Mean age of $40 \pm 6$ years                                                       | <ul style="list-style-type: none"> <li>Vest containing ice packs covered the torso,</li> <li>Ice vest combined with hand/forearm immersion (Vest+W)</li> </ul> Timing: After heat stress trial                           | temperature $49.6 \pm 1.3^{\circ}\text{C}$ and relative humidity $13 \pm 2\%$ ,<br>Heat stress trial: participants walked on treadmill at 5km/h and gradient of 7.5% for 20 min                                                                                                                                                                                                                                   | temperature (GI)*, $\downarrow$ heart rate*, mean $\downarrow$ skin temperature*, $\uparrow$ Rate of perceived exertion, $\downarrow$ thermal sensation*, $\downarrow$ sweat loss          | over design                      |
| Amorim et al (2010) , USA (81)        | Total participants: 10 non-smoking subjects,<br>Sex distribution: 80% men<br>Mean age: $25 \pm 3$ years | Type: Vest perfused by cold water, chilled by an electrolytic chiller to 15 to $16^{\circ}\text{C}$ is perfused at a rate of 0.6 L/min with<br>Body coverage: Thorax<br>Timing: Worn during and after heat stress trial. | Environment: Simulated at $42 \pm 18^{\circ}\text{C}$ , relative humidity of $30 \pm 5\%$ 0.8 ms <sup>-1</sup> air velocity.<br>Heat stress trial: Participants walked at 5.6 km/h at 0% steep for 5 min, followed by 6.7km.h at 4% steep until core temperature reached $38.5^{\circ}\text{C}$ , rested for 40-44 minutes and resumed the same activity until core body temperature reached $39^{\circ}\text{C}$ | $\downarrow$ Core body temperature (rectal)*, $\downarrow$ skin temperature (chest), $\downarrow$ thermal comfort*, $\downarrow$ heart rate*, $\downarrow$ heat storage*                   | RCT cross over design            |
| Zhang et al (2010), Alabama, USA (65) | Total participants: 10 men<br>Mean age: $26 \pm 3$ years                                                | Type: Liquid carbon dioxide cooling shirt (CC)<br>Body coverage: Torso and semi arm sleeve<br>Timing: Worn during heat stress trial                                                                                      | Environment: Simulated at $30^{\circ}\text{C}$ wet bulb globe temperature ( $33^{\circ}\text{C}$ dry bulb, $29^{\circ}\text{C}$ wet bulb, $33^{\circ}\text{C}$ globe, relative humidity of 75%.<br>Heat stress trial: Participants performed leg and arm work at their predetermined treadmill inclination and arm curl pace.                                                                                     | $\downarrow$ Core body temperature (rectal)*, $\downarrow$ skin temperature, $\downarrow$ heart rate*, $\downarrow$ heat storage*, $\downarrow$ sweat rate, $\downarrow$ sweat evaporation | RCT cross over design            |
| Wickwire et al                        | Total participants: 10                                                                                  | Type: Cooling pad                                                                                                                                                                                                        | Environment: Simulation to                                                                                                                                                                                                                                                                                                                                                                                        | Core body                                                                                                                                                                                  | Non- RCT                         |

| Citation, Country                         | Participant description                             | Intervention                                                                                          | Heat stress exposure                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Outcome variables                                                                                                                                   | Study design, additional remarks |
|-------------------------------------------|-----------------------------------------------------|-------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| (2009), USA (63)                          | men<br>Mean age: 26±5.8 years                       | fastened to the helmet<br>Body coverage: Head<br>Timing: During the heat stress trial                 | heat at 35.2±0.3°C, (wet temperature 33.79±1.03 °C, dry temperature of 38.47±1.08°C, globe temperature of 38.43±1.04°C), relative humidity of 38.05±7.3%, and air flow of ~6 km/hr.<br>Heat stress trial:<br>Participants walked on a treadmill at a speed of 4.8 km/hr and 0% grade for ~2 hr with intermittent breaks every 12–15 min. The participants also performed 10 biceps curls with 14.3 kg during the breaks. The intermittent breaks lasted for ~ 3 min. | temperature (rectal), ↑skin temperatures (forehead), heart rate, ↓rating of perceived helmet temperature*                                           | cross over design                |
| Barwood et al (2009), United Kingdom (48) | Total participants: 8 men<br>Mean age: 19±1.5 years | Type: Ventilated vest blowing ambient air<br>Body coverage: Torso<br>Timing: During heat stress trial | Environment: Simulated Hot (45°C), dry (10% RH) ambient conditions.<br>44.8 (0.7)°C and 9.5 (1)% RH in the vest condition and 45.0 (0.3)°C and 9.4 (1)% RH in the no vest condition<br>Heat stress trial: Participant walked on a treadmill at 5 km/h and 2% incline and completed cycles of exercise and rest according to their deep body temperature status for a maximum of 6 h.                                                                                 | ↓Core body temperature (rectal)*, ↓skin temperature (arm, chest*, back*, thigh), ↑sweat evaporation, rating of perceived exertion, ↓thermal comfort | Non- RCT cross over design       |
| Choi et al (2008),                        | Total participants: 12                              | Type and body coverage:                                                                               | Environment: Simulated at a                                                                                                                                                                                                                                                                                                                                                                                                                                          | ↓Core body                                                                                                                                          | RCT cross                        |

| Citation, Country                                 | Participant description                                                      | Intervention                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Heat stress exposure                                                                                                                                                                                                         | Outcome variables                                                                                                                                          | Study design, additional remarks |
|---------------------------------------------------|------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| Seoul South Korea (55)                            | men<br>Mean age: 25.4 ±1.6 years                                             | <ul style="list-style-type: none"> <li>• Neck scarf (A) with frozen gel pack (17 x 4 cm), cooling 0.37 % body surface area.</li> <li>• Neck scarf (B): with the frozen gel pack (14 x 11 cm), cooling 0.83 % body surface area</li> <li>• Hat with face-shade and frozen gel pack.</li> <li>• Vest: Frozen gel pack in contact with chest and back.</li> <li>• Hat + Neck Scarf B</li> <li>• Hat + Vest</li> <li>• Hat + Neck Scarf B + Vest.</li> </ul> Timing: During heat stress trial | temperature of 33 ± 0.5°C and 65 ± 5% RH of air humidity. Heat stress trial: Consisted of 120 min total with two bouts of 50 min of harvest work with 10 min of rest.                                                        | temperature (rectal)*, ↓skin temperature*, ↓heart rate*, ↓sweat rate*, ↓physiological strain index*, ↓heat storage*, ↓thermal sensation, ↑thermal comfort  | over design                      |
| Hadid et al (2008), Israel (44)                   | Total participants: 12 men<br>Mean age: 22.4 ± 2.3 years                     | Type: Cooling vest integrated with blower<br>Body coverage: Torso,<br>Timing: Worn during heat stress trial                                                                                                                                                                                                                                                                                                                                                                               | Environment: Simulated 2 conditions<br>Generate a flow of air at 40°C with 40% RH<br>Generate a flow of air at 35°C with 60% RH<br>Heat stress trial: Participant walked for 100 min on treadmill at 5 km/h with 2% incline. | ↓Core body temperature (rectal)*, ↓skin temperature*, ↓heart rate*, ↓heat storage, ↓sweat rate*, ↓physiological strain index*, ↓rate of perceived exertion | Non-RCT cross over design        |
| Cadarette et al (2007), Afghanistan and Iran (53) | Total participants: 4 Male acclimatized soldiers<br>Mean age: 21.5±1.9 years | Type: RTI (Reflectec™) thermal inserts reflecting the heat irradiation<br>Body coverage: Vest (torso) and helmet (head)<br>Timing: During the heat                                                                                                                                                                                                                                                                                                                                        | Environment: Simulated at 40.0°C dry bulb Temperature, 12.4°C dew point Temperature, and 1.0 m/s wind speed.<br>Heat stress trial:                                                                                           | ↓Core body temperature (rectal)*, ↓heart rate*, ↓sweat rate, ↓Physiological strain index*, ↓heart rate*                                                    | Non-RCT cross over design        |

| Citation, Country                     | Participant description                                            | Intervention                                                                                                                                                                               | Heat stress exposure                                                                                                                                                                                                | Outcome variables                                                                                                                        | Study design, additional remarks |
|---------------------------------------|--------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                       |                                                                    | stress trial,                                                                                                                                                                              | Participants walked on treadmill for 100 min (continuous exercise) at 1.56 m/s, 0% grade.<br>With supplementary irradiance<br>Without supplementary irradiance                                                      |                                                                                                                                          |                                  |
| Duffield et al (2007), Australia (72) | Total participants: 9 male rugby players<br>Mean age: 21.4±3 years | Type and body coverage:<br>• Ice vest covering the torso<br>Participants immersed in cold water (14 ± 1°C) for 15-min followed by donning ice-vest<br>Timing: During the heat stress trial | Environment: Simulated hot / warm condition (32 ± 1°C and 30 ± 3% humidity)<br>Heat stress trial: Participants ran on synthetic track for 20 min with speed increments each minute and 5 min of passive stretching. | ↓Core body temperature (GI)*, ↓skin temperature*, ↓sweat loss*, ↓heart rate, rate of perceived exertion, heat storage, ↓thermal comfort* | RCT cross over design            |
| Cadarette et al (2006), USA (51)      | Total participants: 4 men<br>Mean age: 26±9 years                  | Type: Liquid cooling garment cooled with water at 21°C.<br>Body coverage: head, torso, and legs,<br>Timing:<br>• Constant cooling<br>• Intermittent cooling at 2-minute intervals.         | Environment: Simulated at 35°C, 50% relative humidity.<br>Heat stress trial: Participants walked for 80 min on a treadmill at 1.36 m/s, 2% grade                                                                    | ↓Core body temperature (Rectal)*, ↓skin temperature*, ↓sweat rate*, ↓heart rate*, ↓physiological strain index *                          | Non-RCT cross over design        |

| Citation, Country                          | Participant description                                                                                                                                                                                                                                                                                                                                                                  | Intervention                                                                                                                                  | Heat stress exposure                                                                                                                                                                                                                                                                       | Outcome variables                                                                                                                                        | Study design, additional remarks |
|--------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| Smolander et al (2004), Sweden (79)        | Total participants: 4<br>Experienced firefighters<br>Mean age $36 \pm 3.33$ years                                                                                                                                                                                                                                                                                                        | Type: Ice vest<br>Body coverage: Torso<br>Timing: During the heat stress trial                                                                | Environment: Simulated air temperature at $45^{\circ}\text{C}$ and relative humidity 30%.<br>Heat stress trial: Participants walked on a treadmill for 30 minutes twice at moderate exercise intensity (4 km/hr, $0^{\circ}$ inclination),                                                 | ↓Core body temperature (rectal), ↓skin temperature (back, chest, extremities), ↓sweat rate, ↓heart rate, ↓rate of perceived exertion, oxygen consumption | RCT cross over design            |
| McLellan et al (2004), Toronto Canada (74) | Overall total participants: 24 firefighters<br>Sex distribution: 92% male<br>Mean age: $39.1 \pm 0.7$ years.<br>Subgroup:<br>Very low group: 6 participants; mean age: $38.3 \pm 1.0$ years<br>Low group: 6 participants; mean age: $39.0 \pm 2.0$ years<br>Moderate group: 6 participants; mean age: $39.0 \pm 1.9$ years<br>High group: 6 participants; mean age: $40.2 \pm 0.9$ years | Type and body coverage: Replaced the long pants with shorts, within the firefighters' protective clothing<br>Timing: During heat stress trial | Environment: Simulated at $35^{\circ}\text{C}$ , 50% relative humidity with a wind speed less than 0.1 m/s.<br>Heat stress trial: Heavy (4.8 km/h and 5% elevation), moderate (4.5 km/h and 2.5% elevation), light (4.5 km/h and 0% elevation) and very light (2.5 km/h and 0% elevation). | ↑Core body temperature (rectal)*, ↓skin temperature*, $\text{VO}_2$ peak, heart rate*, sweat rate*, ratings of perceived exertion, ↑thermal comfort      | Quasi-experimental design        |
| Cadarette et al (2003), USA (52)           | Total participants: 8 participants<br>Sex distribution: 75%                                                                                                                                                                                                                                                                                                                              | Type:<br>• ITAP-SCBA: Improved toxicological agent                                                                                            | Environment: Simulated at $38^{\circ}\text{C}$ , 30% RH ( $28^{\circ}\text{C}$ WBGT) with no wind.                                                                                                                                                                                         | ↓Core body temperature (rectal), ↓sweat rate*, ↓heat                                                                                                     | Non-RCT cross over design        |

| Citation, Country                   | Participant description                                 | Intervention                                                                                                                                                                                                                                                                                    | Heat stress exposure                                                                                                                                                                                                                        | Outcome variables                                                                                                                     | Study design, additional remarks |
|-------------------------------------|---------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                     | male<br>Mean age: 24 ± 4 years                          | protective (ITAP) with personal ice cooling system suit with Self-contained breathing apparatus (SCBA).<br>• ITAP - B: Improved toxicological agent protective suit with lighter respiratory protection (protective mask)<br>Body coverage: Whole body suit<br>Timing: During heat stress trial | Heat stress trial:<br>Participants walked at 1.56 m/sec on a 4% grade for two 50-min exercise sessions with intermediate 10 min of interval.                                                                                                | storage*, physiological strain index, ↑heart rate, ↑metabolic rate*                                                                   |                                  |
| Cotter et al (2001), Australia (87) | Total participants: 9 men<br>Mean age: 32.4 ± 3.6 years | Type and body coverage: Ice-vest for torso and cryogenic cuffs on anterior and lateral thigh surface, exposed to cold air (LC): Additionally parts of thigh were warmed using electric heating blankets (LW)<br>Timing: Before and during the heat stress trial                                 | Environment: Simulated at 33 °C, 60% RH, air flow <0.5 m/s. Heat stress trial: Participants performed 35-minute cycling consisting, 20 minutes of fixed external work rate of 65% VO, then a 15-minute self paced maximal performance trial | ↓Core body temperature* ↓skin temperature*, ↓heart rate*, ↓forearm blood flow*, ↓ratings of exertion*, ↓thermal sensation*, ↓Vo2 peak | RCT cross over design            |
| Constable et al (1994), USA (56)    | Total participants: 8 volunteers<br>Sex: 62.5% male.    | Type: Cooling vest (closed-loop liquid system) worn within the chemical protective ensemble (CPE)<br>Body coverage: Torso<br>Timing: Intermittent cooling during heat stress trail                                                                                                              | Environment: Simulated at 38°C dry bulb, 26°C wet bulb and 43°C black globe temperatures (WBGT= 31°C)<br>Heat stress trial: Participants walked for 80 min on a treadmill at 1.36 m/s at 2% grade                                           | ↓Core body temperature (rectal)*, ↓skin temperature (chest*, thigh*), ↓heart rate, ↓sweat rate*                                       | Non-RCT cross over design        |

| Citation, Country               | Participant description                                                         | Intervention                                                                                                                                                                                                                     | Heat stress exposure                                                                                                                                                                                                                                                                                                                                                                                                 | Outcome variables                                                                                                                                                                               | Study design, additional remarks |
|---------------------------------|---------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| Holmr et al (1992), Sweden (58) | Total participants: 4 men<br>Age: Between 29 - 45 years                         | Type: Various fabrics worn beneath asbestos protective suits<br>Gore-Tex (GT)<br>Polypropylene (PP)<br>Tyvek (TYV)<br>Body coverage: Whole body suit, Timing: Worn during heat stress trial                                      | Environment: Simulated warm-humid condition with air temperature of $24.9 \pm 0.5^{\circ}\text{C}$ and relative humidity of $47 \pm 10\%$ , hot-dry condition with air temperature of $35.7 \pm 0.9^{\circ}\text{C}$ and relative humidity of $26 \pm 3\%$ , air velocity of $0.3 \pm 0.1$ m/s,<br>Heat stress trial: Participants performed 50 min of exercise on an electrically braked bicycle at a load of 90 W. | $\uparrow$ Core body temperature (rectal)*, $\downarrow$ Heart rate, $\downarrow$ skin temperature, $\uparrow$ thermal sensation*, $\uparrow$ heat storage, $\downarrow$ sweat evaporation rate | Non-RCT cross over design        |
| Bishop et al (1991), USA (49)   | Total participants: 14 U.S. air force personnel<br>Sex distribution: 85.7% male | Type: Two different vests<br>Air cooling system vest with manifolds (open weave air distribution vest over an undershirt)<br>Liquid cooling<br>Body coverage: Torso<br>Timing: Worn after heat stress trial (during rest period) | Environment: Simulated at the WBGT of $26^{\circ}\text{C}$ ; dry, wet bulb and black globe temperature of 28, 22 and $34^{\circ}\text{C}$ respectively. Heat stress trial: Participants walked on a treadmill at 1.34 m/sec for 45 min and then rested for 15 min                                                                                                                                                    | $\downarrow$ Core body temperature (rectal)*, $\downarrow$ skin temperature*, $\downarrow$ heart rate*, $\downarrow$ sweat rate                                                                 | Non-RCT cross over design        |

| Citation, Country                                 | Participant description                                                                   | Intervention                                                                                                                                                                                                                                                                                                         | Heat stress exposure                                                                                                                                                                                                                                  | Outcome variables                                                                                  | Study design, additional remarks |
|---------------------------------------------------|-------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|----------------------------------|
| White et al (1991), USA (62)                      | Total participants: 6 male fire-fighter and 3 male coast guard<br>Mean age: 28.9±4.1years | Type: Two different cooling interventions <ul style="list-style-type: none"> <li>Cooled by ice and water with closed loop circulating system</li> <li>Evaporative freon r-114 in 16 thin, flat membrane capsules inside the sleeveless vest.</li> </ul> Body coverage: Full body<br>Timing: During heat stress trial | Environment: Simulated at 33.9 °C with 82% RH. Heat stress trial: Series of four 45-minute exercise test on treadmill at constant speed of 4 km/h                                                                                                     | ↓Core body temperature (rectal)*, ↓skin temperature*, ↓heart rate*, ↓weight loss*, ↑heat exchange* | RCT cross over design            |
| Van et al (1972), Johannesburg, South Africa (88) | Total participants: 2 bantu community men,<br>Age: 20 years                               | Type: Cooling interventions <ul style="list-style-type: none"> <li>Water-cooled vest with insulated cooling tubes</li> <li>Pre-frozen jacket (sleeveless canvas jacket-outside sealed freezable plastic bags attached)</li> </ul> Body coverage: Torso<br>Timing: During heat stress trial                           | Environment: Simulated at 33.9°C dry bulb and 32.2°C wet bulb with low wind velocity (less than 0.5 m/sec).<br>Heat stress trial: Men worked at a rate of 35 watts in all experiments by stepping on and off an adjustable block 12 times per minute. | ↓Core body temperature (rectal)*, ↓heart rate*, ↓sweat rate*                                       | Non-RCT cross over design        |
| Wang et al (2024), China (38)                     | Total participants: 18 men<br>Mean age: 22±3 years                                        | Type: Phase change cooling blanket<br>Body coverage: whole body,                                                                                                                                                                                                                                                     | Environment: Simulated at temperature of 33°C; relative humidity of 40%.<br>Heat stress trial:                                                                                                                                                        | ↓Core body temperature (GI)*, ↓skin temperature*, ↓oral temperature,                               | RCT cross over design            |

| Citation, Country                 | Participant description                                                              | Intervention                                                                                                                                                   | Heat stress exposure                                                                                                                                                                                                                                                                                        | Outcome variables                                                                                                                                               | Study design, additional remarks |
|-----------------------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                   |                                                                                      | Timing: After heat stress trial                                                                                                                                | Participants performed three 10-min cooling trials between two exhaustive treadmill running bouts (initial speed of 15 km/h and slope of 0%).                                                                                                                                                               | ↓heart rate*, ↑mean arterial pressure, ↓respiratory rate*, ↑peripheral capillary oxygen saturation*, ↓rating of perceived exertion*                             |                                  |
| Byrne et al (2023), USA (50)      | Total participants: 30<br>Male orthopedic surgeons<br>Mean age: 37±9 years           | Type: Cooling vest with ice packs inserts (worn between scrubs and PPE)<br>Body coverage: Torso<br>Timing During exposure to heat stress (surgery procedures). | Environment: Ambient operating room temperature was maintained near 20°C.<br>Heat stress trial: Each surgeon performed total-joint arthroplasties expected to last 90-150 min.                                                                                                                              | ↓Core body temperature (GI), ↓skin temperature*, ↓rating of perceived exertion*, ↓thermal comfort*, ↓fatigue*, processing speed test score, visual memory test* | RCT cross over design            |
| Wang et al (2023), China (61)     | Total participants: 12 men<br>Mean age: 22±1.3 years                                 | Type: Phase change cooling blanket<br>Body coverage: whole body<br>Timing: After heat stress trial                                                             | Environment: Ambient air temperature of 30°C, and relative humidity of 66%.<br>Heat stress trial: Participants completed 30 min of running exercise on a flat road to produce exercise-induced hyperthermia and then 3 min after cessation of exercise, transferred to an area for 30-minute cooling trial. | ↓Core body temperature (GI)*, ↓Heart rate*                                                                                                                      | RCT cross over design            |
| Soleimani et al (2023), Iran (42) | Total participants: 11<br>Sex distribution: 45.5% males<br>Mean age: 22.2±1.78 years | Type: Cooling interventions<br>Impenetrable gown alone (Go)<br>Gown with air blowing with                                                                      | Environment: Simulated at temperature conditions of 27 °C and 25% relative humidity (RH).<br>Heat stress trial:                                                                                                                                                                                             | ↓Skin temperature (chest*, back*, forehead, forearm), ↓heart rate*, ↓temperature inside                                                                         | Non-RCT cross over design        |

| Citation, Country              | Participant description                                  | Intervention                                                                                                                                                                                                                                                                                            | Heat stress exposure                                                                                                                                                                                                                                                                                                       | Outcome variables                                                                                                                                             | Study design, additional remarks |
|--------------------------------|----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                | (male)<br>22.5 ± 0.54 years<br>(female)                  | volume of air flow at 8 cfm (cubic feet per minute) (Go + 8 cfm Fan)<br>Gown with air blowing at 10 Cfm (Go + 10 cfm Fan)<br>Gown with air blowing at 12 cfm (Go + 12 cfm Fan)<br>Gown with air blowing at 14 cfm (Go + 14 cfm Fan)<br>Body coverage: Fully covered<br>Timing: During heat stress trial | Participants walked on treadmill at a speed of 2 km/h and a slope of 0% for 30 minutes.                                                                                                                                                                                                                                    | of clothes*, ↓thermal sensation*, ↓skin wetness sensation*, ↓thermal comfort*                                                                                 |                                  |
| Inoue et al (2023), Japan (78) | Total participants: 10 men<br>Mean age: 24.8 ± 3.7 years | Type and body coverage: Water-cooled vest<br><ul style="list-style-type: none"> <li>• Complete vest includes upper torso and neck</li> <li>• Partial cooling vest: covered neck, heart, and underarm (axillary) regions</li> </ul> Timing: During heat stress trial                                     | Environment: Rested 15 min at simulated environment at dry-bulb temperature of 25°C and 50% relative humidity.<br>Followed by heat stress trial at simulation at dry-bulb temperature of 40°C and 50% relative humidity, Heat stress trial: Participants performed an ergometer exercise with intensity of 40% for 40 min. | ↓Core body temperature (rectal*, esophageal*, tympanic*), ↓heart rate, ↓sweat volume, ↓thermal sensation*, ↓rating of perceived exertion*                     | RCT cross over design            |
| Mori et al (2022), Japan (60)  | Total participants: 9 men<br>Mean age: 24.1 ± 4.3 years  | Type: The cooling intervention included the fan-attached within the jacket<br>Body coverage: Upper body<br>Timing: during heat stress trial.                                                                                                                                                            | Environment: Simulated hot-dry conditions at 40°C ambient temperature and 30% relative humidity and warm-humid conditions at 30°C ambient temperature and 85% relative humidity.<br>Heat stress trial: Participants rested for 2 min on ergometer, exercised at                                                            | ↓Core body temperature (↓rectal*, ↓esophageal*, ↓tympanic*), ↓skin temperatures (forehead*, chest*, and back*), ↓heart rate, ↓sweat rate*, ↓rate of perceived | RCT cross over design            |

| Citation, Country                 | Participant description                                                                                             | Intervention                                                                                                                                          | Heat stress exposure                                                                                                                                                                                                                                                                                                                 | Outcome variables                                                                                                                                                | Study design, additional remarks |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                   |                                                                                                                     |                                                                                                                                                       | 20W min, after resting on a chair for 15 min, then move to the bicycle ergometer and exercise at a workload of 4 METs for 60 min.                                                                                                                                                                                                    | excretion, ↓thermal comfort*, ↓% change in weight*, thermal sensation                                                                                            |                                  |
| de et al (2022), Denmark(57)      | Total participants: 17 Nurses<br>Sex distribution: 29.4% male<br>Mean age: 31± 8 years                              | Type: A cooling vest with phase-changing material worn underneath the PPE<br>Body coverage: Torso<br>Timing: During exposure to the heat stress trial | Environment: COVID-19 ward with average ambient air temperature at 23.2 ± 0.4°C<br>Heat stress trial: Consisted 3 work bouts of ~3 hours separated by morning and lunch breaks (7:30 a.m. to 4 p.m.)                                                                                                                                 | Core body temperature (GI), heart rate, ↓perceptual strain index*, physiological strain index, thermal sensation, thermal comfort                                | RCT cross over design            |
| Tokizawa et al (2020), Japan (37) | Total participants: 8 men<br>Mean age: 36 ± 9.8 years                                                               | Type: Liquid (iced water) cooling vest comprised a tube-lined water-perfusion vest<br>Body coverage: Vest<br>Timing: During heat stress trial         | Environment: performed in two simulations. One maintained at an ambient temperature of 25°C and 40% relative humidity (RH) and the other was a heated room with an ambient temperature of 33°C and 60% RH. In both rooms, the wind speed was 0.4 m/s.<br>Heat stress trial: Participant walked on a treadmill for 30 min at 3 km/hr. | ↓Core body temperature (rectal)*, ↓skin temperature*, ↓heart rate*, ↓sweat rate*, ↓thermal sensation*, ↑thermal comfort*, physiological fatigue*, blood pressure | Non-RCT cross over design        |
| Chan et al (2019), Hong Kong (77) | Total participants: 10 male volunteers who practiced sports around 3 times per week<br>Median (IQR) age: 22 (18,32) | Type: Hybrid cooling vest containing frozen gel cooling packs and fans<br>Body coverage: Torso<br>Timing: Worn during the heat stress trial           | Environment: Simulated at ambient conditions at 33°C and 75% RH.<br>Heat stress trial: Progressive incremental running test and a 40-minute post-exercise                                                                                                                                                                            | ↓Core body temperature (GI), ↓heart rate, ↓physiological strain index*, ↓sweat rate, ↓rating of perceived exertion                                               | RCT cross over design            |

| Citation, Country                          | Participant description                                               | Intervention                                                                                                                                                                                                                                                                                        | Heat stress exposure                                                                                                                                                                                                                                                                                                                                                                                                                             | Outcome variables                                                                                                                                                                                  | Study design, additional remarks |
|--------------------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                            |                                                                       |                                                                                                                                                                                                                                                                                                     | recovery.                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                    |                                  |
| Willmott et al (2018), United Kingdom (36) | Total participants: 8 men,<br>Mean age: 27± 5 years                   | Type: Chemically activated, non-electrically powered cooling device, (CAER) Vest<br>Body coverage: Torso,<br>Timing: Either prior or during heat stress trial                                                                                                                                       | Environment: simulated at 20°C, 40% relative humidity condition.<br>Heat stress trial: Remained supine on the experimental table for total of 90 minutes                                                                                                                                                                                                                                                                                         | ↓Core body temperature (rectal)*, ↓skin temperature*, ↓thermal sensation*, ↓heart rate, shivering*, ↑cold discomfort*, ↓feeling                                                                    | Non-RCT cross over design        |
| Parameswarappa et al (2017), India (41)    | Total participants: 10 male industrial workers<br>Age: 25 to 55 years | Type: Triple layered cool coat with quilted fabric, exhibits large water-holding capacity when soaked in water<br>Body coverage: Sleeveless coat<br>Timing: Worn during the heat stress trail                                                                                                       | Steel industry (hot zone workplaces -jobs consist of light-to-moderate physical work (approximately 240 kcal/h))                                                                                                                                                                                                                                                                                                                                 | ↓Oral temperature                                                                                                                                                                                  | Non-RCT cross over design        |
| Yi et al (2017), Hong Kong (64)            | Total participants: 10 men<br>Mean age: 21.2 ± 3.4 years              | Type: Uniform designed using improved fabric in terms of heat-moisture performance, designed for better ventilation, comfort and industry specific requirements.<br>Body coverage: Whole body covering whole body except head, forearm, hand and feet<br>Timing: Worn during the heat stress trial. | Environment: Simulated at 34.5 °C temperature and 75% relative humidity, 0.3 m/s air velocity, and solar radiation of 450 W/m <sup>2</sup> . Heat stress trial: Participants rested for 30-minute, warmed-up with 9 min jog (6 - 8 km / h with 1% steep) on treadmill, followed by treadmill running at 5 - 8.5 km/h with 1 - 4% slope until attainment of 95% age-predicted maximum heart rate core body temperature reached 38.5 °C (whichever | ↓Core body temperature (GI)*, ↓skin temperature*, ↓sweat rate*, ↓heart rate*, ↓perceived strain index*, ↓rating of perceived excretion*, ↓thermal sensation*, ↓wetness sensation*, ↓tolerance time | RCT cross over design            |

| Citation, Country                       | Participant description                                                                                                    | Intervention                                                                                                                                                                                                                                                                                | Heat stress exposure                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Outcome variables                                                                                                                             | Study design, additional remarks |
|-----------------------------------------|----------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                                         |                                                                                                                            |                                                                                                                                                                                                                                                                                             | is earlier), later walked at 2 - 3.5 km/h at 0% slope for 6 min and rested for 30 minutes                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                               |                                  |
| Nag et al (1998), Ahmedabad, India (40) | Total participants: 4 men<br>Age: 22-30 years                                                                              | Type: Cooling garment chilled with cold water (10 - 12 °C ) flowing at three different velocities: <ul style="list-style-type: none"> <li>• 2.6 ± 0.28 l/h</li> <li>• 4.3 ± 0.33 l/h</li> <li>• 5.1 ± 0.25 l/h</li> </ul> Body coverage: Torso<br>Timing: Worn during the heat stress trial | Environment: Simulated at, i.e., 30, 35, and 40 °C dry-bulb (DB) temperature with air velocity of 0.3, 0.6 and 0.9 m/s (50 ± 60 % RH).<br>Heat stress trial: Participants remained seated in chamber where by the metabolic load was kept to a minimum (i.e. 1.5 to 2.5 kcal/min)                                                                                                                                                                                                                         | Core body temperature, skin temperature (thigh, forehead, trunk), evaporation through skin, ↓ evaporation required by body*                   | One group pre-post study design  |
| Sainiyom et al (2026), Thailand (69)    | Total participants: 12 (6 male & 6 female)<br>Mean age: 20.8 ± 1.2 years<br>(Male: 20.2 ± 1 years; Female: 21.3 ± 1 years) | Type: Previously refrigerated (cooled) carbon integrated PCM vests, consisting of 14 cooling pads (each weighing 0.18 kg).<br>Body coverage: Torso, Sleeveless coat<br>Timing: Worn during the heat stress trail                                                                            | Environment: Simulated climatic chamber (32 °C, 70% RH)<br>Heat stress trial: Participants completed 100 minutes of healthcare simulated activity. Briefly, four 25-minute phases activity. Each 25-minute phase consisted of 10 minutes of walking at 3.5km/h 0% incline, followed by a 10-minute circuit exercise (i.e. 5 rounds of 1-minute resistance workouts including squats or alternate wood chops to right or left sides, holding 1.5 kg dumbbell, followed by a 1-minute rest) mimicking large | ↓ Core temperature*, ↓ mean skin temperature*, ↓ Heart rate*, ↓ rating of perceived exertion *, ↓ Thermal sensation*, ↓ Thermal Comfort (TC)* | Randomized crossover design      |

| Citation, Country                   | Participant description                                                               | Intervention                                                                                                                                                                                                                   | Heat stress exposure                                                                                                                                                                                                                                                                        | Outcome variables                                                                                                                                 | Study design, additional remarks              |
|-------------------------------------|---------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|
|                                     |                                                                                       |                                                                                                                                                                                                                                | muscles used during patient care and a 5-minute rest,                                                                                                                                                                                                                                       |                                                                                                                                                   |                                               |
| Hutchins et al 2025, Australia (10) | Total participants: Eight (8) recreationally trained male, Mean age: 24.3 ± 4.1 years | Type: Ice vest (4 ice packs stored in -20°C freezer before wearing. Body coverage: Torso Timing: Worn during the heat stress trial                                                                                             | Environment: Simulated climate chamber (35 °C; 50% relative humidity) Heat stress trial: Treadmill walking at 4.5km/h over 60 minutes                                                                                                                                                       | ↑Core temperature, ↓ skin temperature*, ↓ heart rate*, ↓ Physiological strain index*, ↓ Thermal comfort, ↓ Thermal sensation*                     | Randomized cross over trial                   |
| Jamshidi et al 2025, Iran (67)      | Total participants: 20 male & 20 female nurses, Mean age: 31.3 ± 4.7 years            | Type: Ice gel cooling vest Body coverage: Torso, Sleeveless coat Timing: Worn during the heat stress trial                                                                                                                     | Environment: Hospital set – up wearing PPE, during summer, temperature 24 – 28 °C, WBGT 17 – 19 °C. Heat stress trial: Working in hospital for 1 hour                                                                                                                                       | ↓ Core temperature*, ↑Heart rate *, ↓Thermal sensation*, ↓ Fatigue assessment*, ↓ thirst*, ↓ skin moisture*                                       | Random control trial                          |
| Kaufman et al 2025, USA (68)        | Total participants: Fourteen (14); 50% males Mean age: 26 ± 3                         | Type, body coverage & timing: hat, neck gaiter, sun sleeves submerged in ice water (0°C–3°C), t-shirt, boxer briefs (men) during heat stress trial Draped upper body with large wet towel (submerged in ice water) during rest | Environment: Simulated chamber (40°C, 40% relative humidity) Heat stress trial: Three cycles of exercise consisting of two 15-min walk on a treadmill at 30%–40% of their VO <sub>2</sub> peak speed at 5% grade, and single 5-min box lifting activity. Each cycle ended with 10-min rest. | ↓ Core body temperature*, ↓ skin temperature*, ↓ Heart rate*, ↓ rate of perceived exertion*, ↓ thermal sensation*, ↓ fatigue*, ↓ thermal comfort* | Randomized crossover trial.                   |
| Shojaei(70) et al 2025, Iran        | Total participants: 60 male restaurant staff Aged 28 – 50 years                       | Type: Ice gel cooling vests Body coverage: Torso Timing: Worn during the heat stress trial                                                                                                                                     | Environment: Real time in restaurant Heat stress trial: Working at restaurant with WBGT 34.6 – 34.9 and HIS 84.4 – 82.7, while using PPE,                                                                                                                                                   | ↓ Core body temperature*, ↑skin temperature, ↑blood pressure, ↑heart rate, ↑ skin and clothing moisture                                           | Cross-sectional, descriptive analytical study |

| Citation, Country                | Participant description                                                 | Intervention                                                                                                                                                                                                               | Heat stress exposure                                                                                                                                                                                                                                                                                                                                                                                                                   | Outcome variables                                                                                                                                                                  | Study design, additional remarks              |
|----------------------------------|-------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|
|                                  |                                                                         |                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                        | perception,                                                                                                                                                                        |                                               |
| Ciuha et al 2024 (66)            | Total participants: 10 male participants<br>Mean age: $37 \pm 6$ years  | Type: Ventilation to enhance evaporation<br>Body coverage: Torso<br>Timing: Worn during heat stress trial                                                                                                                  | Environment: Simulated chamber ( $35^{\circ}\text{C}$ , 40% relative humidity & 1m/s airflow)<br>Study had 2 types of heat stress trial:<br>March condition comprised a 15-min rest phase followed by a 75-min march at a pace of 4.5 km / h and 2 % incline<br>Guard duty comprised a 15-min rest phase followed by 15 min of marching on a treadmill at a pace of 4.5 km h and 2 % incline followed by 60 min of standing guard duty | ↓ Core body temperature, ↓ Skin temperature, ↓ Thermal comfort, ↓ sweat loss*                                                                                                      | Randomized cross over trial                   |
| Mansouri et al 2024, Canada (82) | Total participants: 6 male & 2 females,<br>Mean age: $27.5 \pm 3$ years | Type: Liquid (water at $2^{\circ}\text{C}$ ) cooling garment<br>Body coverage:<br><ul style="list-style-type: none"> <li>• Upper body (UB)</li> <li>• Whole body (WB)</li> </ul> Timing: Worn during the heat stress trial | Environment: Simulated climate chamber, temperature $40^{\circ}\text{C}$ air and 40% relative humidity.<br>Heat stress trial: 3 cycles of activity, each cycle consisting of 15 min stepping exercise at a rate of 20 steps / min, followed by 5 min break.                                                                                                                                                                            | ↓ Core body temperature*, ↓ skin temperature*, ↓ Heart rate*, ↓ Sweat loss*, ↓ Rating of perceived exertion*, Cognitive function, ↓ ↓ thermal discomfort*, ↓ breathing discomfort* | Three (3) arms<br>Randomized cross over trial |

\*indicates statistically significant difference between the intervention and the control group

↓ & ↑ indicates the intervention group exhibited lower and higher respectively as compared to the control group

### Supplement table 3: Summary of findings of GRADE assessment

Evidence Profile using Grading of Recommendation, Assessment, Development, and Evaluation (GRADE) instrument

**Population:** Apparently healthy adult workers exposed to occupational heat strain or acclimatized adults exposed to heat strain

**Intervention:** All forms of wearable cooling intervention as standalone or combined with other cooling interventions

**Control:** No cooling intervention of any form

**Outcomes:** Physiological and perceptual markers of heat strain

| Outcome: physiological and perceptual markers of heat strain (assessed with mean differences in the levels using meta-analysis)                          |              |                |              |                |                  |                                             |                                                |                   |          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|----------------|--------------|----------------|------------------|---------------------------------------------|------------------------------------------------|-------------------|----------|
| Quality assessment                                                                                                                                       |              |                |              |                |                  | Summary of findings                         |                                                |                   | Comments |
| No of studies                                                                                                                                            | Risk of Bias | Inconsistency  | Indirectness | Imprecision    | Publication Bias | Mean difference                             |                                                | Certainty/Quality |          |
|                                                                                                                                                          |              |                |              |                |                  | INB                                         | 95%CI                                          |                   |          |
| Core body temperature (°C), mean difference between the intervention and control group after exposure to heat strain (assessed with meta-analysis)       |              |                |              |                |                  |                                             |                                                |                   |          |
| 63                                                                                                                                                       | serious      | ↓ <sup>a</sup> | ↑            | ↑ <sup>b</sup> | unlikely         | -0.24 (Rectal)<br>-0.26 (GI) <sup>o</sup> C | -0.37 to -0.1 (Rectal)<br>-0.52 to -0.001 (GI) | ⊕⊕○○<br>Low       | -        |
| Surface (skin) temperature (°C),, mean difference between the intervention and control group after exposure to heat strain (assessed with meta-analysis) |              |                |              |                |                  |                                             |                                                |                   |          |
| 47                                                                                                                                                       | serious      | ↑ <sup>a</sup> | ↑            | ↑ <sup>b</sup> | likely           | -1.14°C                                     | -1.85 to -0.42                                 | ⊕⊕○○<br>Low       | -        |
| Heart rate (beats per minute), mean difference between the intervention and control group after exposure to heat strain (assessed with meta-analysis)    |              |                |              |                |                  |                                             |                                                |                   |          |
| 67                                                                                                                                                       | serious      | ↓ <sup>a</sup> | ↑            | ↑ <sup>b</sup> | likely           | -7.69/min                                   | -11.22 to -4.15                                | ⊕○○○<br>Very Low  | -        |
| Sweat, standardized mean difference (SMD) between the intervention and control group after exposure to heat strain (assessed with meta-analysis)         |              |                |              |                |                  |                                             |                                                |                   |          |
| 31                                                                                                                                                       | serious      | ↓ <sup>a</sup> | ↑            | ↓ <sup>b</sup> | unlikely         | -0.41 (rate)<br>--0.64 (total)              | -0.82 to -0.01 (rate)<br>-2.35 to 1.07 (total) | ⊕○○○<br>Very Low  | -        |
| Rating of perceptual exertion, SMD between the intervention and control group after exposure to heat strain (assessed with meta-analysis)                |              |                |              |                |                  |                                             |                                                |                   |          |
| 20                                                                                                                                                       | serious      | ↓ <sup>a</sup> | ↑            | ↑ <sup>b</sup> | unlikely         | - 0.87                                      | -1.62 to -0.11                                 | ⊕⊕○○<br>Low       | -        |
| Thermal sensation, SMD between the intervention and control group after exposure to heat strain (assessed with meta-analysis)                            |              |                |              |                |                  |                                             |                                                |                   |          |
| 24                                                                                                                                                       | serious      | ↓ <sup>a</sup> | ↑            | ↑ <sup>b</sup> | unlikely         | -1.41                                       | -3.21 to -0.4                                  | ⊕⊕○○<br>Low       | -        |
| Physiological strain index, mean difference between the intervention and control group after exposure to heat strain (assessed with meta-analysis)       |              |                |              |                |                  |                                             |                                                |                   |          |
| 11                                                                                                                                                       | serious      | ↑ <sup>a</sup> | ↑            | ↑ <sup>b</sup> | likely           | -0.76                                       | -1.36 to -0.16                                 | ⊕⊕○○<br>Low       | -        |

<sup>a</sup>  $I^2$  heterogeneity <sup>b</sup> studies included have reported wide confidence intervals

#### GRADE Working Group grades of evidence

**High certainty:** we are very confident that the true effect lies close to that of the estimate of the effect.

**Moderate certainty:** we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

**Low certainty:** our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

**Very low certainty:** we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect

Supplement table 4a: Sub-group analysis of rectal temperature for post intervention comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 5       | -0.24 (-0.65 to 0.17)                   | 72.25                   |
| Ventilating / evaporative | 3       | -0.13 (-0.37 to -0.1)                   | 0                       |
| Phase changing material   | 3       | -0.26 (-0.54 to 0.01)                   | 12.06                   |
| PCM + Ventilating         | 1       | -                                       | -                       |

Supplement table 4b: Sub-group analysis of rectal temperature for post intervention comparison (Non-RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 3       | -0.57 (-2.35 to 1.01)                   | 88.92                   |
| Ventilating / evaporative | 2       | -0.37 (-3.3 to 2.55)                    | 80.18                   |
| Others                    | 1       | -                                       | -                       |

Supplement table 5: Sub-group analysis of gastrointestinal temperature for post intervention comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 3       | -0.11 (-0.23 to 0.01)                   | 0                       |
| Ventilating / evaporative | 2       | 0.01 (-0.67 to 0.68)                    | 0                       |
| Phase changing material   | 5       | -0.52 (-1.13 to 0.09)                   | 98.4                    |
| Others                    | 1       | -                                       | -                       |
| PCM + Ventilating         | 1       | -                                       | -                       |

Supplement table 6a Sub-group analysis of rectal temperature for within-group change comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 6       | -0.6 (-0.73 to -0.47)                   | 95.66                   |
| Ventilating / evaporative | 2       | -0.16 (-1.24 to 0.92)                   | 87.99                   |
| Phase changing material   | 1       | -                                       | -                       |
| Water / Ice + Ventilating | 2       | -0.1 (-0.39 to 0.25)                    | 4.97                    |

Supplement table 6b Sub-group analysis of rectal temperature for within-group change comparison (Non-RCT)

| Cooling intervention | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|----------------------|---------|-----------------------------------------|-------------------------|
|----------------------|---------|-----------------------------------------|-------------------------|

|                           |   |                      |       |
|---------------------------|---|----------------------|-------|
| Water / Ice               | 1 | -                    | -     |
| Ventilating / evaporative | 3 | -0.12 (-0.7 to 0.46) | 83.44 |

Supplement table 7 Sub-group analysis of gastrointestinal temperature for within-group change comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 1       | -                                       | -                       |
| Ventilating / evaporative | 1       | -                                       | -                       |
| Phase changing material   | 4       | -0.36 (-0.9 to 0.17)                    | 99.17                   |
| Others                    | 1       | -                                       | -                       |

Supplement table 8 Sub-group analysis of rectal temperature for change in between-group differences over time (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 5       | 0.18 (-0.3 to 0.65)                     | 99.87                   |
| Ventilating / evaporative | 1       | -                                       | -                       |
| Phase changing material   | 1       | -                                       | -                       |

Supplement table 9: Sub-group analysis of gastrointestinal temperature changes in between-group differences over time (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 1       | -                                       | -                       |
| Ventilating / evaporative | 1       | -                                       | -                       |
| Phase changing material   | 4       | 0.36 (-0.17 to 0.9)                     | 99.17                   |
| Others                    | 1       | -                                       | -                       |

Supplement table 10a: Sub-group analysis of skin temperature for post intervention comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 6       | -1.85 (-3.57 to -0.13)                  | 98.53                   |
| Ventilating / evaporative | 4       | -0.58 (-1.77 to 0.62)                   | 80.37                   |
| Phase changing material   | 4       | -0.74 (-1.86 to 0.39)                   | 86.75                   |

|        |   |   |   |
|--------|---|---|---|
| Others | 1 | - | - |
|--------|---|---|---|

Supplement table 10b: Sub-group analysis of skin temperature for post intervention comparison (Non-RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 6       | -2.50 (-4.79 to -0.21)                  | 99.41                   |
| Ventilating / evaporative | 5       | -1.56 (-3.79 to 0.68)                   | 97.46                   |
| Phase changing material   | 2       | -0.14 (-0.19 to -0.09)                  | 0                       |
| Others                    | 1       | -                                       | -                       |

Supplement table 11a: Sub-group analysis of skin temperature for within-group change comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 5       | -1.57 (-4.26 to 2.66)                   | 39.05                   |
| Ventilating / evaporative | 2       | -0.8 (-4.26 to 2.66)                    | 39.05                   |
| Phase changing material   | 4       | -0.66 (-1.46 to 0.14)                   | 87.5                    |
| Others                    | 1       | -                                       | -                       |

Supplement table 11b: Sub-group analysis of skin temperature for within-group change comparison (Non-RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 3       | -2.9 (-10.46 to 4.66)                   | 99.98                   |
| Ventilating / evaporative | 3       | -0.87 (-3.21 to 1.47)                   | 98.44                   |
| Phase changing material   | 1       | -                                       | -                       |

Supplement table 12a: Sub-group analysis of skin temperature for change in between-group differences over time (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 5       | 1.57 (-0.2 to 3.34)                     | 99.43                   |
| Ventilating / evaporative | 2       | 0.8 (-2.66 to 4.26)                     | 39.05                   |
| Phase changing material   | 3       | 0.79 (-0.53 to 2.1)                     | 90.15                   |
| Others                    | 1       | -                                       | -                       |

Supplement table 12b: Sub-group analysis of skin temperature for change in between-group differences over time (Non-RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 3       | 2.9 (-4.66 to 10.46)                    | 99.98                   |
| Ventilating / evaporative | 1       | -                                       | -                       |

Supplement table 13a: Sub-group analysis of heart rate for post intervention comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI (Per Minute) | $I^2$ heterogeneity (%) |
|---------------------------|---------|--------------------------------------|-------------------------|
| Water / Ice               | 12      | -11.55 (-18.64 to -4.45)             | 76.9                    |
| Ventilating / evaporative | 6       | -1.19 (-10 to 7.62)                  | 50.91                   |
| Phase changing material   | 9       | -7.88 (-12.57 to -3.19)              | 73.35                   |
| Others                    | 3       | -4.64 (-36.34 to 27.05)              | 62.4                    |

Supplement table 13b: Sub-group analysis of heart rate for post intervention comparison (Non-RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI (Per Minute) | $I^2$ heterogeneity (%) |
|---------------------------|---------|--------------------------------------|-------------------------|
| Water / Ice               | 7       | -13.98 (-24.66 to -3.3)              | 74.23                   |
| Ventilating / evaporative | 6       | -7.37 (-25.62 to 10.88)              | 88.29                   |
| Phase changing material   | 2       | -3.06 (-20.21 to 14.1)               | 0                       |
| Others                    | 1       | -                                    | -                       |

Supplement table 14a: Sub-group analysis of heart rate for within-group change comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI (Per Minute) | $I^2$ heterogeneity (%) |
|---------------------------|---------|--------------------------------------|-------------------------|
| Water / Ice               | 10      | -6.57 (-17.12 to 3.98)               | 96.65                   |
| Ventilating / evaporative | 4       | -7.35 (-30.31 to 15.61)              | 85.27                   |
| Phase changing material   | 7       | -7.04 (-13.44 to -0.64)              | 98.33                   |
| Others                    | 2       | 0.18 (-176.52 to 176.88)             | 90.69                   |
| Water / Ice + Ventilating | 2       | 0.87 (-125.05 to 126.78)             | 90.75                   |

Supplement table 14b: Sub-group analysis of heart rate for within-group change comparison (non-RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI (Per Minute) | $I^2$ heterogeneity (%) |
|---------------------------|---------|--------------------------------------|-------------------------|
| Ventilating / evaporative | 1       | -                                    | -                       |
| Phase changing material   | 2       | 0.46 (-73.65 to 74.57)               | 97.71                   |
| Others                    | 1       | -                                    | -                       |

Supplement table 15a: Sub-group analysis of heart rate for change in between-group differences over time (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI (Per Minute) | $I^2$ heterogeneity (%) |
|---------------------------|---------|--------------------------------------|-------------------------|
| Water / Ice               | 9       | 8.84 (-1.45 to 19.14)                | 97                      |
| Ventilating / evaporative | 3       | 2.36 (-23.64 to 28.35)               | 85.25                   |
| Phase changing material   | 6       | 8.88 (2.8 to 14.97)                  | 97.5                    |
| Others                    | 2       | -0.98 (-177.8 to 175.9)              | 97.11                   |

Supplement table 15b: Sub-group analysis of heart rate for change in between-group differences over time (non-RCT)

| Cooling intervention    | Numbers | Pooled mean with 95% CI (Per Minute) | $I^2$ heterogeneity (%) |
|-------------------------|---------|--------------------------------------|-------------------------|
| Water / Ice             | 2       | 8.04 (-30.07 to 46.16)               | 95.81                   |
| Phase changing material | 1       | -                                    | -                       |

Supplement table 16a: Sub-group analysis of sweat production for post intervention comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 3       | -1.16 (-2. 7 to 0.38)                   | 35.25                   |
| Ventilating / evaporative | 1       | -                                       | -                       |

Supplement table 16b: Sub-group analysis of sweat production for post intervention comparison (non-RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Ventilating / evaporative | 2       | -0.47 (-8.72 to 7.78)                   | 71.43                   |
| Phase changing material   | 1       | -                                       | -                       |

Supplement table 17: Sub-group analysis of sweat production for within-group change comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI (units) | $I^2$ heterogeneity (%) |
|---------------------------|---------|---------------------------------|-------------------------|
| Water / Ice               | 3       | -0.74 (-2.06 to 0.58)           | 11.59                   |
| Ventilating / evaporative | 1       | -                               | -                       |

Supplement table 18a: Sub-group analysis of sweat rate for post intervention comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI (units) | $I^2$ heterogeneity (%) |
|---------------------------|---------|---------------------------------|-------------------------|
| Water / Ice               | 4       | -0.58 (-1.22 to -0.05)          | 0.94                    |
| Ventilating / evaporative | 2       | -0.52 (-9.66 to 8.62)           | 83.93                   |
| Phase changing material   | 1       | -                               | -                       |
| Others                    | 1       | -                               | -                       |
| PCM + Ventilating         | 1       | -                               | -                       |

Supplement table 18b: Sub-group analysis of sweat rate for post intervention comparison (non-RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI (units) | $I^2$ heterogeneity (%) |
|---------------------------|---------|---------------------------------|-------------------------|
| Water / Ice               | 3       | -1.55 (-3.77 to 0.66)           | 45.55                   |
| Ventilating / evaporative | 3       | -0.56 (-2.56 to 1.45)           | 79.08                   |
| Phase changing material   | 1       | -                               | -                       |

Supplement table 19a: Sub-group analysis of RPE for post intervention comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI (units) | $I^2$ heterogeneity (%) |
|---------------------------|---------|---------------------------------|-------------------------|
| Water / Ice               | 4       | -1.12 (-3.08 to 0.85)           | 90.46                   |
| Ventilating / evaporative | 3       | -0.76 (-1.26 to -0.26)          | 0                       |
| PCM + Ventilator          | 1       | -                               | -                       |

Supplement table 19b: Sub-group analysis of RPE for post intervention comparison (non-RCT)

| Cooling intervention | Numbers | Pooled mean with 95% CI (units) | $I^2$ heterogeneity (%) |
|----------------------|---------|---------------------------------|-------------------------|
|----------------------|---------|---------------------------------|-------------------------|

|                           |   |                      |       |
|---------------------------|---|----------------------|-------|
| Ventilating / evaporative | 3 | -0.58 (-2.7 to 1.55) | 70.34 |
|---------------------------|---|----------------------|-------|

Supplement table 20: Sub-group analysis of RPE for within-group comparison

| Cooling intervention      | Numbers | Pooled mean with 95% CI (units) | $I^2$ heterogeneity (%) |
|---------------------------|---------|---------------------------------|-------------------------|
| Water / Ice               | 2       | -0.32 (-1.66 to 1.03)           | 0                       |
| Ventilating / evaporative | 1       | -                               | -                       |

Supplement table 21: Sub-group analysis of RPE for change in between-group differences over time

| Cooling intervention      | Numbers | Pooled mean with 95% CI (units) | $I^2$ heterogeneity (%) |
|---------------------------|---------|---------------------------------|-------------------------|
| Water / Ice               | 1       | -0.32 (-1.66 to 1.03)           | 0                       |
| Ventilating / evaporative | 2       | -                               | -                       |

Supplement table 22a: Sub-group analysis of thermal sensation for post intervention comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI (units) | $I^2$ heterogeneity (%) |
|---------------------------|---------|---------------------------------|-------------------------|
| Water / Ice               | 5       | -1.41 (-3.21 to 0.4)            | 80.31                   |
| Ventilating / evaporative | 1       | -                               | -                       |

Supplement table 22b: Sub-group analysis of thermal sensation for post intervention comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI (units) | $I^2$ heterogeneity (%) |
|---------------------------|---------|---------------------------------|-------------------------|
| PCM + Ventilating         | 1       | -                               | -                       |
| Ventilating / evaporative | 1       | -                               | -                       |

Supplement table 23a: Sub-group analysis of PSI for post intervention comparison (RCT)

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 2       | -0.88 (-4.29 to 2.53)                   | 0                       |
| Ventilating / evaporative | 1       | -                                       | -                       |
| Phase changing material   | 1       | -                                       | -                       |

Supplement table 23b: Sub-group analysis of PSI for post intervention comparison (Non-RCT)

| Cooling intervention | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|----------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice          | 2       | -2.4 (-35.43 to 30.63)                  | 96.77                   |

Supplement table 24: Sub-group analysis of PSI for within-group change comparison

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 1       | -                                       | -                       |
| Ventilating / evaporative | 2       | -0.37 (05.22 to 4.49)                   | 87.2                    |
| Phase changing material   | 1       | -                                       | -                       |

Supplement table 25: Sub-group analysis of PSI for change in between-group differences over time

| Cooling intervention      | Numbers | Pooled mean with 95% CI ( $^{\circ}$ C) | $I^2$ heterogeneity (%) |
|---------------------------|---------|-----------------------------------------|-------------------------|
| Water / Ice               | 1       | -                                       | -                       |
| Ventilating / evaporative | 1       | -                                       | -                       |
| Phase changing material   | 1       | -                                       | -                       |



## PRISMA 2020 Checklist

| Section and Topic             | Item # | Checklist item                                                                                                                                                                                                                                                                                       | Location where item is reported |
|-------------------------------|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|
| <b>TITLE</b>                  |        |                                                                                                                                                                                                                                                                                                      |                                 |
| Title                         | 1      | Identify the report as a systematic review.                                                                                                                                                                                                                                                          |                                 |
| <b>ABSTRACT</b>               |        |                                                                                                                                                                                                                                                                                                      |                                 |
| Abstract                      | 2      | See the PRISMA 2020 for Abstracts checklist.                                                                                                                                                                                                                                                         |                                 |
| <b>INTRODUCTION</b>           |        |                                                                                                                                                                                                                                                                                                      |                                 |
| Rationale                     | 3      | Describe the rationale for the review in the context of existing knowledge.                                                                                                                                                                                                                          | 5                               |
| Objectives                    | 4      | Provide an explicit statement of the objective(s) or question(s) the review addresses.                                                                                                                                                                                                               | 5                               |
| <b>METHODS</b>                |        |                                                                                                                                                                                                                                                                                                      |                                 |
| Eligibility criteria          | 5      | Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.                                                                                                                                                                                          | 6                               |
| Information sources           | 6      | Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.                                                                                            | 6                               |
| Search strategy               | 7      | Present the full search strategies for all databases, registers and websites, including any filters and limits used.                                                                                                                                                                                 | Sup table 1                     |
| Selection process             | 8      | Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.                     | 6, 7                            |
| Data collection process       | 9      | Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process. | 7                               |
| Data items                    | 10a    | List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.                        | 7, 8                            |
|                               | 10b    | List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.                                                                                         | 7                               |
| Study risk of bias assessment | 11     | Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.                                    | 8, 9                            |
| Effect measures               | 12     | Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.                                                                                                                                                                  | Sup table 2                     |
| Synthesis methods             | 13a    | Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).                                                                                 | 8                               |
|                               | 13b    | Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.                                                                                                                                                | 8                               |
|                               | 13c    | Describe any methods used to tabulate or visually display results of individual studies and syntheses.                                                                                                                                                                                               | 8                               |
|                               | 13d    | Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.                                          | 8                               |
|                               | 13e    | Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).                                                                                                                                                                 | 8                               |
|                               | 13f    | Describe any sensitivity analyses conducted to assess robustness of the synthesized results.                                                                                                                                                                                                         | 8                               |



## PRISMA 2020 Checklist

| Section and Topic             | Item # | Checklist item                                                                                                                                                                                                                                                                       | Location where item is reported |
|-------------------------------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|
| Reporting bias assessment     | 14     | Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).                                                                                                                                                              | 8. 9                            |
| Certainty assessment          | 15     | Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.                                                                                                                                                                                | 9                               |
| <b>RESULTS</b>                |        |                                                                                                                                                                                                                                                                                      |                                 |
| Study selection               | 16a    | Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.                                                                                         | 9                               |
|                               | 16b    | Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.                                                                                                                                                          | 9                               |
| Study characteristics         | 17     | Cite each included study and present its characteristics.                                                                                                                                                                                                                            | 10                              |
| Risk of bias in studies       | 18     | Present assessments of risk of bias for each included study.                                                                                                                                                                                                                         | 10                              |
| Results of individual studies | 19     | For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.                                                     | 11 - 14                         |
| Results of syntheses          | 20a    | For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.                                                                                                                                                                               | 10                              |
|                               | 20b    | Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect. | 11 - 14                         |
|                               | 20c    | Present results of all investigations of possible causes of heterogeneity among study results.                                                                                                                                                                                       | 11 – 14                         |
|                               | 20d    | Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.                                                                                                                                                                           | 11 – 14                         |
| Reporting biases              | 21     | Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.                                                                                                                                                              | 10                              |
| Certainty of evidence         | 22     | Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.                                                                                                                                                                                  | 11                              |
| <b>DISCUSSION</b>             |        |                                                                                                                                                                                                                                                                                      |                                 |
| Discussion                    | 23a    | Provide a general interpretation of the results in the context of other evidence.                                                                                                                                                                                                    | 15 – 16                         |
|                               | 23b    | Discuss any limitations of the evidence included in the review.                                                                                                                                                                                                                      | 16                              |
|                               | 23c    | Discuss any limitations of the review processes used.                                                                                                                                                                                                                                | 15                              |
|                               | 23d    | Discuss implications of the results for practice, policy, and future research.                                                                                                                                                                                                       | 16                              |
| <b>OTHER INFORMATION</b>      |        |                                                                                                                                                                                                                                                                                      |                                 |
| Registration and protocol     | 24a    | Provide registration information for the review, including register name and registration number, or state that the review was not registered.                                                                                                                                       | 6                               |
|                               | 24b    | Indicate where the review protocol can be accessed, or state that a protocol was not prepared.                                                                                                                                                                                       | 6                               |
|                               | 24c    | Describe and explain any amendments to information provided at registration or in the protocol.                                                                                                                                                                                      | 6                               |
| Support                       | 25     | Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.                                                                                                                                                        | 20-21                           |
| Competing                     | 26     | Declare any competing interests of review authors.                                                                                                                                                                                                                                   | 20-21                           |



## PRISMA 2020 Checklist

| Section and Topic                              | Item # | Checklist item                                                                                                                                                                                                                             | Location where item is reported |
|------------------------------------------------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|
| interests                                      |        |                                                                                                                                                                                                                                            |                                 |
| Availability of data, code and other materials | 27     | Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review. | 20-21                           |

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71 For more information, visit: <http://www.prisma-statement.org/>