

Institution: Leeds Trinity University		
Unit of Assessment: 24		
Title of case study: Menthol as an ergogenic aid: enhancing human performance and health in sporting and clinical settings		
Period when the underpinning research was undertaken: Paper 1, research undertaken between January 2019 and May 2020. Paper 2, research undertaken as part of a collaborative project between July 2014 and October 2018.		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Dr Martin Barwood	Role(s) (e.g. job title): Reader in Physical Activity and Health, Director of Postgraduate Research	Period(s) employed by submitting HEI: September 2016 - present
Period when the claimed impact occurred: November 2016 to December 2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact Leeds Trinity University's (LTU) research (led by Dr Martin Barwood) describes the safe and effective use of a novel performance and health enhancing intervention, namely L-menthol application and ingestion. This published guidance has been issued to sports practitioners, exercise scientists, coaches, athletes and clinical (e.g., thermal physiologists) professionals to inform best practice when administering menthol as a nutritional supplement, ergogenic aid and therapeutic intervention to alleviate heat strain. The research outcomes have impacts on (i) Internationally distributed and embedded advice on safe concentrations, preparation protocols and use of menthol-based interventions benefitting practitioners and professional services; (ii) the development of menthol-based products for ingestion and application in athletes and multiple sclerosis sufferers; and (iii) improved exercise outcomes for hard-to-reach groups.		
2. Underpinning research Context: Competitive sporting events and recreational activities in clinical groups can be limited by unpleasant perceptions of thermal discomfort and sensation (i.e., feeling unpleasantly hot). Accordingly, clinicians, exercise scientists, practitioners and elite sports organisations have become interested in interventions that relieve thermal discomfort and thereby enhance performance or exercise outcomes. Where the environmental conditions are extremely hot and additionally limiting (i.e., Tokyo 2020 (2021) Olympic games; 2022 Qatar FIFA World Cup) evoking perceptual improvement magnifies the benefits and can aggregate to marginal gains that enhance performance or exercise outcomes. Menthol is a naturally occurring cyclic terpene alcohol that is extracted from plants of the <i>Mentha</i> genus (e.g., peppermint and corn mint) and evokes a fresh pleasant taste and cooling sensation when applied to mucous membranes or the skin biochemically mirroring temperature change within the range of 8 to 28°C. Menthol-induced stimulation of thermal receptors during periods of heat stress has consistently been shown to improve thermal comfort (i.e., feels more comfortable) and decreases thermal sensation (i.e., feels cooler) which is ergogenic in endurance sports and may also be of relevance to clinical populations. An expanding body of research using menthol is evident in the current REF census period, yet few studies have reported the thresholds for the safe and effective administration of menthol interventions with a lack of authoritative guidelines particularly for use in hard-to-reach groups such as elite athletes and those with clinical thermal impairments. Guidance on safe products for use in these scenarios is similarly lacking.		

Nature of the Insight: The impact contributes to LTU's "Enhancing Human Performance" research theme and used an international consensus-based approach to developing authoritative guidance (paper 1) on the safe and effective use of menthol-based interventions in preparation for use prior to and during the upcoming Olympic Games (Tokyo 2020 [2021]) and beyond; thereby enhancing the understanding of safe practice and identifying intervention opportunities. These recommendations and our prior empirical work (paper 2) have been fundamental to the development of specific consumer products, including menthol-containing ingestible gels and sprays applied directly to the skin; the latter for use in clinical trials.

Our consensus guidelines were formed with 13 internationally recognised experts from a range of backgrounds linked to elite sport and health providing a clear pathway for dissemination to enhance understanding. We established an agreed risk of heat related illness, including an impairment to sweat response (paper 2), associated with the improper use of menthol-based interventions confirming the need for guidance. Upper limits were established for safe use of menthol applications to the skin (0.8% for menthol sprays and 8.0% for menthol gels) with safe doses for ingestion not to exceed 0.5 g·L⁻¹. Cases of lethal doses of menthol application and ingestion were collated and established at 50 to 150 mg·kg⁻¹ of body weight. Caveats were established for the evidence base underpinning safe use in under-researched groups including females, elite athletes and an absence of work in Paralympic athletes was evident thereby informing our onward guidance. World Anti-Doping Agency (WADA) codes were not infringed with the use of menthol-based products at published concentrations although the possibility of cross contamination between supplements was noted thereby stimulating our inclusion of a menthol product preparation protocol. Where menthol dispersions were considered (paper 2) we established the efficacy of more stable ingredients for effective menthol dispersion to the skin to minimise skin irritation thereby changing active ingredients and informing product development.

3. References to the research

All outputs referenced have been published in peer-reviewed upper quartile sports science journals; each having undergone rigorous peer review that was based on initial editor screening and anonymised (double-blind) refereeing by at least two referees (including at least one round of author revision).

Paper 1. Barwood, M.J., Gibson, O.R., Gillis, D.J., Jeffries O., Morris N.B., Pearce, J., *et al.* (2020). Menthol as an ergogenic aid for the Tokyo 2021 Olympic Games: an expert led consensus statement using the modified Delphi method. *Sports Medicine*, 50(10) 1709-1727. <https://doi.org/10.1007/s40279-020-01313-9>

- Key findings include:
 - Menthol application to the skin was noted to increase the risk of heat-related illness at some concentrations; caution was urged in using this modality in our onward guidance.
 - Safe doses for menthol mouth-rinsing were established up to 0.1 and not to exceed 0.5 g·L⁻¹ thereby informing safe concentrations for product development.
 - Safe doses for menthol application were established as 0.8% for menthol sprays and 8.0% for menthol gels but are noted as surface area, concentration and exercise protocol dependent.
 - Lethal dose ranges were established from reports from animal and human studies; set at 50 to 150 mg·kg⁻¹ of body weight.
 - Consensus guidance on safe preparation protocol to minimise risks to health included: preparing menthol interventions from crystals in ventilated environments, using food grade hazard certified sources of menthol, applying modest (but not excessive) topical applications in accordance with manufacturer instructions, and delimiting doses to those that have been examined in the peer-reviewed literature to ensure menthol use minimises the health risk to the end user.
- Altmetric: Reached **327,288** followers (<https://link.altmetric.com/details/85232092/twitter>)

Paper 2. Barwood, M.J., Kapusarevic, J., & Goodall, S. (2019). Repeated Menthol spray application enhances exercise capacity in the heat. *International Journal of Sports Physiology and Performance*, 14(5): 644-649. <https://doi.org/10.1123/ijspp.2018-0561>

Key findings include:

- Repeated menthol application induced a 48% performance improvement in high intensity exercise undertaken in a hot (35°C), dry (22% RH) environment vs placebo control.
- The performance effect seen was an increase in exercise time to exhaustion; 4.6 (1.74) minutes vs 2.4 (1.55) minutes in the placebo control.
- Thermal sensation was 30% lower after initial menthol application corresponding to feeling “cold” compared to “warm/hot”.
- The perceptual benefits were noted to diminish on secondary application indicating an habituation thereby informing onward application protocols.
- Estimated sweat rate was 12% lower despite exercising for longer in the menthol condition (827 (327) mL·hr⁻¹ versus placebo control (941 (319) mL·hr⁻¹) potentially increasing the risk of heat-related illness.
- No skin irritation was noted when using the menthol spray.
- Altmetric: Reached **2,995** followers (<https://www.altmetric.com/details/52174873/twitter>)

4. Details of the impact

Our strategy for impact involved taking our research on developing consensus guidelines for the safe and effective use of menthol and co-constructing research agendas with academic and user groups. We developed academic partnerships with elite sport organisations (e.g., Australian Institute of Sport - AIS; High-Performance Sport, New Zealand; Arkea Samsic Pro Cycling Team, France) to enable a direct pathway to inform coaches, practitioners and athletes. We also partnered with health focussed research groups (e.g., Mary MacKillop Institute for Health Research, Australia; School of Health and Social Care, Teesside University, U.K) to enable wider application to health scenarios; our advice was later adopted by University of Sydney, Australia. This approach has enabled: professional standards and guidelines to be influenced by our research; professional bodies and learned societies to use our research to define best practice; as a result practices have changed including the implementation of new protocols and discontinuation of previous, less effective and less safe practices; the guidelines have informed two types of product development which has extended to the trialling of a new clinical intervention to alleviate heat strain in multiple sclerosis sufferers.

Accordingly, in relation to elite sport guidance issued to athletes, coaches and practitioners by the Australian Institute of Sport has changed providing a traceable reference to inclusion of our research in authoritative guidance (source 1). Best practice guidance issued by the AIS now recommends the discontinuation of the application of menthol creams or gels whilst recognising menthol-based body sprays as the preferred method (source 1) thereby confirming evidence from our experimental trials (paper 2). In relation to nutrition, the AIS Sports Supplement Framework now considers menthol to be a “B Group” supplement (source 2) defined as having “Emerging scientific support” but “deserving of further research” whilst recognising it could be performance enhancing. Our pathway to the education of hard-to-reach groups such as elite athletes is confirmed by source 2a (https://www.ais.gov.au/nutrition/supplements#group_b) and source 2b. Accordingly, our work has improved the understanding of international sports organisations and the guidance issued to its practitioners, coaches and athletes on the safe and effective use of an ergogenic and nutritional supplement as evidence by these changes.

The expanding use of menthol-based strategies by elite athletes has been acknowledged and predicted to grow by practitioners and scientists (source 3) describing elite level sports performance in hot environments (i.e., Doha, World Athletics Championships; source 3). This provides traceable references by practitioners to research papers confirming that the need for guidance was warranted and has been met. Our consensus guidance (paper 1) has informed the product development stages and guidance for effective use of a cooling menthol energy gel trialled in elite and national standard athletes (source 4). Our published upper threshold for menthol

ingestion was incorporated in these studies (0.5 g.L⁻¹ or 0.5% concentration). Athlete testimony confirmed our consensus view of the upper threshold for menthol concentration in ingested supplements at which negative health outcomes (e.g., sickness, gastrointestinal disturbance) were noted for some athletes (source 4) above which an improved exercise outcome is unlikely in this hard-to-reach group. Nevertheless, no performance decrement was reported even at the higher concentrations. Our published protocol for preparation of the menthol gels was adopted and advocated in this study by using food grade menthol secured from a reputable resource, with an associated hazard statement, and cross checking with WADA for cross-contamination for banned performance enhancing substances prior to use. This provides traceable reference to research papers describing the use of our guidance and its impact.

In relation to health, our consensus guidance and empirical work (papers 1 and 2) has achieved recognition by clinical researchers (i.e., University of Sydney, Australia; source 5) culminating in the development of a new clinical intervention. As a result of our guidance (source 5), researchers at the University of Sydney (Australia) have prioritised the inclusion of a menthol-based spray in clinical trials to alleviate heat strain in multiple sclerosis sufferers. Our long-standing partnership with an independent chemical consultant (source 6) has informed the iterative steps to finalise the chemical constituents of the new menthol-based spray for use in these trials thereby improving product quality. The included spray minimises skin irritation (which was confirmed as efficacious in our prior research; paper 2) thereby enabling a new product to be adopted for use (source 5 and 6). The trials are pending and have been delayed by the Covid-19 pandemic. However, based on our consistent evidence of thermal perceptual improvement in healthy controls (paper 2), we anticipate a positive health outcome of enhanced perception and improved exercise tolerance in multiple sclerosis sufferers.

In summary, research led by Dr Barwood et al. at LTU since 2016 has clearly informed the scientific evidence base underpinning the safe and effective use menthol-based products in hard-to-reach groups. Pathways to impact have included: working with partners, and engaging stakeholders and beneficiaries.

5. Sources to corroborate the impact

Source 1. Australian Institute of Sport Tokyo 2020 - Menthol Factsheet (see PDF)

Source 2a&b. Australian Institute of Sport – B Group Supplements (source 2a: https://www.ais.gov.au/nutrition/supplements#group_b) (source 2b: see PDF for confirmation of update)

Source 3. Racinais et al (2020) – Elite Athlete Use of Menthol Cooling

- Racinais, S., Ihsan, M., Taylor, L., Cardinale, M., Adami, P.E., Alonso, J.M. 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*, (epub ahead of print), February 4; 1–8. <http://dx.doi.org/10.1136/bjsports-2020-103613>

Source 4. Stevens et al (2021) – Development of Menthol Cooling Gel

- Stevens, C.J., Ross, M.L., & Vogel, R.M. (2020). Development of a “cooling” menthol energy gel for endurance athletes: effect of menthol concentration on acceptability and preferences. *International Journal of Sport Nutrition and Exercise Metabolism*, (epub ahead of print), November 27; 1-6. <https://doi.org/10.1123/ijsnem.2020-0190>

Source 5. University of Sydney, Australia - Testimony from Dr Nicole Vargas (see PDF)

Source 6. Chemical Associates – Statement on Menthol Product Development from Prof Peter Smallwood (see PDF)