Cooling與運動訓練

112年教練增能教育訓練系列課程

- 2023 Jun
  - 運動科學處
  - 陸康豪

變溫/恆溫動物

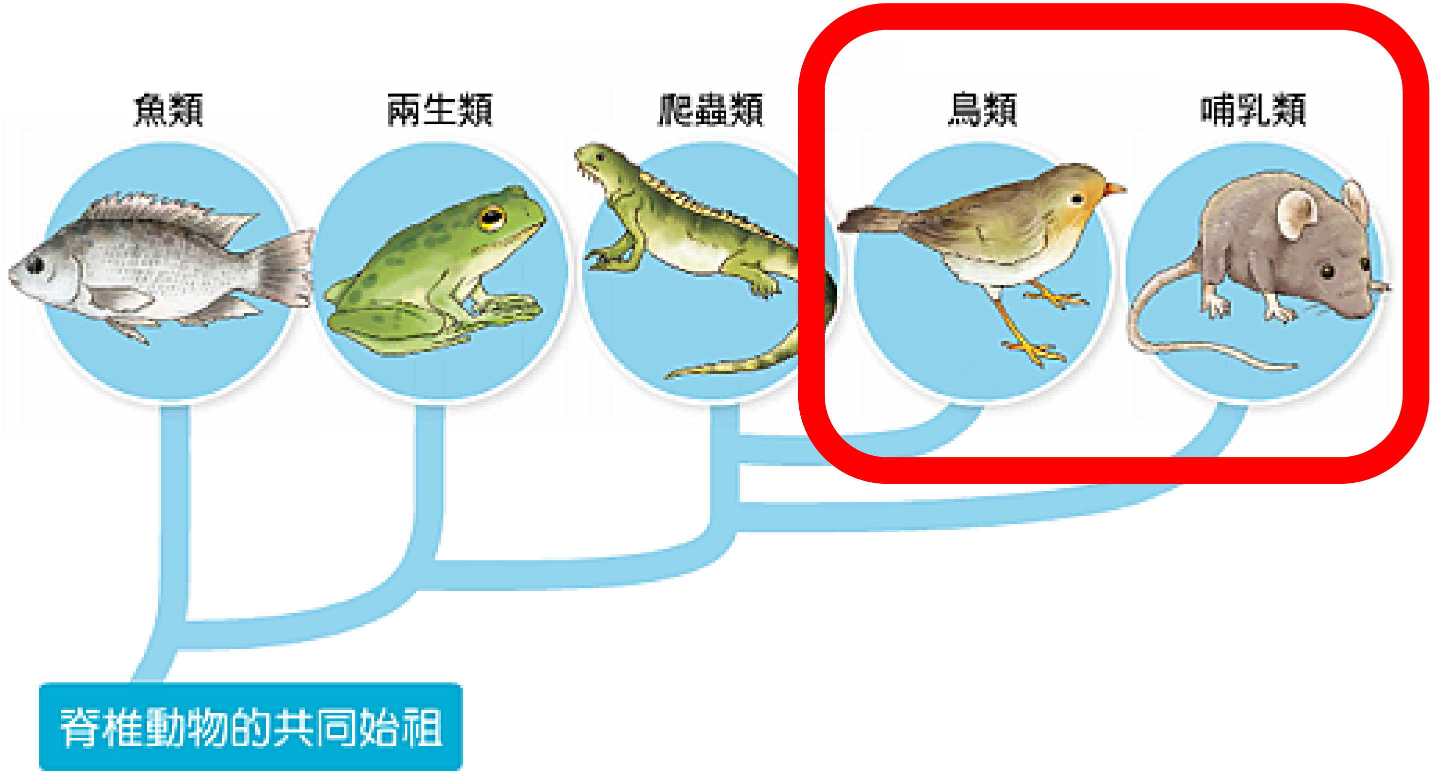
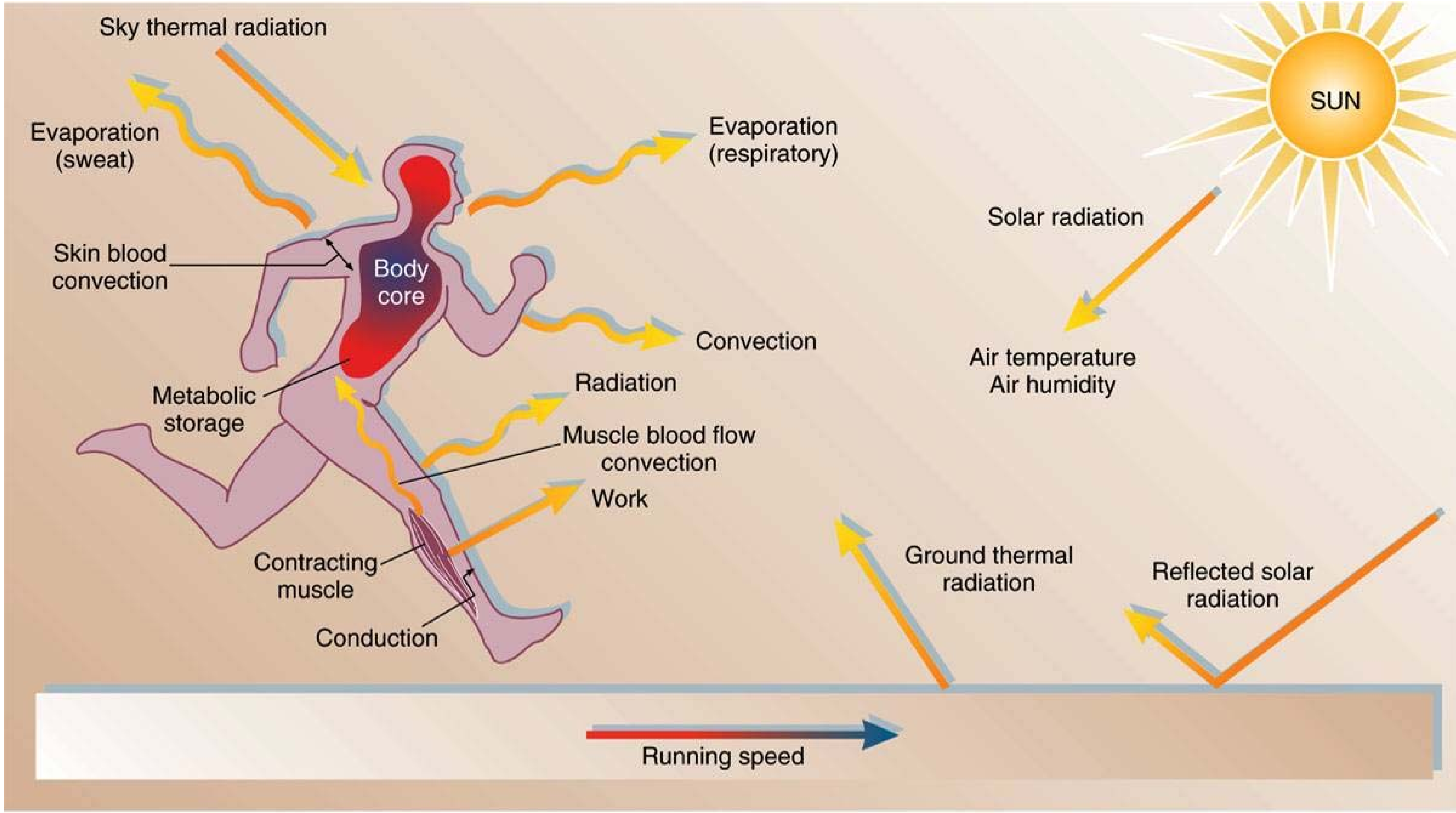


圖3-20 脊椎動物可能的演化順序

圖片出自南一課本

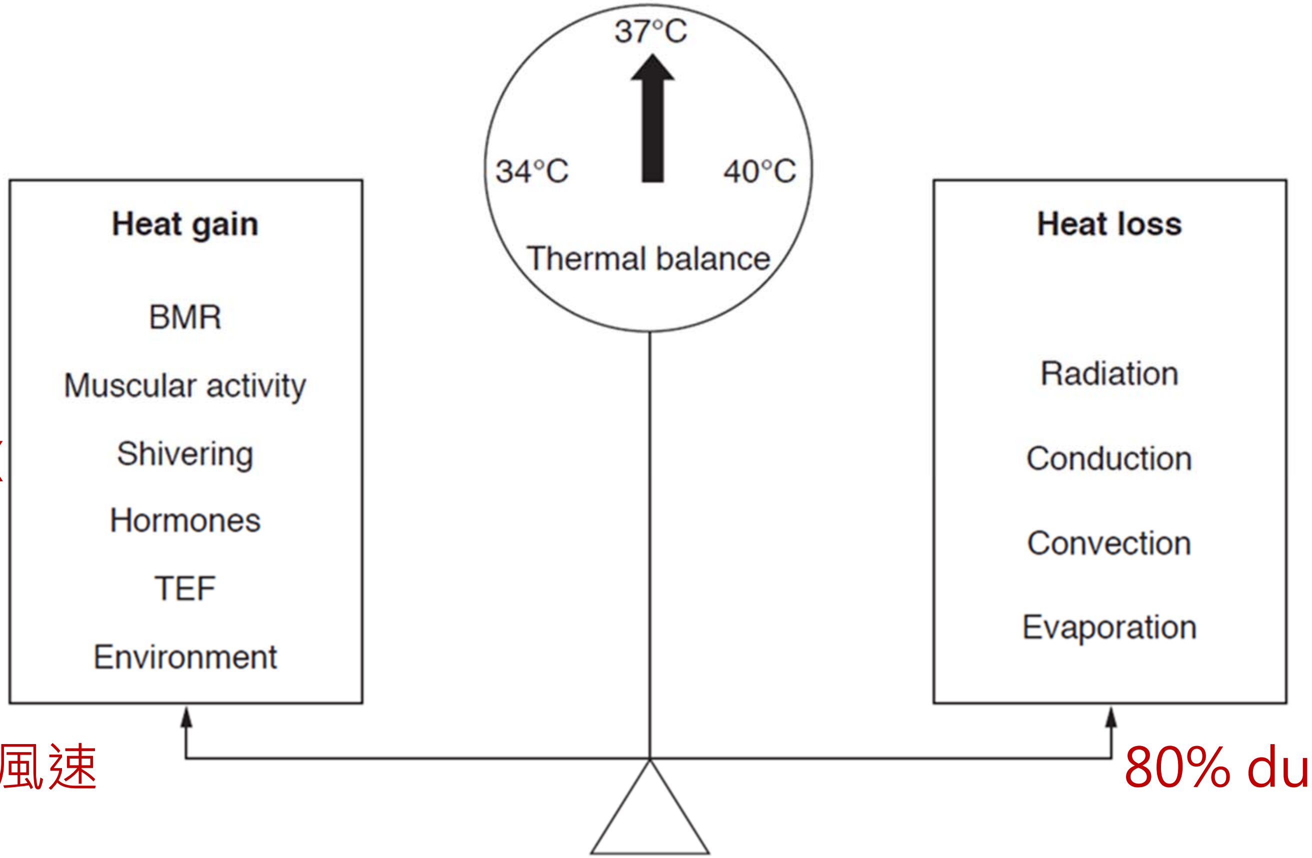
Heat Exchange Mechanisms During Exercise



Powers, S. K., & Howley, E. T. (2012). *Exercise physiology: Theory and application to fitness and performance* (8th ed.).

體溫恆定

70-80%
during EX



溫/濕度、風速

80% during EX

Figure 16.1 Factors that contribute to body temperature homeostasis

Kang, J. (2018). *Nutrition and metabolism in sports, exercise and health* (2nd ed.) (p. 409).

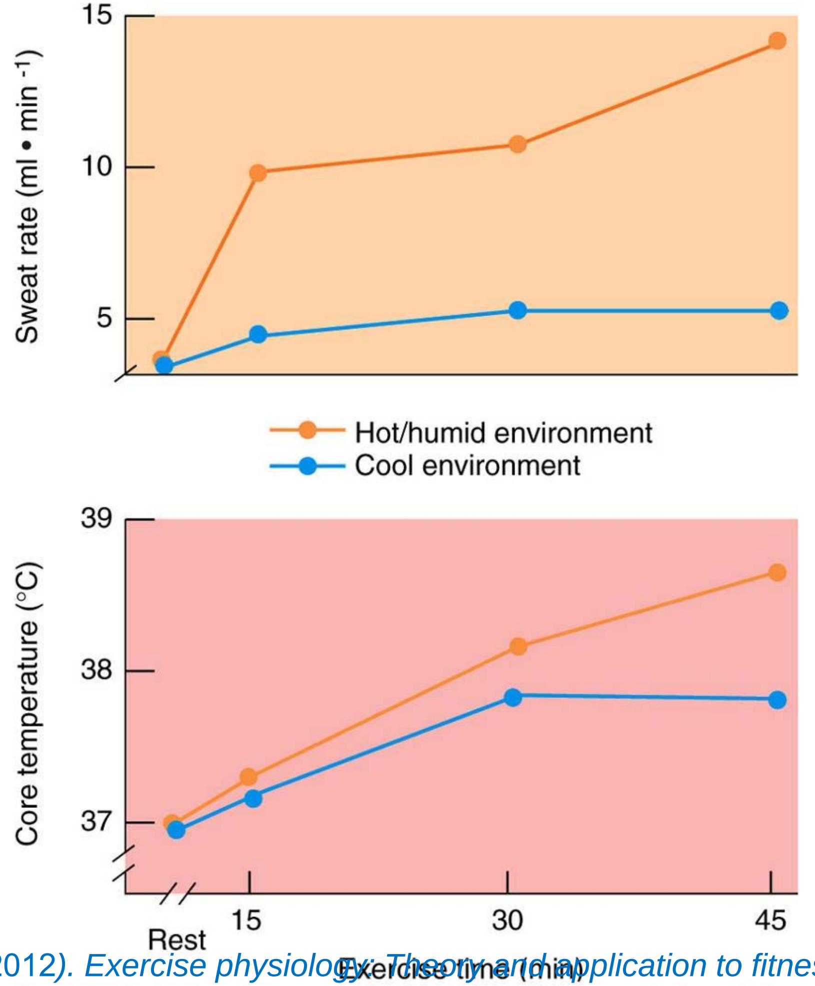
Relationship of Relative Humidity (%), Temperature, and Heat Index

Temperature °F (°C)	Relative Humidity (%) 40	45	50	55	60	65	70	75	80	85	90	95	100
110 (47)	136 (58)												
108 (43)	130 (54)	137 (58)											
106 (41)	124 (51)	130 (54)	137 (58)										
104 (40)	119 (48)	124 (51)	131 (55)	137 (58)									
102 (39)	114 (46)	119 (48)	124 (51)	130 (54)	137 (58)								
100 (38)	109 (43)	114 (46)	118 (48)	124 (51)	129 (54)	136 (58)							
98 (37)	105 (41)	109 (43)	113 (45)	117 (47)	123 (51)	128 (53)	134 (57)						
96 (36)	101 (38)	104 (40)	108 (42)	112 (44)	116 (47)	121 (49)	126 (52)	132 (56)					
94 (34)	97 (36)	100 (38)	103 (39)	106 (41)	110 (43)	114 (46)	119 (48)	124 (51)	129 (54)	135 (57)			
92 (33)	94 (34)	96 (36)	99 (37)	101 (38)	105 (41)	108 (42)	112 (44)	116 (47)	121 (49)	126 (52)	131 (55)		
90 (32)	91 (33)	93 (34)	95 (35)	97 (36)	100 (38)	103 (39)	106 (41)	109 (43)	113 (45)	117 (47)	122 (50)	127 (53)	132 (56)
88 (31)	88 (31)	89 (32)	91 (33)	93 (34)	95 (35)	98 (37)	100 (38)	103 (39)	106 (41)	110 (43)	113 (45)	117 (47)	121 (49)
86 (30)	85 (29)	87 (31)	88 (31)	89 (32)	91 (33)	93 (34)	95 (35)	97 (36)	100 (38)	102 (39)	105 (41)	108 (42)	112 (44)
84 (29)	83 (28)	84 (29)	85 (29)	86 (30)	88 (31)	89 (32)	90 (32)	92 (33)	94 (34)	96 (36)	98 (37)	100 (38)	103 (39)
82 (28)	81 (27)	82 (28)	83 (28)	84 (29)	84 (29)	85 (29)	86 (30)	88 (31)	89 (32)	90 (32)	91 (33)	93 (34)	95 (35)
80 (27)	80 (27)	80 (27)	81 (27)	81 (27)	82 (28)	82 (28)	83 (28)	84 (29)	84 (29)	85 (29)	86 (30)	86 (30)	87 (31)

Category	Heat Index
Extreme Danger	130°F or higher (54°C or higher)
Danger	105–129°F (41–54°C)
Extreme Caution	90–105°F (32–41°C)
Caution	80–90°F (27–32°C)

Powers, S. K., & Howley, E. T. (2012). *Exercise physiology: Theory and application to fitness and performance* (8th ed.).

Core Temperature and Sweat Rate During Exercise in a Hot/Humid Environment



Powers, S. K., & Howley, E. T. (2012). *Exercise physiology: Theory and application to fitness and performance* (8th ed.).

Core-to-skin thermal gradient

Table 4.2 Estimated skin blood flow requirements during prolonged high-intensity running at different body core and skin temperatures

Core temp. (°C)	*Skin temp. (°C)*	*Temp. gradient (°C)*	*Skin blood flow (litres per min)*
38	30	8	1.1
38	32	6	1.5
38	34	4	2.2
38	36	2	4.4
39	30	9	1.0
39	32	7	1.3
39	34	5	1.8
39	36	3	2.9

Note: At any given skin temperature, increased core temperature increases the temperature gradient between the core and the skin, and there is a reduction in skin blood flow. At any given core temperature, increasing the skin temperature reduces the temperature gradient between the core and the skin, and there is an increase in skin blood flow.

Source: Sawka *et al.*[49]

Phillips, S. (2015). *Fatigue in sport and exercise* (p. 101).

舒適vs. 熱環境

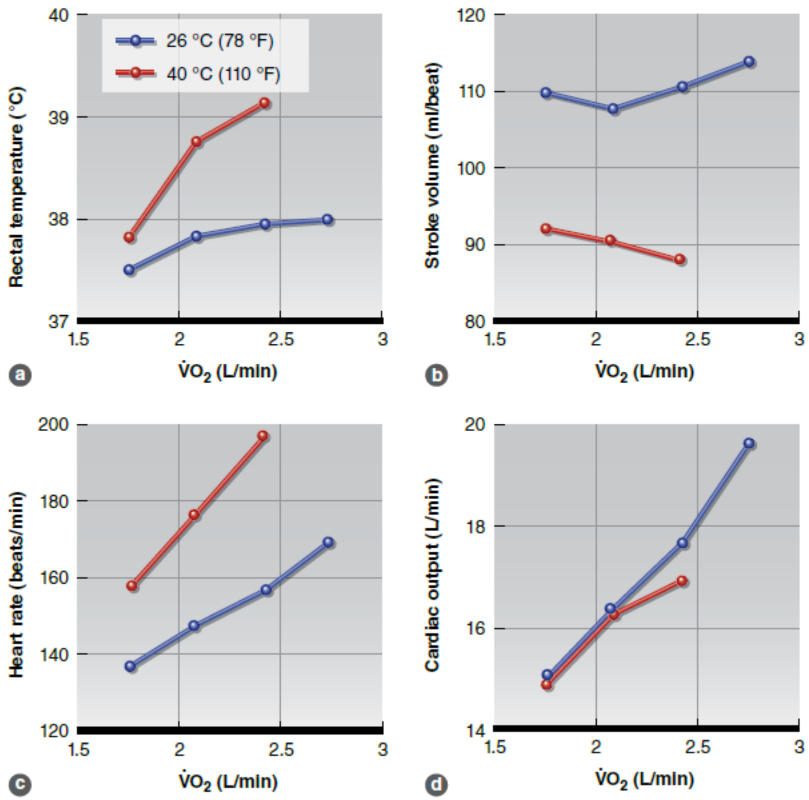


FIGURE 12.6 (*a*) Rectal temperature and (*b-d*) cardiovascular responses to graded exercise in thermoneutral (26 °C, 78 °F; open circles) and hot (43 °C, 110 °F; filled circles) environments. Note that, in addition to directional changes in these variables caused by heat stress, the maximal intensity is decreased when exercise is performed in a hot environment.
Based on Rowell, 1974.

Kenney, W. L., et al. (2012). *Physiology of sports and exercise* (5th ed.) (p. 292).

電擊

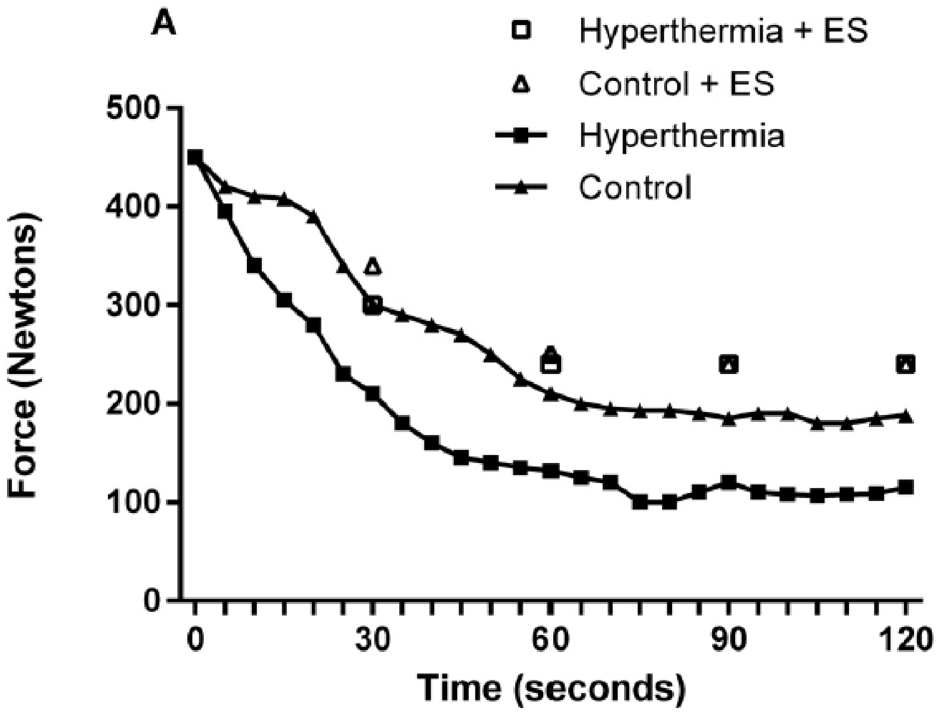


Figure 4.5 Force production from the thigh muscle during a 2 minute maximal knee extension during hyperthermia (core temperature of 40°C) and control (core temperature of 38°C). Participants were asked to make a maximal effort for the entire 2 minutes. Electrical stimulation of the muscle was applied every 30 seconds during the contraction. Electrical stimulation showed that the ability of the muscle to contract was not influenced by hyperthermia. However, participants were not able to voluntarily maintain the level of force production that the muscle was capable of, or that they could maintain in the control trial. This suggests that the causes of reduced force production in the hyperthermia trial were central in origin. From Nybo and Nielsen.[48]

Phillips, S. (2015). *Fatigue in sport and exercise* (p. 98).

體溫過高與疲勞

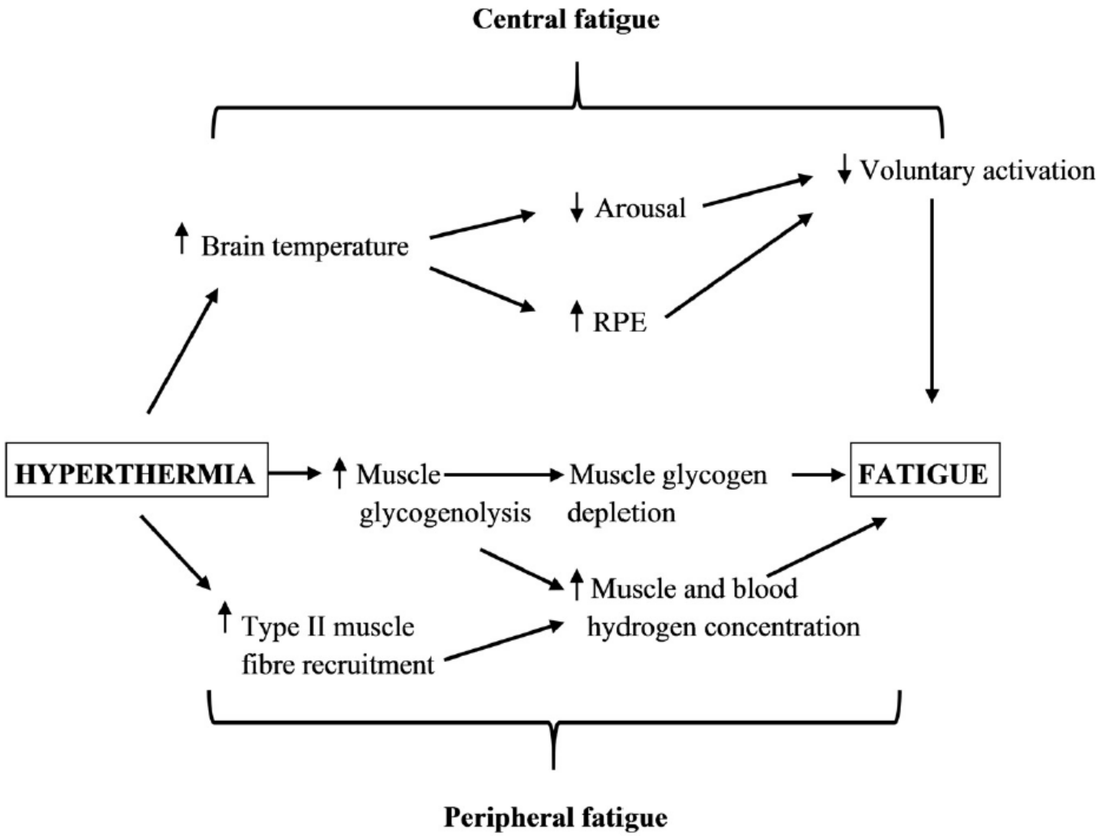
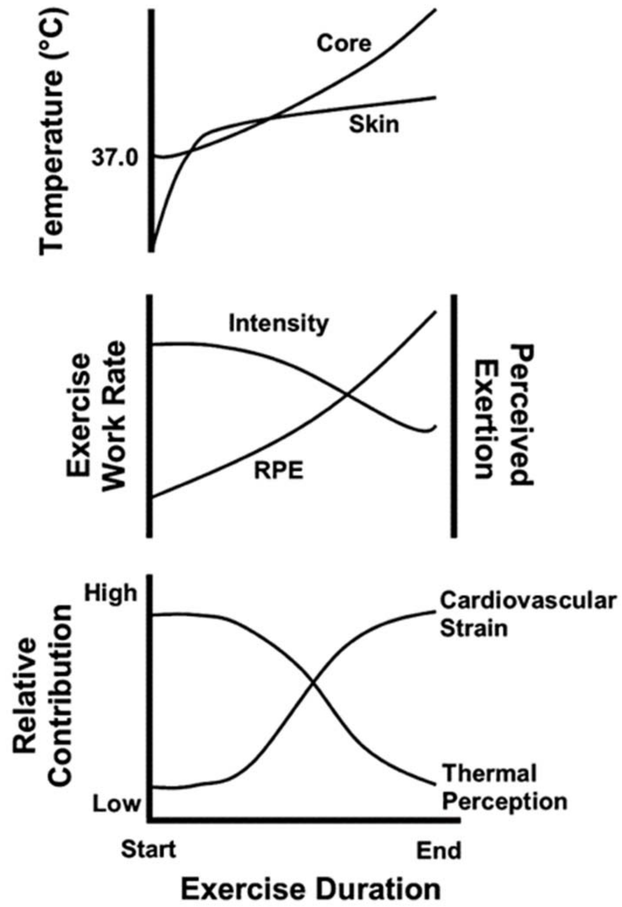


Figure 4.4 Potential causes of hyperthermia-induced fatigue during exercise. The causes of fatigue are characterised as central or peripheral in origin. Adapted from Cheung and Sleivert.[44]

Phillips, S. (2015). *Fatigue in sport and exercise* (p. 95).

Self-paced exercise



Flouris, A. D., & Schlader, Z. J. (2015). Human behavioral thermoregulation during exercise in the heat. *Scandinavian Journal of Medicine & Science in Sports.*

環境溫度與疲勞

Brearley and Saunders

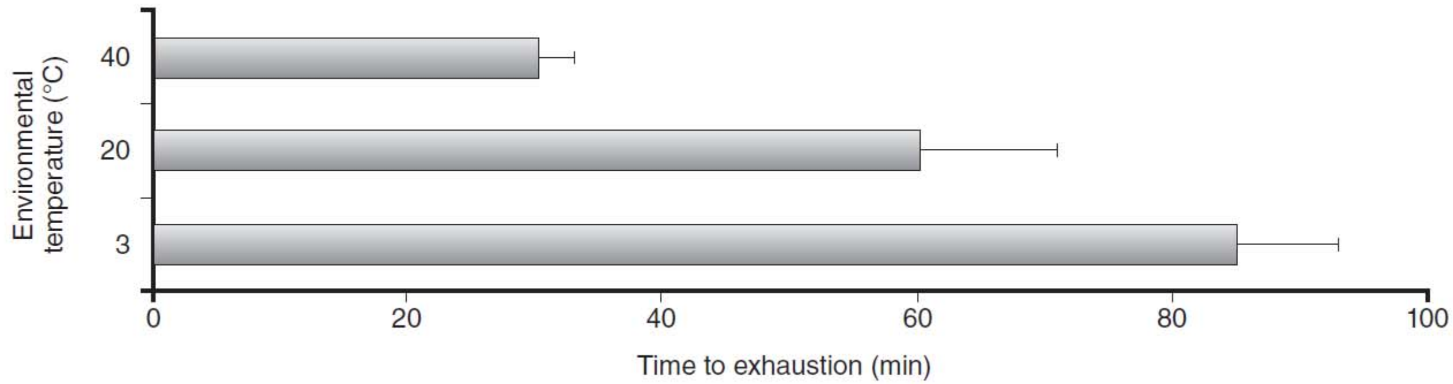


FIGURE 9.2 Time to exhaustion at 70% $\dot{V}O_2$max in 3, 20, and 40 °C (<50% relative humidity). Data given as mean with error bars representing standard deviation.

Adapted from J.M. Parkin et al., 1999, "Effect of ambient temperature on human skeletal muscle metabolism during fatiguing submaximal exercise," *Journal of Applied Physiology* 86(3):902-908. Used with permission.

Australian Institute of Sport. (Ed.). (2013). *Physiological tests for elite athletes* (2nd ed.) (p. 134).

田徑

1999-2011
世錦賽
成績分析

Effect on exercise performance **67**

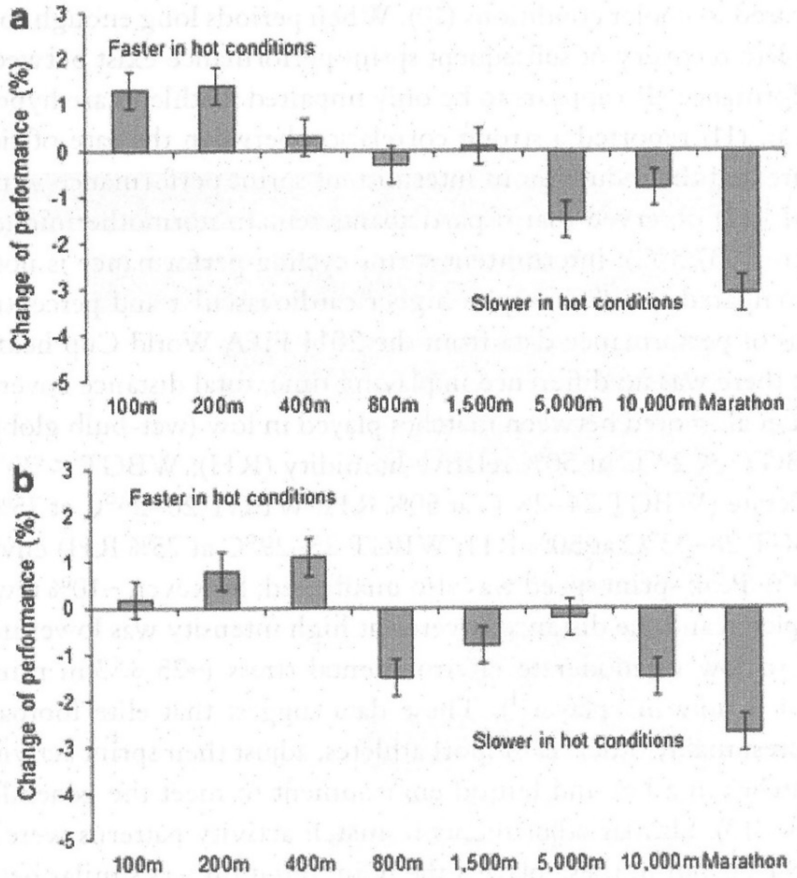


FIGURE 4.1 Mean (±95% confidence intervals) percentage change in performance observed in temperate (<25°C) and hot (>25°C) IAAF World Championship track events (1999–2011) in male (a) and female (b) athletes. Reprinted by permission from Springer Nature: Sports Medicine. Guy et al. (2). Adaptation to Hot Environmental Conditions: An Exploration of the Performance Basis, Procedures and Future Directions to Optimise Opportunities for Elite Athletes. *Sports Medicine*, 45(3): 303–11. Springer 2015.

Tyler, C. J. (2019). *Maximising performance in hot environments: A problem-based learning approach* (p. 67).

Pre- and per-cooling

https://keynutrients.com/blogs/learn/can-you-be-overhydrated

冰水浴

Review > Exerc Sport Sci Rev. 2007 Jul;35(3):141-9. doi: 10.1097/jes.0b013e3180a02bec.

Cold water immersion: the gold standard for exertional heatstroke treatment

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Affiliations + expand

PMID: 17620933 DOI: 10.1097/jes.0b013e3180a02bec

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Abstract

The key to maximize the chances of surviving exertional heatstroke is rapidly decreasing the elevated core body temperature. Many methods exist to cool the body, but current evidence strongly supports the use of cold water. Preferably, the athlete should be immersed in cold water. If lack of equipment or staff prevents immersion, a continual dousing with cold water provides an effective cooling modality. We refute the many criticisms of this treatment and provide scientific evidence supporting cold water immersion for exertional heatstroke.

Cold water immersion (CWI)

https://www.ishn.com/articles/112410-heat-illness-more-dangerous-easier-to-prevent-than-you-think

https://www.polarproducts.com/polarshop/pc/Polar-Life-Pod-Cold-Water-Immersion-System-p2105.htm

CWI實用性??

https://today.line.me/tw/v2/article/eDlxqx

https://www.setn.com/News.aspx?NewsID=1144435

韓國選手

https://news.tvbs.com.tw/world/438063

HPSC JISS

競技者のための
暑熱対策
ガイドブック
【実践編】

目　次

● はじめに ●

東京2020オリンピック・パラリンピック競技大会は7月24日～9月6日に開催されます。この時期は猛暑日になることも多く、熱中症が多発する時期であり、非常に過酷な環境になることが予想されます。ハイパフォーマンススポーツセンター（HPSC）国立スポーツ科学センター（JISS）では、東京2020大会に向けたプロジェクト研究の一つとして、2015年度から「暑熱対策に関する研究」に取り組んできました。その中では、暑熱環境下の運動による生理学的変化や特定の暑熱対策の効果を調べるための実験を行うとともに、競技団体関係者に情報提供を行うことを目的とした暑熱対策セミナーを開催しました。さらに、競技者、コーチ・指導者および情報・医・科学スタッフを対象とした暑熱環境対策に関するアンケート調査の結果や、暑熱環境での運動や暑熱対策に関するこれまでの国内外の研究知見をまとめた「競技者のための暑熱対策ガイドブック」を2017年に刊行しました。

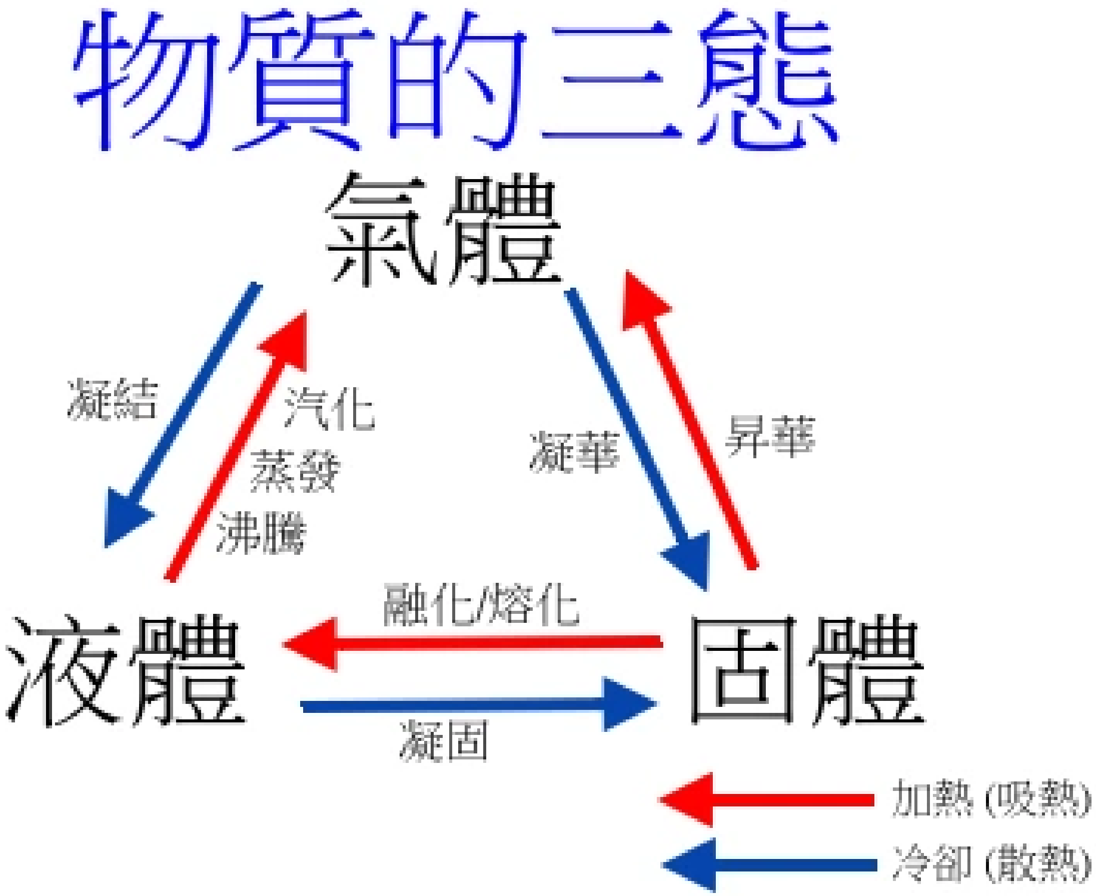
Ice slurry冰沙

アイススラリー

アイススラリーは、水と微小な氷がシャーベット状に混ざった氷飲料です（写真 1-1）。アイススラリーは低温で流動性が高く、氷が水に溶ける際に体内の熱を多く吸収することができます。そのため、アイススラリーの摂取は冷たい飲料の摂取よりも非常に高い冷却効果を有しており、有用な暑熱対策の一つです。

写真 1-1　アイススラリーとスラリーマシン

冰vs. 水



https://wiki-co-notes.fandom.com/zh/wiki/State_of_matter%E7%89%A9%E8%B3%AA%E7%8B%80%E6%85%8B?file=%E7%89%A9%E8%B3%AA%E7%9A%84%E4%B8%89%E6%85%8B.png

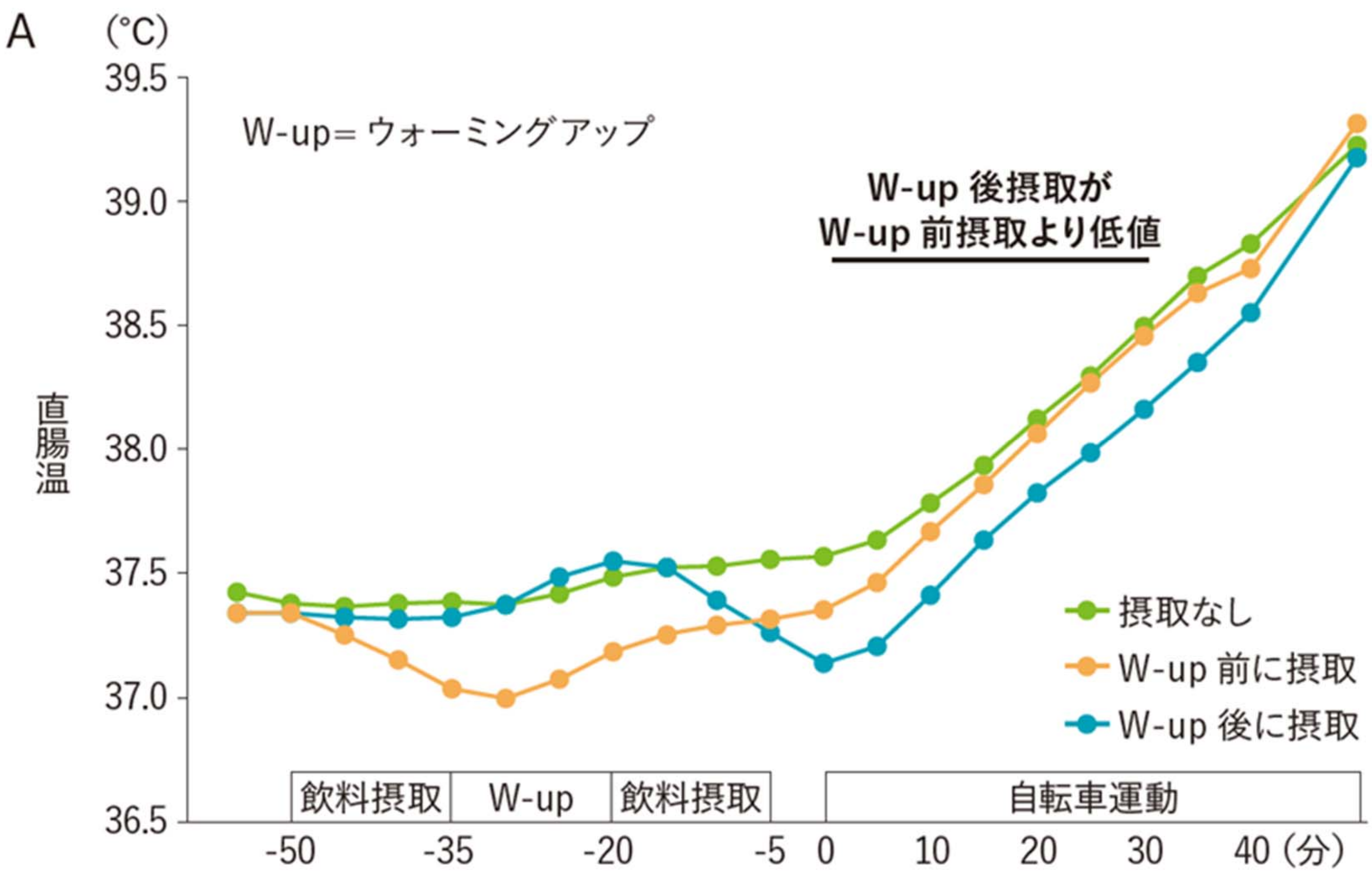
建議攝取量

アイススラリー摂取のタイミング・量

研究結果では、運動前の摂取であれば、体重1kgあたり7.5g（60kgの選手であれば450g）をこまめに摂取すると十分な深部体温の低下が認められています。また、深部体温はアイススラリーをウォーミングアップ（W-up）前よりも後に摂取すると低下が大きく、持久性運動パフォーマンスに対しても有効であることが報告されています（図1-1A)。

競技中に給水ができる競技では運動中に、競技中に休憩が設けられている競技ではその休憩中に、アイススラリー摂取をすることができます。摂取量は、休憩ごとに体重1kgあたり1.25g（60kgの選手であれば75g）を摂取すると、運動後半の深部体温の上昇を抑制することが報告されています（図1-1B)。

Cycling trials to exhaustion at 55% peak PPO



Running protocol to simulate match-play tennis

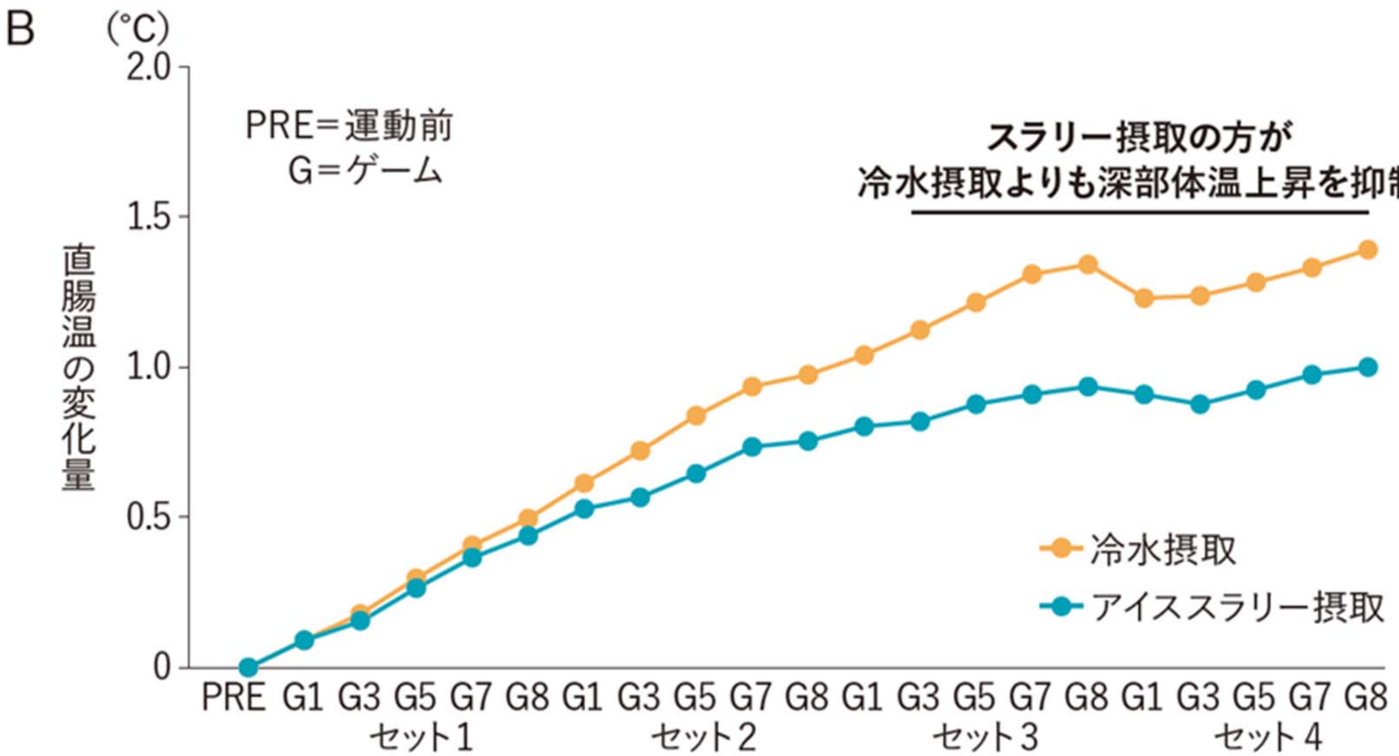


図1-1　運動前・休憩中のアイススラリー摂取と深部体温（直腸温）の変化
（A：Takeshima et al., 2017から作図　B：Naito et al., 2018から作図）

自製碎冰

図1-2　クラッシュドアイスの作製例

氷とスポーツ飲料の割合は氷３：スポーツ飲料１～２程度で、スポーツ飲料の糖度によって割合を調節すると良いでしょう。保存は魔法瓶が実用的です。

Core-to-skin thermal gradient

Stanley, Peake, Coombes, & Buchheit, 2014). Moreover, the increase in core-to-skin thermal gradient is associated with the 'after-drop' effect, which allows for continued cooling, even upon the commencement of exercise task (Kay, Taaffe, & Marino, 1999). Conversely, CWI has been shown to reduce peripheral blood flow and muscle metabolic activity, which may negatively impact the performance of exercise tasks of certain nature (Choo et al., 2016; Ihsan, Watson, Lipski, & Abbiss, 2013; Stanley et al., 2014). Whereas, ICE has been shown to decrease core body temperature, without influencing skin or muscle temperature, offering no benefit of an 'after-drop' mechanism, but in turn also not likely to result in impaired muscle metabolism (Siegel, Maté, Watson, Nosaka, & Laursen, 2012; Stevens, Thoseby, et al., 2016). Moreover, ICE has been purported to enhance exercise performance, in part through improved thermal perception via the stimulation of thermoreceptors located within oral and

Accordingly, the present review aimed to compare the psychophysiological responses and the effect of precooling via CWI and ICE on exercise performance undertaken in the heat.

Methods

Inclusion criteria

Studies were screened and selected for data synthesis based on the following criteria: (i) cooling was performed before exercise, and included studies where cooling treatment was undertaken between repeated exercise bouts; however, studies which performed an additional cooling manoeuvre during exercise were excluded; (ii) precooling was performed with ICE or CWI, while studies involving the combined use of additional cooling methods were considered as mixed cooling methods and were excluded; (iii) exercise longer than 6 min was performed in

Choo, H. C., et al. (2018). Ergogenic effects of precooling with cold water immersion and ice ingestion: A meta-analysis. *European Journal of Sport Science.*

Ice vest冰背心

アイスベスト

　アイスベストとは、冷却剤がポケットに入ったベストのことで、着用して身体外部から冷却することで活動筋を冷やすことなく深部体温、冷却剤が内包されている頸部、胸部および背部の皮膚温を低下させることができます。これらの部位の冷却は冷涼感を得ることができ、感覚的にも好影響を及ぼします。また、ベストを着用することで皮膚を効率よく冷やして熱放散が抑えられるため、余分な発汗を抑えることができます。

アイスベスト着用のタイミング・時間

　アイスベストによる冷却は、運動前・W-up中・運動中と場面を限定せずに使用することができます（図1-3）。W-up中であれば、20～30分の着用は、着用しない場

Phase Change Material (PCM)

Kwiecien et al. Phase Change Material and Recovery

FIGURE 2 | Two Glacier Tek 15°C PCM packs in the frozen state **(left)**, and in their melted state **(right)**.

Kwiecien, S. Y., et al. (2020). Don't lose your cool with cryotherapy: The application of phase change material for prolonged cooling in athletic recovery and beyond. *Frontiers in Sports and Active Living.*

Rugby match-specific 30-min warm-up

合と比べてW-upの質を低下させることなく深部体温上昇を抑制し（図1-4）、持久性運動パフォーマンスの低下を抑制することが報告されています。また、ハーフタイムなどの運動間では、15分程度の着用で運動後半のパワー発揮の低下を抑制することが示されています。

図1-3　運動間のアイスベスト着用イメージ

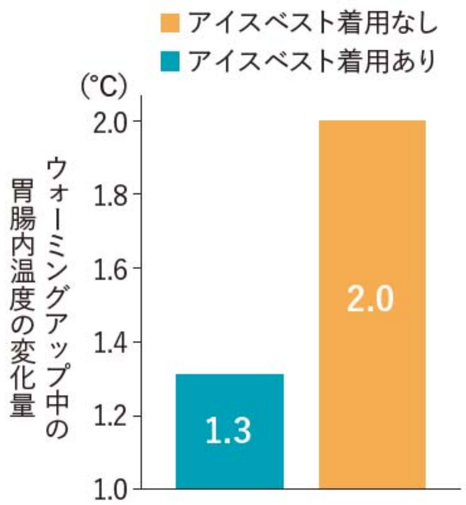


図1-4　W-up中の深部体温（胃腸内温度）の変化量
（Taylor et al., 2019から作図）

Hand/palm cooling

手掌前腕冷却

手掌前腕冷却は手の掌（ひら）と前腕を冷水に浸けて、身体外部から冷却をしていく方法です。手の掌には、動脈と静脈が直接連絡している特殊な血管（動静脈吻合（ふんごう））が存在しています。通常の血管より多くの血液が動静脈吻合を通過するので、手掌前腕冷却を行うことで冷却された血液が深部に戻り（還流）、身体が冷却されます（図1-5）。また、手の掌と前腕は体幹部と比べて容積に対する表面積の比が大きく、熱を身体の外へ逃がしやすい構造となっています。

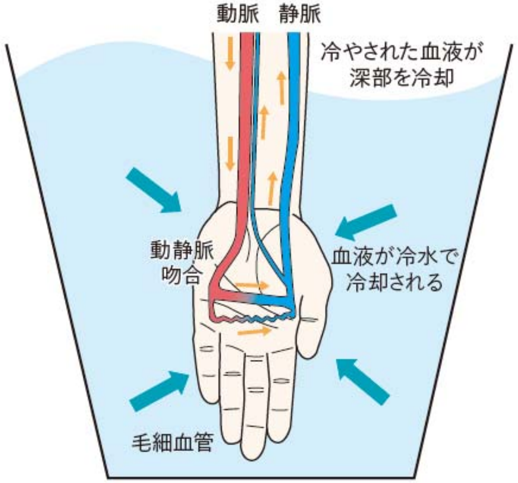


図1-5　手掌前腕冷却（浸水）
（Hirata, 1990から改変作図）

Hand/palm cooling

手掌前腕冷却のタイミング・水温・時間

手掌前腕冷却は運動前や運動間で実施することができますが、研究結果から運動間での使用が有効かもしれません。背景として、手掌部を流れる血流量が運動によって増加し、より多くの血液を冷却することができるためと考えられています。例えば、運動間の10分の浸水（10℃）は直腸温を低下（**図1-6**）させるだけではなく、皮膚温や心拍数も低下させることができます。水温は運動間であれば、10～15℃程度が効果的な温度とされています。それ以下の温度では血管を収縮させてしまうため、冷却効率は良くありません。冷却時間は深部体温の低下には10分程度が望ましいですが、短時間でも冷涼感を得ることができます。

Uncompensable heat stress

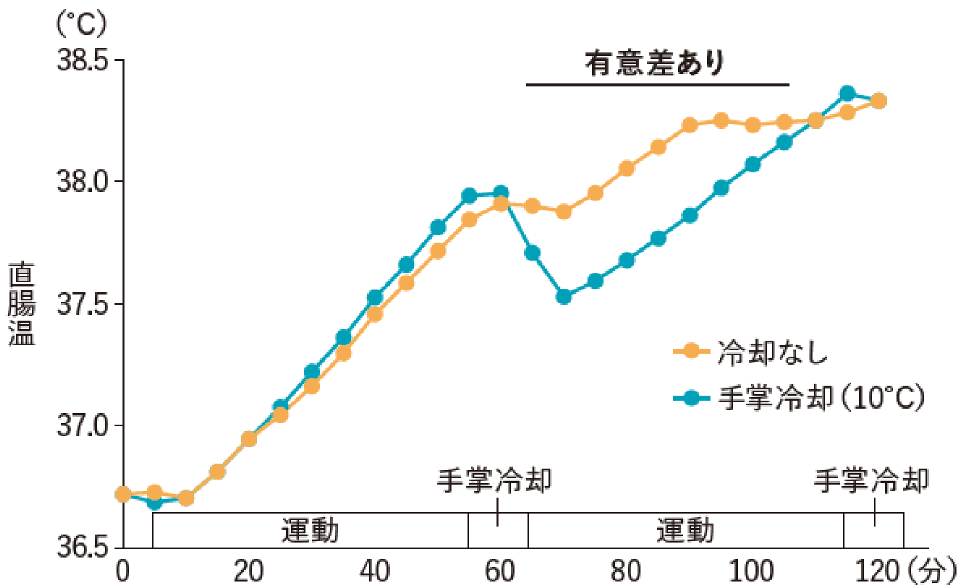


図1-6　運動間の手掌冷却と深部体温（直腸温）の変化

（Khomenok et al., 2008から改変作図）

Subjects wearing a semi-permeable NBC protective garment and a light bulletproof vest were exposed to a 125 min exercise-heat stress (35 degrees C, 50% RH; 5 km/h, 5% incline).

冰水配方

TABLE 9.2 Volume of Ice Required to Lower Water Temperature of a 600 L Bath From 25 °C to Desired Temperature

Desired water temperature	20 °C	14 °C	8 °C
Ice requirement, kg	37.5	82.5	127.5

Australian Institute of Sport. (Ed.). (2013). *Physiological tests for elite athletes* (2nd ed.) (p. 139).

Rapid thermal exchanger (RTX)

https://news.stanford.edu/2012/08/29/cooling-glove-research-082912/

https://www.medgadget.com/2007/05/rtx_cooling_glove_hits_the_market_1.html

Arm Immersion Cooling

https://www.mindef.gov.sg/web/portal/pioneer/article/feature-article-detail/ops-and-training/2018-Q3/sep18_fs3

https://twitter.com/fortleonardwood/status/1420861914893127684

Arm Immersion Cooling System (AICS)

https://techlinkcenter.org/technologies/portable-body-cooling-system-for-preventing-heat-injury/b5ea71e9-affd-45fc-84c2-cad9f15ed0b5

Arm Immersion Cooling System (AICS)

Benefits

The Opportunity

Articles & Downloads

- Impact of Arm Immersion Cooling During Ranger Training on Exertional Heat Illness and Treatment Costs
- Extremity cooling for heat stress mitigation in military and occupational settings

IP

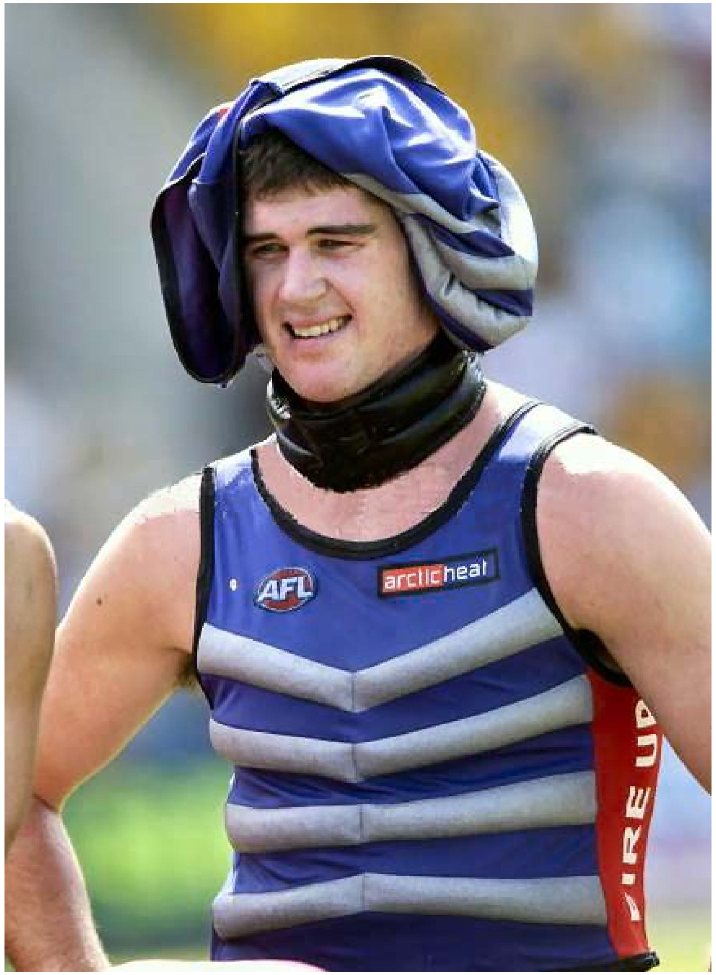
- International filing WO/2012/162,199

https://techlinkcenter.org/technologies/portable-body-cooling-system-for-preventing-heat-injury/b5ea71e9-affd-45fc-84c2-cad9f15ed0b5

Arm Cooler Harness

https://harcor.com.au/products/fire-fighting-arm-cooler-harness

Ice packs/ Neck cooling collar



https://www.prweb.com/releases/2005/08/prweb268766.htm

Cooling in NSTC

JISS自由車

対象選手	日本自転車競技女子強化指定選手1名
実施期間	2018年8月3日～6日
測定場所	山梨県道志みち山岳区間
環境条件	気温（33.1±0.9℃）、湿度（49.3±3.6%）、WBGT（27.9±0.4℃）
冷却方法	運動前のアイススラリー摂取
実施方法	1時間半のウォーミングアップ後、タイムトライアル開始30分前から体重1kgあたり1.25gのアイススラリーもしくは常温のスポーツ飲料を5分間隔ごとに6回摂取（合計約400g）（写真2-1）。アイススラリー摂取の場所は、写真のように日陰を利用。その後、標高差352mを含む6.8kmのコースでタイムトライアルを実施。

写真2-1　タイムトライアル前のアイススラリー摂取

JISS網球

対象選手	テニス選手８名（男子：４名、女子：４名）
実施期間	2019年８月５日～10日
測定場所	四日市テニスセンター（三重県）
環境条件	気温（31.7～36.3℃）、湿度（41.1～58.4%）、WBGT（28.4～32.5℃）
冷却方法	アイススラリー摂取、アイスベスト着用
実施方法	屋外テニスコートで模擬試合を実施。内容は、１ゲーム3.5分を目安とした６ゲーム先取の試合を、勝敗に関係なく３セット（ゲームブレイク：３～６回、セットブレイク：２回）。冷却介入はウォーミングアップ時、試合までの休憩時、ゲームブレイクおよびセットブレイク時に実施し、組み合わせを含め４条件行った（表2-1）。自由飲水はスポーツ飲料と水を摂取。

写真2-2　ブレイク時の冷却実施の様子（BINE条件）

JISS帆船

対象選手	エリート女子ウィンドサーフィン選手1名
実施期間	2018年7月21日～23日
測定場所	神奈川県 江ノ島・葉山沖
環境条件	表2-3に記載
冷却方法	頸部冷却：保冷剤を頸部に密着させ固定 前腕冷却：13℃の水が入ったバケツに手掌および前腕部を浸水 アイススラリー摂取：体重1kgあたり4gを摂取
実施方法	コーチが設定したコースを2周するレース形式の練習を2回実施。1回目と2回目のレースの合間に約20分間の休憩時間を設け、その際選手は船上に上がり、以下の表2-2にある3条件の冷却介入を実施。

写真2-3　船上で冷却実施の様子(NAS条件)

JISS足球

対象選手	日本代表男子サッカー選手20名
実施期間	第18回アジア競技大会（2018/ジャカルタ・パレンバン）
測定場所	ジャカルタ
環境条件※	温度(29±1℃)、湿度(67±9%)、WBGT(26±1℃)　※7試合平均
冷却方法	アイススラリー摂取と手掌前腕冷却
実施方法	表2-5に示すように、ウォーミングアップから試合開始前ロッカーアウトまでとハーフタイム中にアイススラリー摂取※※と手掌前腕冷却を実施。

写真2-4　トレーニング中のアイススラリー摂取と手掌前腕冷却の様子

Fan cooling/water spray

Sally McRae's crew carrying a spray bottle they used to spray her head, face, neck, and body during the 2018 Badwater 135. Image courtesy of Sally McRae.

https://www.irunfar.com/stay-cool-cooling-techniques-in-endurance-running

Menthol薄荷醇

Review > J Sci Med Sport. 2019 Jun;22(6):707-715. doi: 10.1016/j.jsams.2018.12.002.
Epub 2018 Dec 6.

The effects of menthol on exercise performance and thermal sensation: A meta-analysis

Owen Jeffries [1], Mark Waldron [2]

Affiliations + expand

PMID: 30554924 DOI: 10.1016/j.jsams.2018.12.002

Abstract

Objectives: Menthol is an organic compound with non-thermal cooling properties that has been shown to relieve thermal strain associated with exercise in the heat; however, its effects on performance have not been systematically analysed. The aims were to determine the effects of menthol applied (1) internally and (2) externally on exercise performance and thermal sensation.

Design: Meta-analysis METHODS: A search was performed using various databases in August 2018. The studies were screened using search criteria for eligibility. Thirteen peer-reviewed articles were identified for inclusion in a primary analysis on the effect of menthol on exercise performance;

Melatonin退黑激素

Meta-Analysis > Eur J Appl Physiol. 2013 Sep;113(9):2323-9. doi: 10.1007/s00421-013-2668-x.
Epub 2013 Jun 16.

A meta-analytic approach to quantify the dose-response relationship between melatonin and core temperature

K Marrin [1], B Drust, W Gregson, G Atkinson

Affiliations + expand

PMID: 23771573 DOI: 10.1007/s00421-013-2668-x

Abstract

A melatonin-mediated reduction in body temperature could be useful as a "pre-cooling" intervention for athletes, as long as the melatonin dose is optimised so that substantial soporific effects are not induced. However, the melatonin-temperature dose-response relationship is unclear in humans. Individual studies have involved small samples of different sexes and temperature measurement sites. Therefore, we meta-analysed the effects of exogenous melatonin on body core temperature to quantify the dose-response relationship and to explore the influence of moderating variables such as

Cooling調査

> Br J Sports Med. 2021 Dec;55(23):1335-1341. doi: 10.1136/bjsports-2020-103613. Epub 2021 Feb 12.

Hydration and cooling in elite athletes: relationship with performance, body mass loss and body temperatures during the Doha 2019 IAAF World Athletics Championships

Sebastien Racinais [1], Mohammed Ihsan [2, 3], Lee Taylor [4, 5], Marco Cardinale [2, 6], Paolo Emilio Adami [7], Juan Manuel Alonso [8], Nicolas Bouscaren [9], Sebastian Buitrago [10], Chris J Esh [2, 4], Josu Gomez-Ezeiza [11], Frederic Garrandes [7], George Havenith [12], Mariem Labidi [2], Gunter Lange [7], Alexander Lloyd [12], Sebastien Moussay [13], Khouloud Mtibaa [14], Nathan Townsend [2, 15], Mathew G Wilson [2, 6], Stephane Bermon [7, 16]

Affiliations + expand

PMID: 33579722 PMCID: PMC8606454 DOI: 10.1136/bjsports-2020-103613

Free PMC article

Abstract

2019 IAAF World Athletics Championships

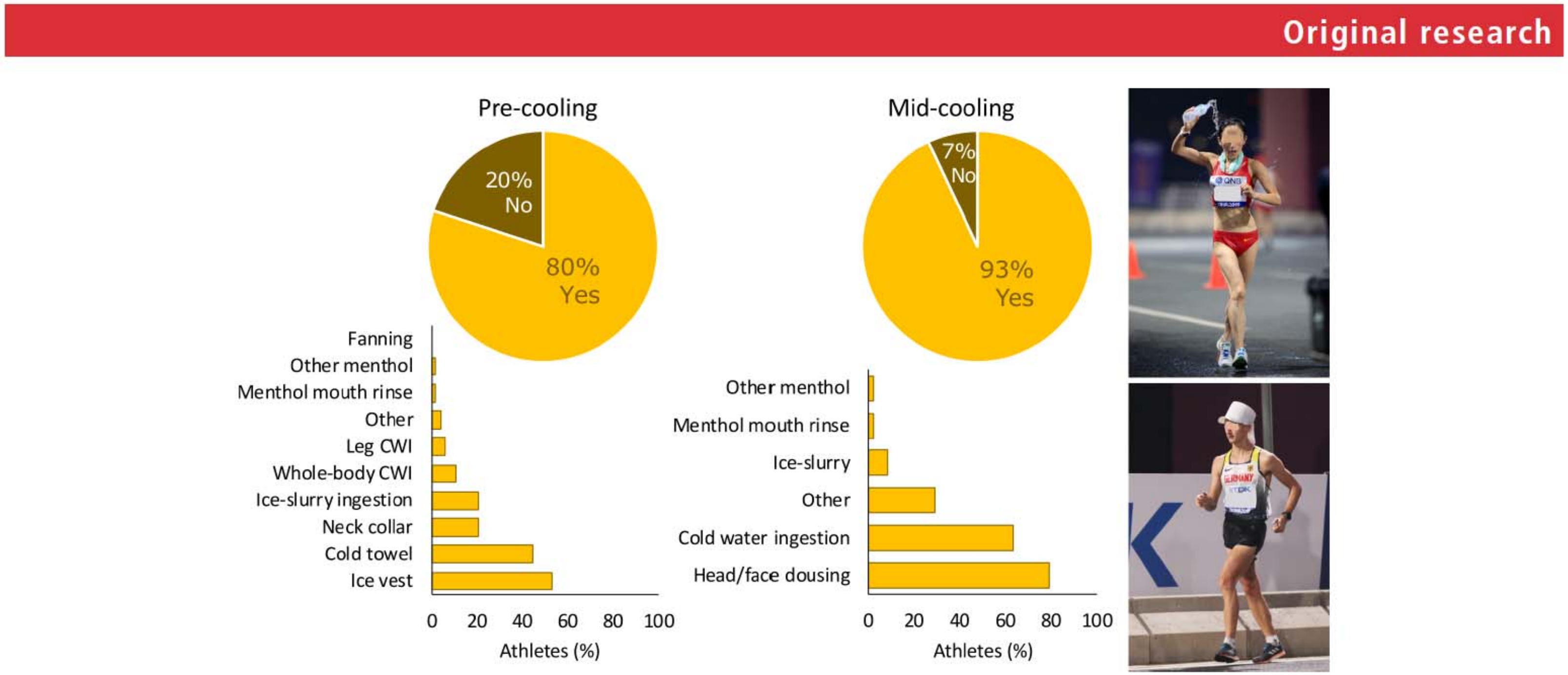


Figure 2 Pre-cooling and mid-cooling strategy during the World Athletics Championships. Upper panel: percentage of athletes declaring to plan a pre/mid-cooling strategy. Lower panel: details of the strategy declared (in per cent of athletes). Right panel: example of water dousing plus neck collar, and ice in cap with neck flap. Getty images for World Athletics.

Racinais, S., et al. (2021). Hydration and cooling in elite athletes: Relationship with performance, body mass loss and body temperatures during the Doha 2019 IAAF World Athletics Championships. *British Journal of Sports Medicine.*

Cooling先驅

Precooling

Where cooling during exercise is not possible, precooling—decreasing body temperature before exercise—has been popular among athletes prior to exercise in the heat. Some of the initial athletic proponents included the Australian rowing teams prior to the 1996 Atlanta Olympics, whose members used vests containing ice packs during warm-ups before competition. Since then, precooling has become popular for a variety of sports, including athletics, swimming, and cycling. In clinical settings, cooling helmets have been employed to induce brain hypothermia rapidly following cardiac

Cheung, S. S. (2010). *Advanced environmental exercise physiology* (p. 42).

系統性回顧/統合分析

Level I	Anecdotal evidence or expert opinion	These are common in the supplement marketplace, particularly when high-profile athletes promote the use of a particular supplement
Level II	Case series or observational studies	Less common in the supplement research literature
Level III	Randomised control trials (RCT)	The most common type of research undertaken in the supplement literature. However, it is key that the research is of suitable quality (Figure 5)
Level IV	Systematic reviews and meta-analysis	The highest level of evidence to show efficacy of a supplement. However, these are rare and may not always be available, especially for newer supplements which appear on the market

FIGURE 4 Levels of evidence

Castell, L. M., et al. (Eds.). (2015). *Nutritional supplements in sport, exercise and health: An A–Z guide* (p. 21).

2010系統性回顧

Review > J Strength Cond Res. 2010 Dec;24(12):3488-96. doi: 10.1519/JSC.0b013e3181fb3e15.

Effect of body cooling on subsequent aerobic and anaerobic exercise performance: a systematic review

Gregory F Ranalli [1], Julianne K Demartini, Douglas J Casa, Brendon P McDermott, Lawrence E Armstrong, Carl M Maresh

Affiliations + expand

PMID: 21088554 DOI: 10.1519/JSC.0b013e3181fb3e15

Abstract

Body cooling has become common in athletics, with numerous studies looking at different cooling modalities and different types of exercise. A search of the literature revealed 14 studies that measured performance following cooling intervention and had acceptable protocols for exercise and performance measures. These studies were objectively analyzed with the Physiotherapy Evidence Database (PEDro) scale, and 13 of the studies were included in this review. These studies revealed that body cooling by various modalities had consistent and greater impact on aerobic exercise performance (mean increase in performance = 4.25%) compared to anaerobic (mean increase in

Ranalli et al. (2010)

the Journal of Strength and Conditioning Research™ | www.nsca-jscr.org

有氧運動

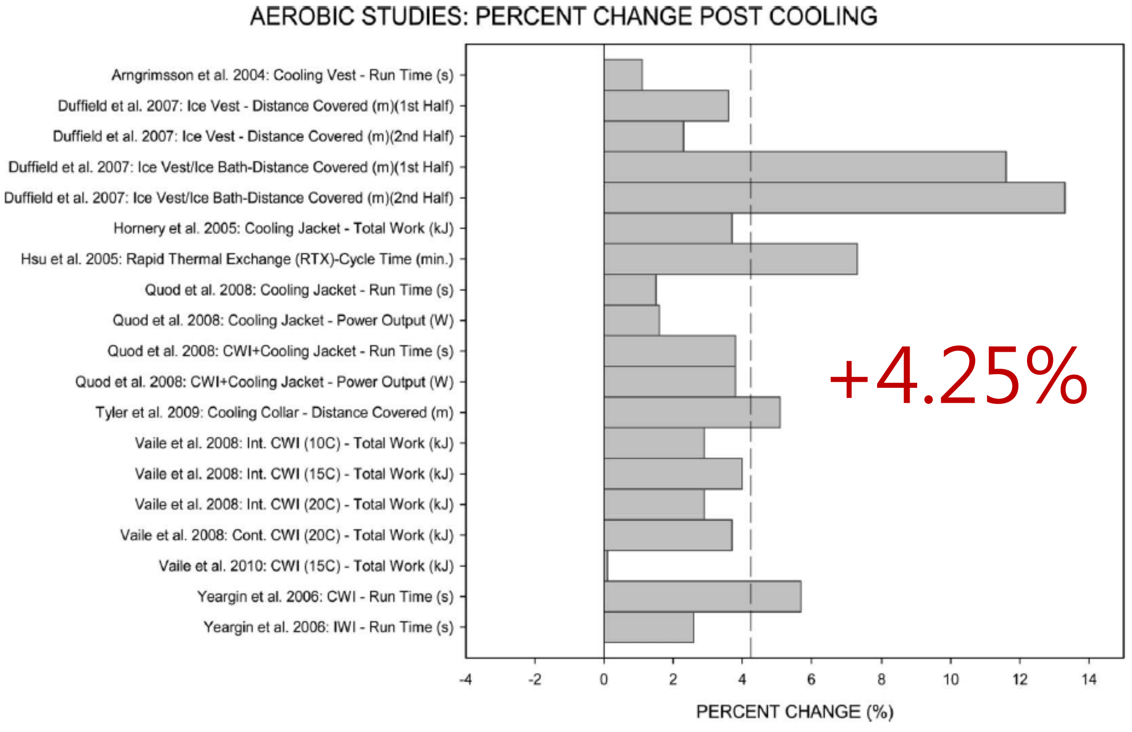


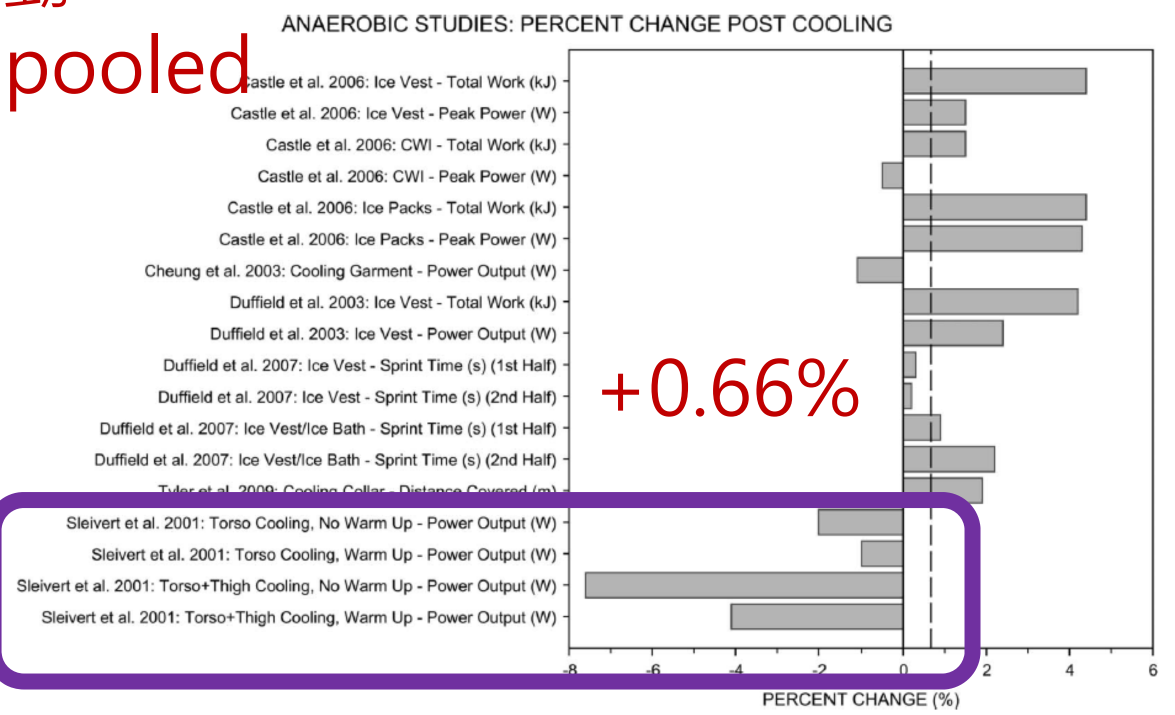
Figure 2. Percentage of change in aerobic studies, with each individual trial listed separately. The percentages are shown as an increase or decrease vs. control trials. (The dashed line represents the average percent increase across all trials + 4.25%).

Ranalli et al. (2010)

Body Cooling and Athletic Performance: A Systematic Review

無氧運動

S & IS pooled



+0.66%

45 s cycling

Figure 3. Percentage of change in anaerobic studies, with each individual trial listed separately. The percentages are shown as an increase or decrease compared to control trials. (The dashed line represents the average percent increase across all trials +0.66%.)

2012統合分析

Review > Sports Med. 2012 Jul 1;42(7):545-64. doi: 10.2165/11630550-000000000-00000.

Pre-cooling and sports performance: a meta-analytical review

Melissa Wegmann [1], Oliver Faude, Wigand Poppendieck, Anne Hecksteden, Michael Fröhlich, Tim Meyer

Affiliations + expand

PMID: 22642829 DOI: 10.2165/11630550-000000000-00000

Abstract

Pre-cooling is used by many athletes for the purpose of reducing body temperature prior to exercise and, consequently, decreasing heat stress and improving performance. Although there are a considerable number of studies showing beneficial effects of pre-cooling, definite conclusions on the effectiveness of pre-cooling on performance cannot yet be drawn. Moreover, detailed analyses of the specific conditions under which pre-cooling may be most promising are, so far, missing. Therefore, we conducted a literature search and located 27 peer-reviewed randomized controlled trials, which addressed the effects of pre-cooling on performance. These studies were analysed with regard to

Wegmann et al. (2012)

- Pre-cooling had a larger effect on performance in hot (+6.6%) (>26°C) than in moderate temperatures (+1.4%).
- The largest performance enhancements were found for endurance (+4.2-8.6%).
  - ETE +8.6%, GXT +6.0%, TT+ 4.2%
- A similar effect was observed for intermittent sprints (+3.3%), whereas performance changes were smaller during short-term, high-intensity sprints (-0.5%).

Before 2012

- Ranalli et al. (2010)
  - Pre- and/or per-cooling
    - ice vest, ice packs, CWI or IWI (n=6 of 13)
- Wegmann et al. (2012)
  - Pre-cooling
    - water application (n=12 of 27), cooling packs, cold drinks, cooling vest and a cooled room
- CWI or cooled room應用性??

2015統合分析

Review > Br J Sports Med. 2015 Jan;49(1):7-13. doi: 10.1136/bjsports-2012-091739.
Epub 2013 Aug 14.

The effect of cooling prior to and during exercise on exercise performance and capacity in the heat: a meta-analysis

Christopher James Tyler [1], Caroline Sunderland [2], Stephen S Cheung [3]

Affiliations + expand

PMID: 23945034 DOI: 10.1136/bjsports-2012-091739

Abstract

Exercise is impaired in hot, compared with moderate, conditions. The development of hyperthermia is strongly linked to the impairment and as a result various strategies have been investigated to combat this condition. This meta-analysis focused on the most popular strategy: cooling. Precooling has received the most attention but recently cooling applied during the bout of exercise has been investigated and both were reviewed. We conducted a literature search and retrieved 28 articles which investigated the effect of cooling administered either prior to (n=23) or during (n=5) an exercise test

Tyler et al. (2015)

- Cooling which was external in nature.
  - cooling jackets/vests, forearm/leg/neck/head cooling
- Fluids (eg, ice slurries) were not considered.

ES

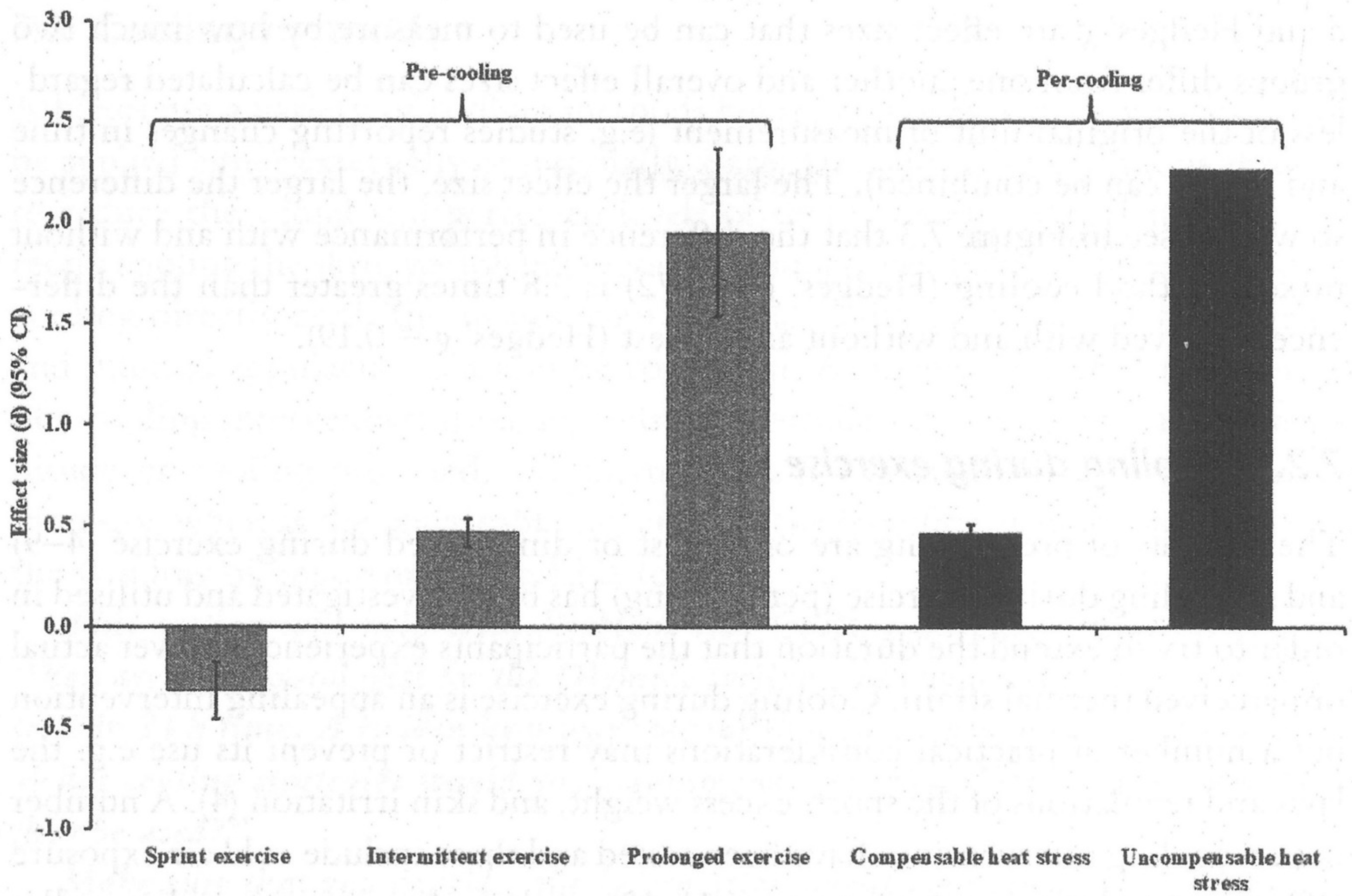


FIGURE 7.2 Effect sizes observed with pre- and per-cooling approaches broken down by activity (for pre-cooling) and heat stress (for per-cooling). Data extracted from the meta-analysis conducted by Tyler et al. (3).

Data:
Tyler, C. J., et al. (2015). *British Journal of Sports Medicine.*

圖片重製
Tyler, C. J. (2019). *Maximising performance in hot environments: A problem-based learning approach* (p. 135).

2015統合分析

Review > Br J Sports Med. 2015 Mar;49(6):377-84. doi: 10.1136/bjsports-2013-092928.
Epub 2014 Apr 19.

Precooling and percooling (cooling during exercise) both improve performance in the heat: a meta-analytical review

Coen C W G Bongers [1], Dick H J Thijssen [2], Matthijs T W Veltmeijer [1], Maria T E Hopman [1], Thijs M H Eijsvogels [3]

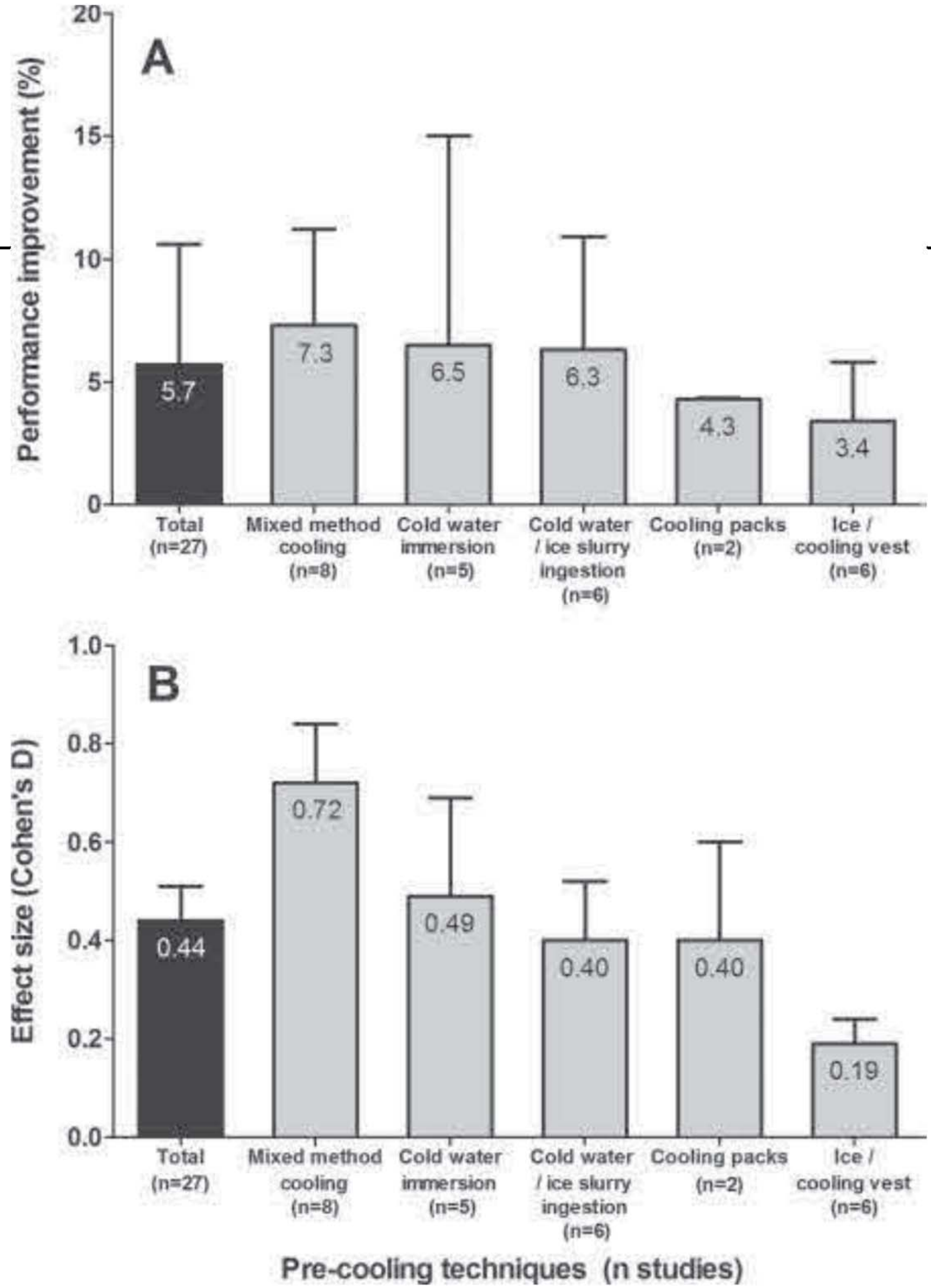
Affiliations + expand

PMID: 24747298 DOI: 10.1136/bjsports-2013-092928

Abstract

Background: Exercise increases core body temperature (Tc), which is necessary to optimise physiological processes. However, excessive increase in Tc may impair performance and places participants at risk for the development of heat-related illnesses. Cooling is an effective strategy to attenuate the increase in Tc. This meta-analysis compares the effects of cooling before (precooling) and during exercise (percooling) on performance and physiological outcomes.

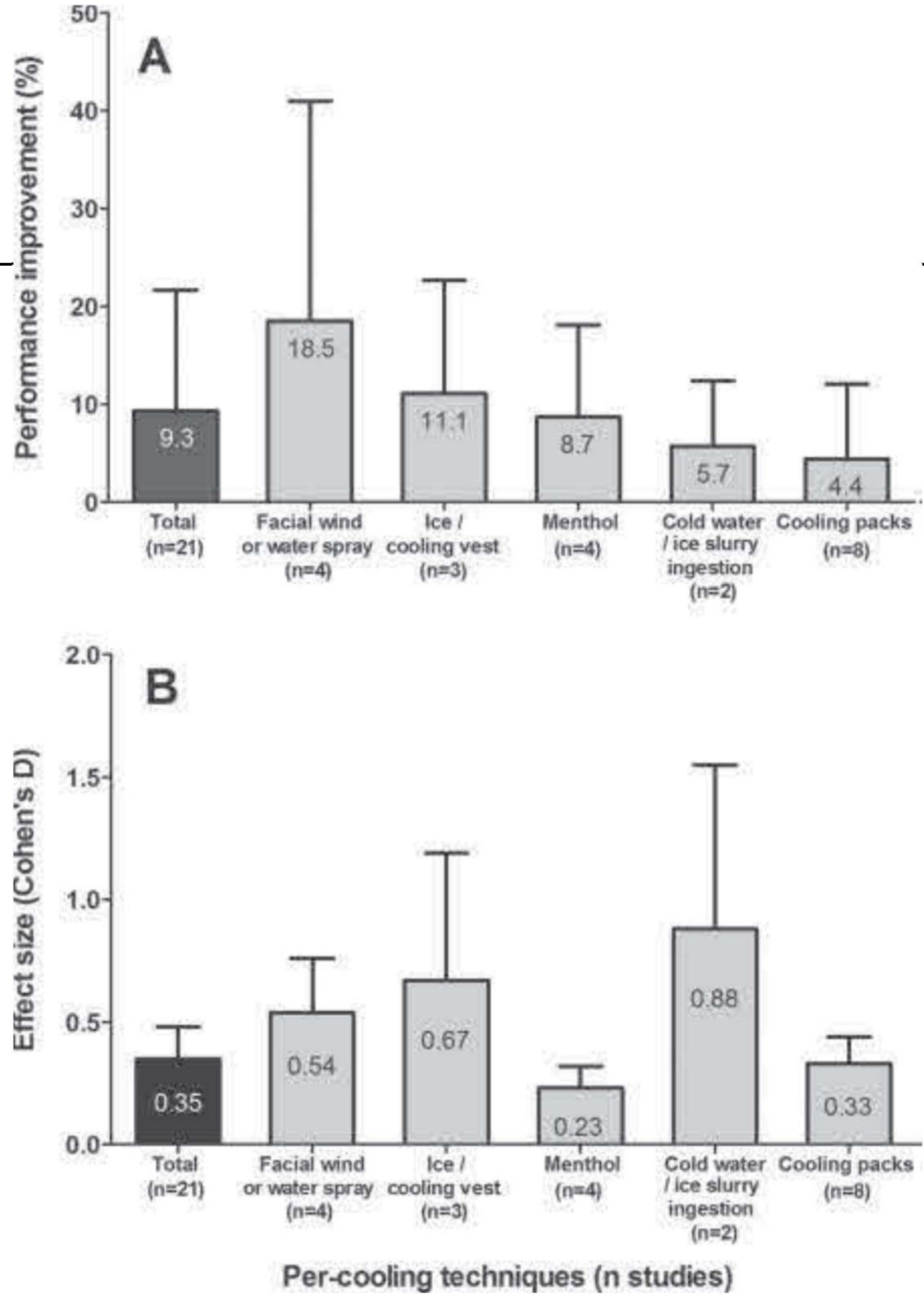
Pre-



Data:
Bongers, C. C. et al. (2015). *British Journal of Sports Medicine.*

圖片重製
Bongers, C. C. et al. (2017). *Temperature.*

Per-



Data:
Bongers, C. C. et al. (2015). *British Journal of Sports Medicine.*

圖片重製
Bongers, C. C. et al. (2017). *Temperature.*

Bongers et al. (2015)

- No correlation between Tc and performance was found.

2017統合分析

Review > Sports Med. 2017 Mar;47(3):517-532. doi: 10.1007/s40279-016-0592-z.

Practical Cooling Strategies During Continuous Exercise in Hot Environments: A Systematic Review and Meta-Analysis

Alan Ruddock [1], Brent Robbins [2], Garry Tew [3], Liam Bourke [4], Alison Purvis [5]

Affiliations + expand

PMID: 27480762 PMCID: PMC5309298 DOI: 10.1007/s40279-016-0592-z

Free PMC article

Abstract

Background: Performing exercise in thermally stressful environments impairs exercise capacity and performance. Cooling during exercise has the potential to attenuate detrimental increases in body temperature and improve exercise capacity and performance.

Objective: The objective of this review was to assess the effectiveness of practical cooling strategies applied during continuous exercise in hot environments on body temperature, heart rate, whole body

Ruddock et al. (2017)

- Cooling strategy that would be practical for athletes to apply during competitive performance.
  - cold/ice slurry ingestion, neck/palm/head cooling
- Continuous exercise (≥25°C)
  - core/skin temperature, HR, WB sweat production, RPE and thermal perception

Ruddock et al. (2017)

- Unclear effects for cooling during exercise on mean core temperature, core/skin temperature, HR, WB sweat production.
- Cooling during exercise was beneficial for self-paced exercise performance.
  - RPE and thermal perception were also improved and are likely mediators of performance during continuous exercise.

2019統合分析

Meta-Analysis > Scand J Med Sci Sports. 2019 Nov;29(11):1660-1676. doi: 10.1111/sms.13521.
Epub 2019 Aug 14.

Cooling during exercise enhances performances, but the cooled body areas matter: A systematic review with meta-analyses

Wafa Douzi [1], Benoit Dugué [1], Ludwig Vinches [2], Chady Al Sayed [2], Stéphane Hallé [2], Laurent Bosquet [1], Olivier Dupuy [1]

Affiliations + expand

PMID: 31340407 DOI: 10.1111/sms.13521

Abstract

Introduction: Hyperthermia during exercise induces central and peripheral fatigue and impairs physical performance. To facilitate heat loss and optimize performance, athletes can hasten body cooling prior (pre-cooling) or during (per-cooling) exercise. However, it is unclear whether per-cooling effect is the same on 'aerobic' and 'anaerobic' types of exercise (duration <75 and >76 seconds, respectively, according to Gastin [Sports Med 2001;31:725-741]) and whether the body area that is

Douzi et al. (2019)

(A) 有氧運動　　　　(B) 無氧運動

1670 WILEY　　DOUZI ET AL.

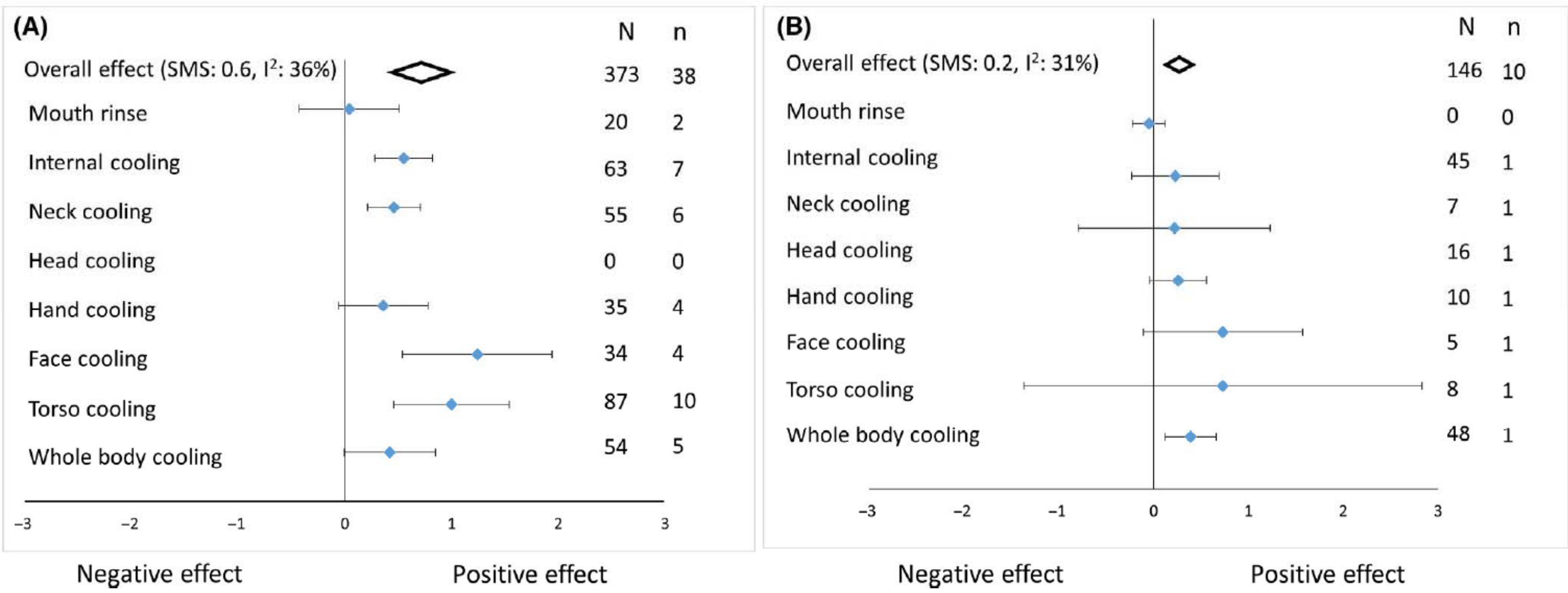


FIGURE 4 Effect of cooled body area on 'aerobic' (A) and 'anaerobic' (B) exercise performances, N, number of subjects; n, number of experimental groups

2020系統性回顧

> Int J Environ Res Public Health. 2020 Apr 24;17(8):2952. doi: 10.3390/ijerph17082952.

A Matter of Degrees: A Systematic Review of the Ergogenic Effect of Pre-Cooling in Highly Trained Athletes

Miguel Ángel Rodríguez [1], José Víctor Piedra [1], Mario Sánchez-Fernández [1], Miguel Del Valle [2], Irene Crespo [1] [3], Hugo Olmedillas [1] [4]

Affiliations + expand

PMID: 32344616 PMCID: PMC7215649 DOI: 10.3390/ijerph17082952

Free PMC article

Abstract

The current systematic review evaluated the effects of different pre-cooling techniques on sports performance in highly-trained athletes under high temperature conditions. PubMed/MEDLINE, EMBASE, Web of Science, CENTRAL, Scopus, and SPORTDiscus databases were searched from inception to December 2019. Studies performing pre-cooling interventions in non-acclimatized highly-trained athletes (>55 mL/kg/min of maximal oxygen consumption) under heat conditions (≥30

2022系統性回顧

› Front Nutr. 2022 Oct 14;9:959516. doi: 10.3389/fnut.2022.959516. eCollection 2022.

Performance effects of internal pre- and per-cooling across different exercise and environmental conditions: A systematic review

Maria Roriz [1, 2], Pedro Brito [3], Filipe J Teixeira [4, 5, 6], João Brito [7], Vitor Hugo Teixeira [1, 2, 8, 9]

Affiliations + expand

PMID: 36337635 PMCID: PMC9632747 DOI: 10.3389/fnut.2022.959516

Free PMC article

Abstract

Exercise in a hot and humid environment may endanger athlete's health and affect physical performance. This systematic review aimed to examine whether internal administration of ice, cold beverages or menthol solutions may be beneficial for physical performance when exercising in different environmental conditions and sports backgrounds. A systematic search was performed in PubMed, Web of Science, Scopus and SPORTDiscus databases, from inception to April 2022, to identify studies meeting the following inclusion criteria: healthy male and female physically active

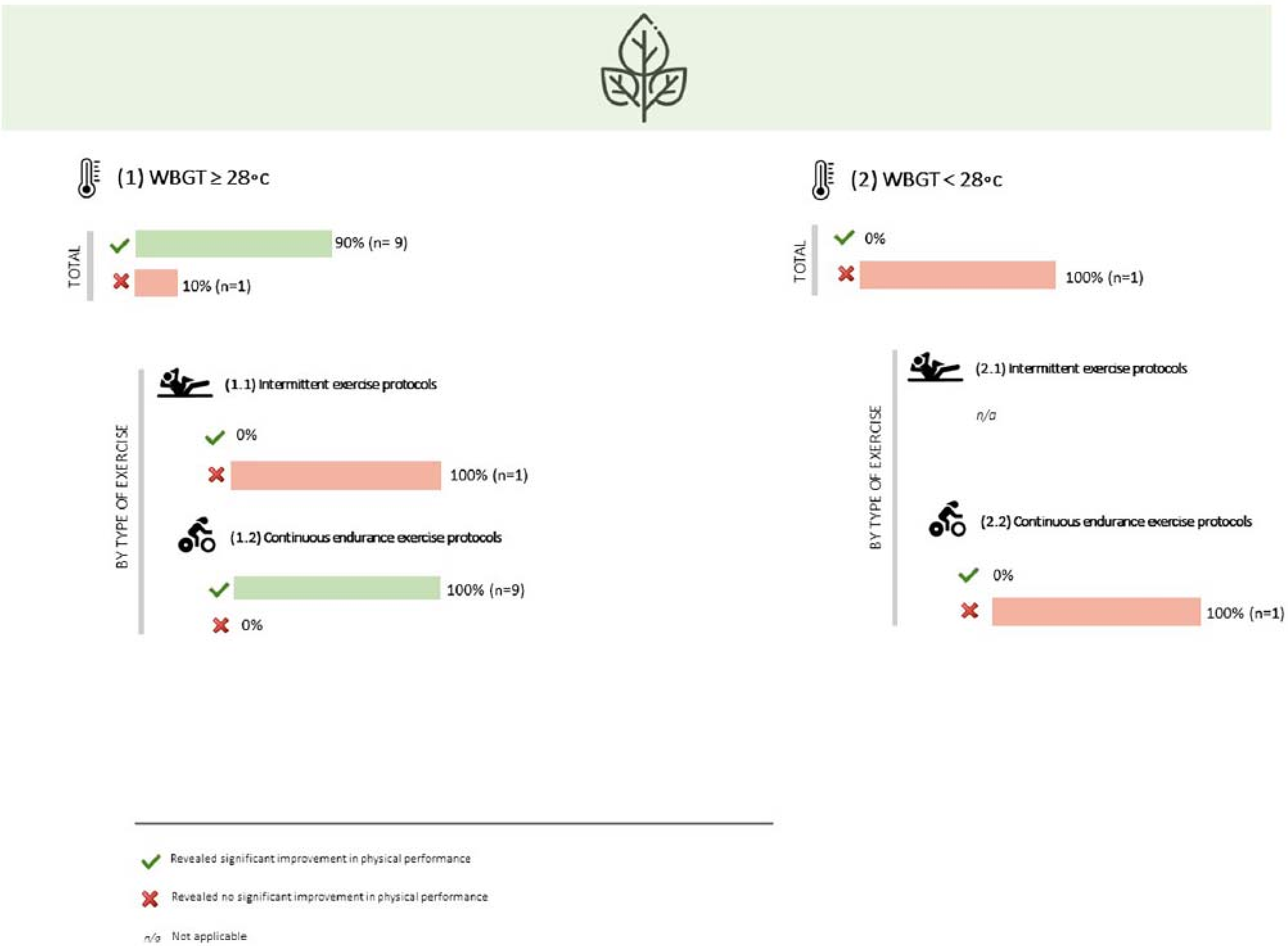


FIGURE 5
Overall results of oral menthol administration effect on physical performance, by environmental conditions and type of exercise.

FIGURE 7
Overall results of ice or cold beverages administration effect on physical performance, by environmental conditions and type of exercise.

2023統合分析

> Front Physiol. 2023 Jan 10;13:1091228. doi: 10.3389/fphys.2022.1091228. eCollection 2022.

Effects of different external cooling placements prior to and during exercise on athletic performance in the heat: A systematic review and meta-analysis

Dongting Jiang [1], Qiuyu Yu [1] [2], Meng Liu [1], Jinjin Dai [1]

Affiliations + expand

PMID: 36703929 PMCID: PMC9871495 DOI: 10.3389/fphys.2022.1091228

Free PMC article

Abstract

Background: Nowadays, many high-profile international sport events are often held in warm or hot environments, hence, it is inevitable for these elite athletes to be prepared for the challenges from the heat. Owing to internal cooling may cause gastrointestinal discomfort to athletes, external cooling technique seems to be a more applicable method to deal with thermal stress. Central cooling mainly refers to head, face, neck and torso cooling, can help to reduce skin temperature and relieve thermal perception. Peripheral cooling mainly refers to four limbs cooling, can help to mitigate metabolic heat

Jiang et al. (2023)

- Central cooling was most effective in improving athletic performance in the heat (≥ 28°C), followed by central and peripheral cooling, AND peripheral cooling.
- The enhancement effects of peripheral cooling require sufficient rewarming, otherwise it will be trivial.

2023統合分析

Review > Bioengineering (Basel). 2023 Jan 18;10(2):132. doi: 10.3390/bioengineering10020132.

Is the Cooling Vest an Ergogenic Tool for Physically Active Individuals? Assessment of Perceptual Response, Thermo-Physiological Behavior, and Sports Performance: A Systematic Review and Meta-Analysis

Diego Fernández-Lázaro [1] [2], Juan F García [3], Luis Antonio Corchete [4], Miguel Del Valle Soto [5], Gema Santamaría [6], Jesús Seco-Calvo [7] [8]

Affiliations + expand

PMID: 36829626 PMCID: PMC9952803 DOI: 10.3390/bioengineering10020132

Free PMC article

Abstract

Exercise capacity is limited by environmental heat stress because thermoregulatory systems are altered and cannot prevent the elevation of body temperature due to a complex interplay of

Fernández-Lázaro et al. (2023)

- The significant improvements in time-trial exercise and important improvements in MxPO could be directly influenced by the significant reduction in Tsk, indirectly by the significant improvement in perceptual responses, essentially RPE, and without the involvement of Tc.

2016游泳研究

› J Sports Med Phys Fitness. 2016 Mar;56(3):185-91. Epub 2015 Sep 2.

The effect of hand cooling during intermittent training of elite swimmers

Thomas Zochowski [1], David Docherty

Affiliations + expand

PMID: 26333791

Abstract

Background: The aim of this paper was to determine the effects of using intermittent hand cooling during high intensity, intermittent training on thermoregulatory, performance and psychophysical variables in elite level swimmers in a training pool (30.5±0.5 °C).

Methods: Randomized cross-over design. Following a standard warm-up, ten male swimmers (20.3±3.2 years) were instructed to maintain the fastest 100-m time (on average) for an 8 x 100 m freestyle swimming set performed either in a training pool with cooling (TPC) or a training pool with no-cooling (TPNC). Time at 100 m, core temperature (Tc), heart rate (HR), ratings of perceived exertion (RPE), thermal comfort (ThC) and thermal sensation (ThS) were recorded following each repetition. Participants were cooled during the 90 s rest interval between repetitions using the Rapid Thermal

Zochowski et al. (2016)

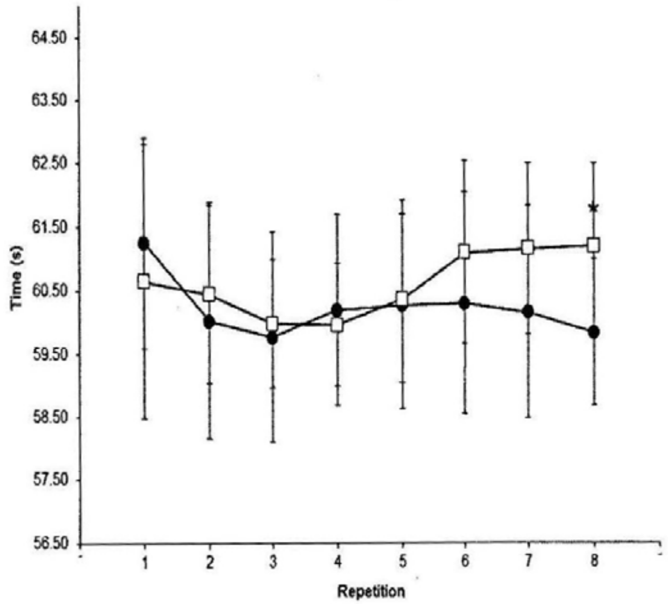


Figure 2.—Mean (SD) 100 m time for each repetition during TPC and TPNC conditions. (TPC and TPNC significantly different = *P<0.05, N.=10).

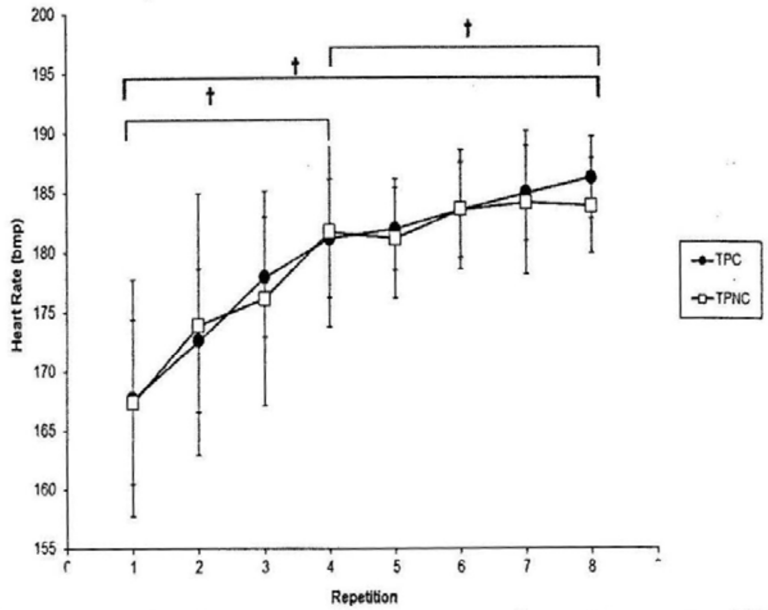


Figure 3.—Mean (SD) heart rate (bpm) for each repetition during TPC and TPNC condition (Significant repetition effect [†] between Rep1 *vs.* Rep4, Rep1 *vs.* Rep8, and Rep4 *vs.* Rep8 (P<0.05, N.=10).

2021阻力訓練研究

> Int J Exerc Sci. 2021 Apr 1;14(2):295-303. eCollection 2021.

Different Cooling Strategies Applied During Inter-Set Rest Intervals in High-Intensity Resistance Training

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Affiliations + expand

PMID: 34055152 PMCID: PMC8136565

Free PMC article

Abstract

The purpose of this study was to verify whether cooling between sets during high-intensity resistance exercise improves physical performance and to compare performance among different sites of cooling. It is important because delaying the muscular fatigue could improve total volume at a training session which could lead to greater hypertrophy. Nine healthy and recreational resistance training experienced men, performed six tests of a biceps curl exercise on different days. The first test was the one-repetition maximum test (1RM). Following, we applied five sessions, in crossover and

Esteves et al. (2021)

No cooling strategy was able to improve performance compared to control. However, neck cooling compared to control showed a 71% probability of increasing the total volume of repetitions (figure 3).

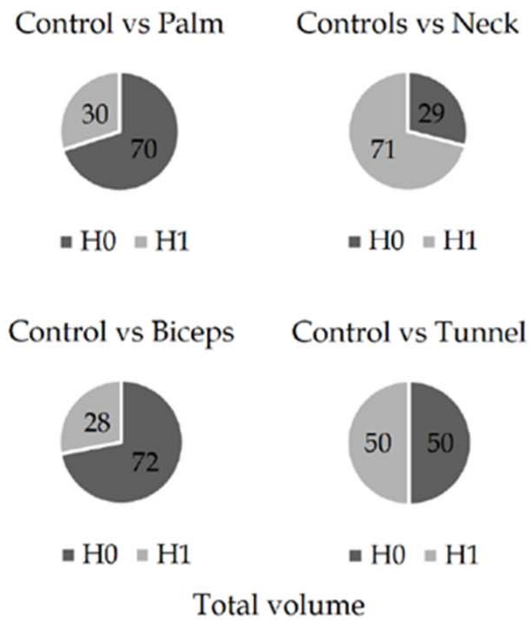


Figure 3. The probability that the null hypothesis holds across all cooling procedures to the exercise total volume.

可能疑問

Case 4　屋内競技であるため、身体冷却は必要ない？

屋内競技は空調が効いていること、日光による輻射熱がないことから、過度な深部体温上昇は屋外競技に比べると起こりにくいと考えられます。しかし、一方で空気が冷やされて体積が小さくなっても、空気中の湿気の量は変わらないため湿度は高くなり、屋内競技における熱中症も確認されています。また、脱水は深部体温上昇の要因の一つとなりますので、屋内競技においても冷たい（5℃程度）水やスポーツドリンクを用いた水分補給が必要不可欠です。

一方、特別なウエアを着用する屋内競技においては、過度な深部体温上昇がみられることから注意が必要です。例えば、フェンシングのように防具をつけて行う競技においては、空調の効いた屋内であってもトレーニング中の深部体温が高体温になることがわかっています。

図2-11に、2017年夏季にJISSのフェンシング場において、スパーリング形式のトレーニングを行った際のエリートフェンシング選手の深部体温の変化を示します。ト

撃剣

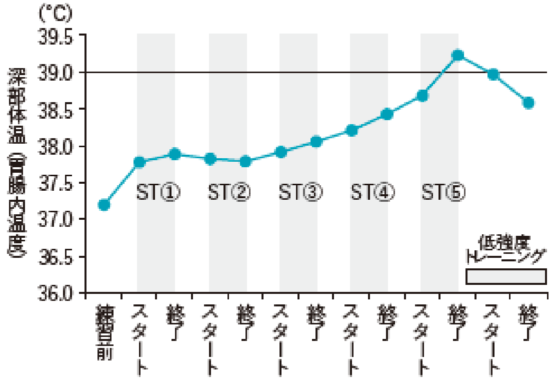


図2-11　スパーリング形式のトレーニングの継続と深部体温の変化(D選手)
ST；スパーリング形式のトレーニング、低強度トレーニング；コーチとの基礎トレーニング

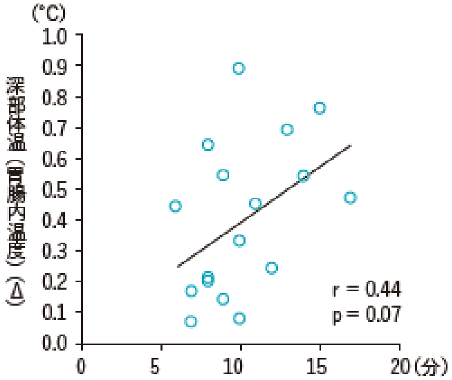


図2-12　トレーニング時間と深部体温の関係
試合形式の練習時間が長くなると深部体温の上昇が大きくなる傾向がみられる。深部体温の上昇は各試合形式のトレーニング前後から算出。

レーニング前半は深部体温をある一定レベルで維持していますが、トレーニング後半になると深部体温が39℃を超えています。また、試合形式のトレーニングの継続時間が長くなると、深部体温の上昇度も大きくなる傾向が認められました(図2-12)。

この時空調は効いており、気温26～27℃、相対湿度50～57%、WBGT23℃という環境でした。しかしながら、フェンシングのように防具をつける競技では外部への熱放散がうまくできず、深部体温の過度な上昇がみられました。したがって、屋内競技であっても特別なウエアを着用する競技においては身体冷却の実施が必要です。ただし、競技の特性上、アイスベストの着用や手掌前腕冷却などは実施が難しいので、アイススラリー摂取や送風/冷風といった方法の組み合わせが好ましいと考えられます。

写真2-5　セット間のアイススラリー摂取の様子

2019柔道研究

Randomized Controlled Trial > J Strength Cond Res. 2019 Aug;33(8):2241-2250.
doi: 10.1519/JSC.0000000000002443.

Intermittent Cooling During Judo Training in a Warm/Humid Environment Reduces Autonomic and Hormonal Impact

Eduardo Carballeira [1], José Morales [2], David H Fukuda [3], María L Granada [4], Vicente Carratalá-Deval [5], Alfonso López Díaz de Durana [6], Jeffrey R Stout [3]

Affiliations + expand

PMID: 29324576 DOI: 10.1519/JSC.0000000000002443

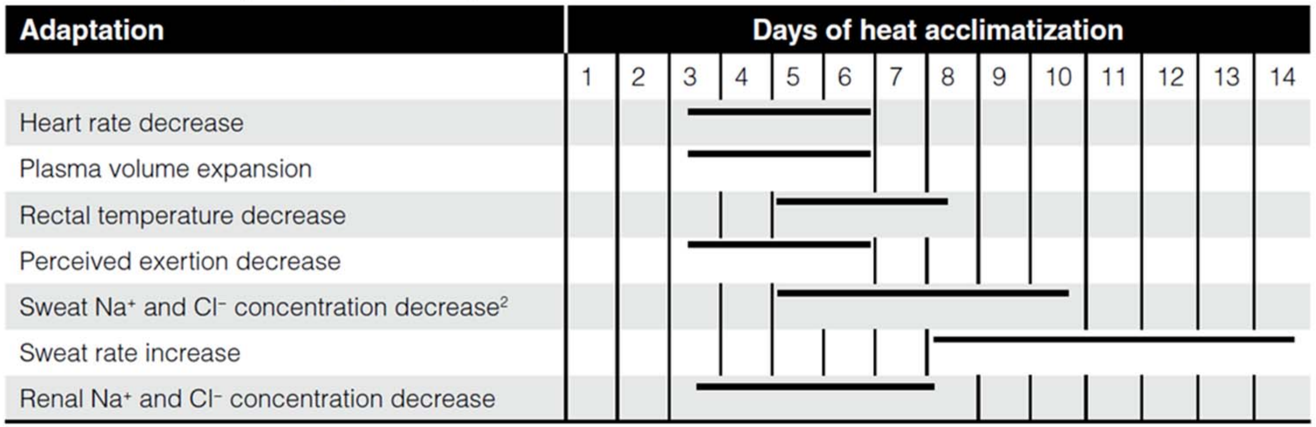
Abstract

Carballeira, E, Morales, J, Fukuda, DH, Granada, ML, Carratalá-Deval, V, López Díaz de Durana, A, and Stout, JR. Intermittent cooling during Judo training in a warm/humid environment reduces autonomic and hormonal impact. J Strength Cond Res 33(8): 2241-2250, 2019-The purpose of this study was to identify the effects of superficial cooling on physiological responses while training in a warm, humid environment during an international Judo training camp. Sixteen judokas (8 women and 8 men)

可能疑問

- 比賽地點/季節天氣不熱，平時訓練有需要cooling？
- 使用cooling是否會干擾熱適應成效？

Table 21.1 Physiological Adaptations to Heat Acclimatization[1]



[1]Point at which approximately 95% of the adaptation occurs.
[2]During consumption of a low NaCl diet.
Adapted from Armstrong and Dziados 1986.

Hoffman, J. (2014). *Physiological aspects of sport training and performance* (2nd ed.) (p. 359).

個人淺見

- 訓練品質
  - 品質 (強度) 不佳的訓練是否有效益？
  - 比賽地點/季節天氣不熱，但若平時訓練地點高溫炎熱，訓練品質打折
    - 競賽對手可維持良好訓練品質 (相對強度)
- 兼顧熱適應與訓練品質
  - 上半場不使用，中場休息或下半場使用
  - 模擬比賽時使用

可能疑問

- 運動項目為極高強度/極短時間，是否該使用cooling？
  - 除專項訓練外，其餘輔助/體能訓練內容有無耐力訓練？
- 實際訓練/比賽中無法使用cooling設備
  - 運動前pre-cooling
  - 中場休息/暫停per-cooling

Pre-cooling

A track-and-field athlete warms up while wearing an ice vest before his event. Image: IAAF Twitter account

https://www.irunfar.com/stay-cool-cooling-techniques-in-endurance-running

Pre-cooling

Brearley and Saunders

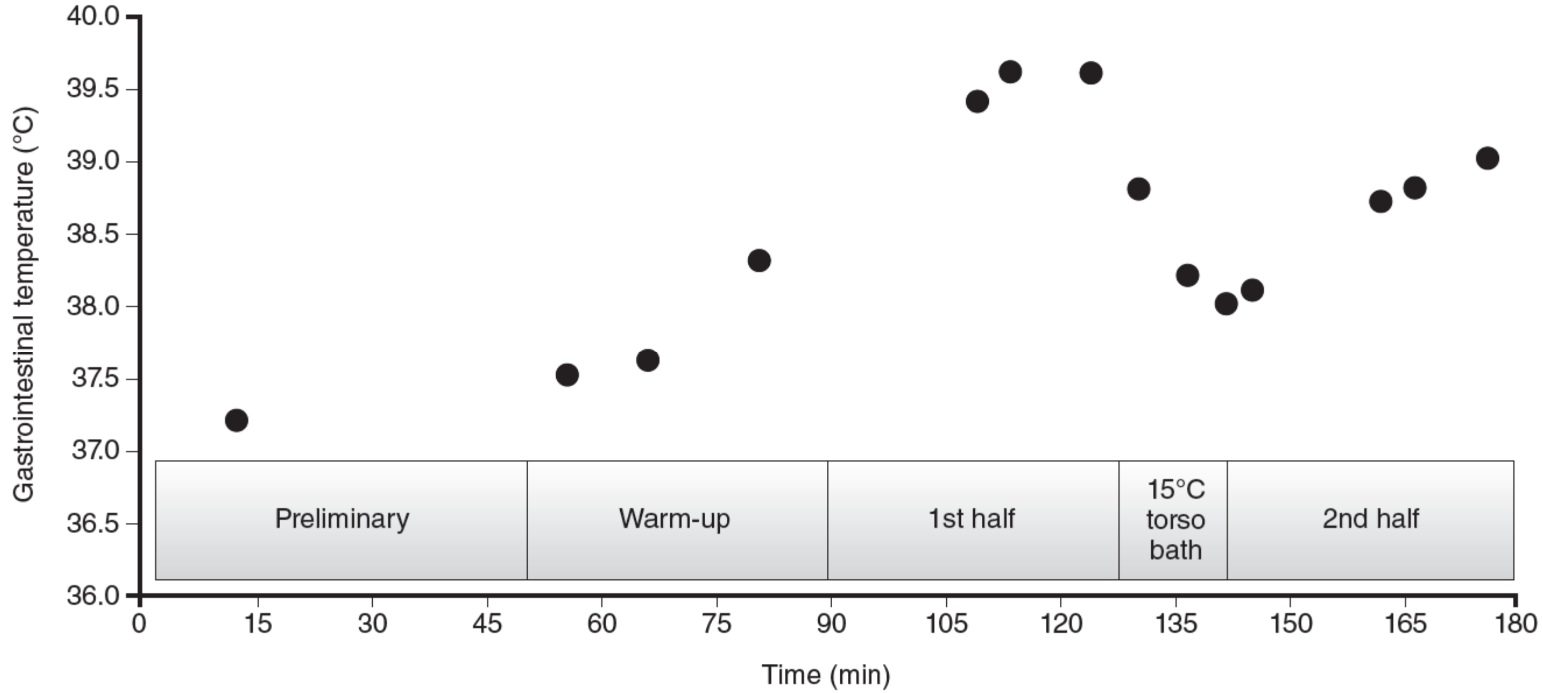


FIGURE 9.4 Gastrointestinal temperature response of an international field hockey athlete to 8 min of 15 °C torso immersion at half-time during a test match played in hot and humid conditions.

Australian Institute of Sport. (2013). *Physiological tests for elite athletes* (2nd ed.) (p. 134).

速度/力量/耐力

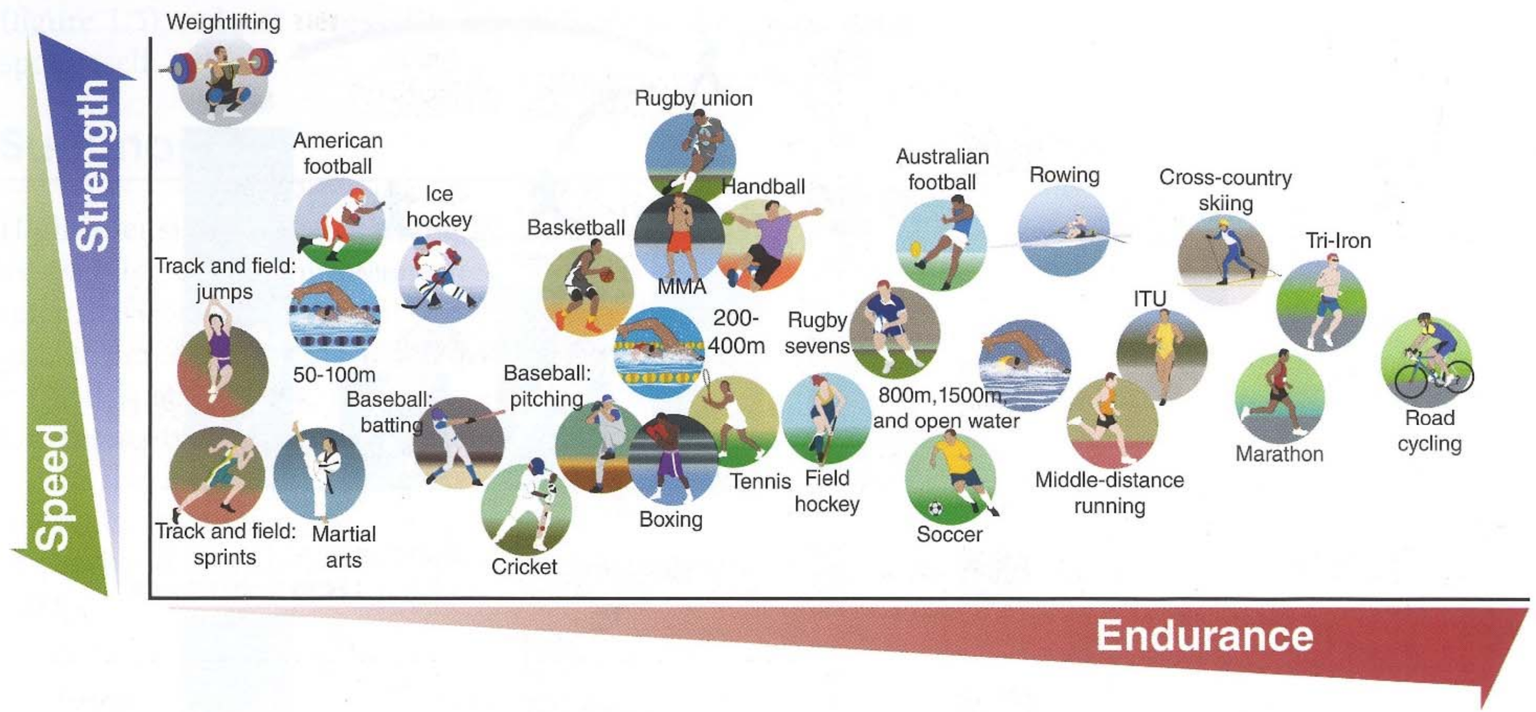


Figure 1.6 Various sports, their physical demands relative to needed speed, strength, and endurance.

Adapted from G.A. Nader, "Concurrent Strength and Endurance Training: From Molecules to Man," *Medicine & Science in Sports & Exercise* 38, no. 11 (2006): 1965-1970.

圖片重製Laursen, P., & Buchheit, M. (Eds.) (2019). *Science and application of high-intensity interval training: Solutions to the programming puzzle* (p. 13).

總結與後續應用

- 在熱環境時 (≥ 25°C)，pre- and/or per-cooling可提升耐力與間歇衝刺運動表現，但對單趟衝刺運動無明顯益處。
- 內部或外部降溫各有其利弊，同時使用多種cooling手段之成效優於使用單一方法。
- Cooling增進耐力表現的原因可能為降低RPE、促進thermal perception；對生理指標 (體溫、心率) 的研究結果不一致。

總結與後續應用

- Internal cooling
  - 內部降溫
    - 冰沙
    - 冷飲
    - 薄荷醇漱口
    - 薄荷醇飲料
    - 退黑激素
- External cooling
  - 外部降溫
- 中樞降溫
  - 頭/臉/頸cooling
    - 冰帽/噴霧/冰領巾
  - 軀幹cooling
    - 冰背心/CWI
- 周邊降溫
  - 四肢cooling
    - 手掌、前臂降溫/冰雹/CWI

NSTC cooling

- Internal cooling
  - 內部降溫
    - 冰沙
    - 冷飲
    - 薄荷醇漱口
    - 薄荷醇飲料
    - ~~退黑激素~~
- External cooling
  - 外部降溫
- 中樞降溫
  - 頭/臉/頸cooling
    - ~~冰帽/噴霧~~/冰領巾
  - 軀幹cooling
    - 冰背心/~~CWI~~
- 周邊降溫
  - 四肢cooling
    - 手掌、前臂降溫/冰雹/~~CWI~~

感謝聆聽

Thank you!