2019

Limiting the rise in core temperature during a rugby sevens warm-up with an ice vest

Lee Taylor
Aspetar, Qatar

Christopher J. Stevens
Southern Cross University, Australia

Heidi R. Thornton
La Trobe University, Australia

Nick Poulos
Australian Rugby Union, Sydney, Australia

Bryna CR Chrismas
Qatar University, Qatar

Publication details

Postprint of: Taylor, L, Stevens, CJ, Thornton, HR, Poulos, N & Chrismas, BCR 2019, 'Limiting the rise in core temperature during a rugby sevens warm-up with an ice vest', *International Journal of Sports Physiology and Performance.*
Published version available from:
https://dx.doi.org/10.1123/ijspp.2018-0821

Title: An ice vest limits the rise in core temperature during a Rugby Sevens warm-up

Submission Type: Original Research

Authors: Lee Taylor[1,2]*, Christopher J. Stevens[3], Heidi R. Thornton[4], Nick Poulos[5], Bryna C.R. Chrismas[6]

Affiliations:

[1]ASPETAR, Qatar Orthopaedic and Sports Medicine Hospital, Athlete Health and Performance Research Centre, Doha, Qatar.

[2]Loughborough University, School of Sport, Exercise and Health Sciences, Loughborough, UK.

[3]Southern Cross University, School of Health and Human Sciences, Coffs Harbour, Australia.

[4]La Trobe University, La Trobe Sport and Exercise Medicine Research Centre, Melbourne, Australia.

[5]Australian Rugby Union, Sydney, Australia.

[6]Qatar University, Sport Science Program, College of Arts and Science, Doha, Qatar.

***Address for Correspondence**

Dr Lee Taylor

Aspetar - Qatar Orthopaedic and Sports Medicine Hospital

Athlete Health and Performance Research Centre

Aspire Zone, Doha, Qatar, P.O. BOX 29222

Email: Lee.Taylor@aspetar.com **Phone:** +974 4413 2403

Preferred Running Head: Ice vest use during Rugby Sevens warm-up

Abstract word count:	249
Text-only word count:	2936
Number of figures:	2
Number of tables:	2
References:	30

Abstract

Purpose: Determine how a cooling vest worn during a warm-up could influence selected performance [counter movement jump (CMJ)], physical (GPS metrics) and psycho-physiological (body temperature and perceptual) variables. **Methods:** In a randomized crossover design, twelve elite male World Rugby Sevens Series athletes completed an outdoor (WBGT: 23-27°C) match-specific externally-valid 30 min warm-up wearing a phase change cooling vest (VEST) and without (CONTROL), on separate occasions 7 days apart. CMJ was assessed before and after the warm-up, with GPS indices and heart rate monitored during the warm-ups, whilst core temperature (Tc; ingestible telemetric pill; n = 6) was recorded throughout the experimental period. Measures of thermal sensation (TS) and comfort (TC) were obtained pre- and post-warm-ups, with rating of perceived exertion (RPE) taken post-warm-ups. **Results:** Athletes in VEST had a lower ΔTc [mean (SD) VEST 1.3°C (0.1°C); CONTROL 2.0°C (0.2°C)] from pre-warm-up to post-warm-up [effect size (ES) ± 90% confidence limit; -1.54; ±0.62] and Tc peak [mean (SD) VEST 37.8°C (0.3°C); CONTROL 38.5°C (0.3°C)] at the end of the warm-up (-1.59; ±0.64) compared to CONTROL. Athletes in VEST demonstrated a decrease in ΔTS (-1.59; ±0.72) and ΔTC (-1.63; ±0.73) pre- to post-warm-up, with a lower RPE post warm-up (-1.01; ±0.46), compared to CONTROL. Changes in CMJ and GPS indices were *trivial* between conditions (ES < 0.2). **Conclusions:** Wearing the vest prior-to and during a warm-up can elicit favorable alterations in physiological (Tc) and perceptual (TS, TC and RPE) warm-up responses, without compromising the utilized warm-up characteristics or physical performance measures.

Keywords: Cooling; heat; elite; telemetric; hyperthermia

Introduction

During World Rugby Sevens Series (WRSS) match-play in temperate [wet bulb globe temperature (WBGT) range: 14°C – 19.2°C] and warm (WBGT range: 25°C - 27°C) conditions, peak player core temperatures (Tc) of 39.6°C and 39.9°C respectively, have been observed.[1] When Tc is >39°C, intermittent sprint performance can be decreased.[2,3] Given WRSS game demands are predominately glycolytic (e.g. passing, tackling, competing at the ruck contest, breakdown, lineout or scrum as well as running, sprinting etc.) and their execution is a key determinate of WRSS match outcome and game actions,[4-7] large increases in Tc during WRSS match-play (e.g. Tc >39°C[2]) may limit physical performance.[1]

A WRSS tournament day is typically characterized by three matches in close proximity (~3 h between matches) and ~20-30 min allocated for a team to warm-up prior to each match.[1] The warm-up is implemented to raise skeletal muscle temperature and activate relevant metabolic and neural pathways to prepare players with specificity for the upcoming, predominantly glycolytic, game demands.[4-7] However, it appears on occasions that WRSS match-day warm-ups may increase Tc in excess of what is desirable (e.g. ≥39°C[2]).[1] Pre- and mid-cooling can reduce perceptual and peak body temperature responses to an endurance or intermittent-sprint based exercise bout, eliciting favorable physical performance outcomes (e.g. increased distances covered)[2,8-13]. Therefore, WRSS practitioners may benefit from body cooling techniques that are compatible within the constraints of WRSS match-day preparations.

Minimal use of pre-cooling techniques were observed during WRSS competition in temperate and warm environments,[1] whilst such interventions are absent from recent WRSS specific physical preparation recommendations;[7] perhaps due to practitioner concerns regarding the potential of pre-cooling to reduce explosive maximal physical performance early within a match.[14,15] A light-weight phase change cooling garment (e.g. an 'ice' vest) can moderate Tc increase during a warm-up and positively influence subsequent high intensity exercise.[16] Although in practice, this vest must not interfere with the desired physical and technical outcomes from an effective warm-up. Given Rugby Sevens is an Olympic sport (2016 and 2020) and that Tokyo 2020 is predicted to be the hottest modern Olympics to-date (temperatures ~30°C and relative humidity ~75%),[16,17] practically valid empirical data supporting cooling strategy use (e.g. as described above) would be well received by practitioners. Although such data is currently lacking from elite Rugby Sevens athletes within an ecologically valid setting.

The experimental aims were therefore to use a phase change cooling vest within elite WRSS players during an externally valid match-day warm-up. Specifically, the performance [counter movement jump (CMJ)], physical [global positioning system (GPS) metrics] and psycho-physiological (body temperature and perceptual variables) responses to wearing the vest relative to the warm-up were examined. It was hypothesized that body temperatures and perceptions of heat/exertion would be favorably influenced whilst performance (CMJ) and warm-up characteristics (GPS) would not be negatively influenced, when wearing the vest compared to control (e.g. not wearing the vest).

Methods

Subjects

Data were collected from 12 elite male squad members (25.0 ± 4.5 y, 87.5 ± 8.5 kg, 180.5 m ± 7.6 cm) of a single 2017-18 WRSS international team (several athletes competed at the 2016 Olympic Games and/or 2018 Commonwealth Games and/or 2018 World Rugby 7s World Cup) after written informed consent was provided. Ethical approval from the Southern Cross University Human Research Ethics Committee (ECN-17-2017) in the spirt of the Helsinki Declaration was granted.

Design (*** Insert Figure 1 near here ***)

A standardized 30 min externally valid match-day warm-up (referred to from here on as 'warm-up') was performed outdoors on two occasions, separated by 7 d, within near identical environmental conditions [wet bulb globe temperatures (WBGT) range on both days: 23-27°C]. The warm-ups were performed prior to scheduled training sessions and not during a WRSS tournament, and thus match-performance metrics (e.g. physical performance) are not available. The warm-up involved a specific combination and sequence of drills (including passing, dynamic stretching, defensive structures and accelerations) leading into contested and contact specific work, followed by progressive sprints over 30 – 40m and finishing with team structure drills. With a randomized, crossover design, squad members completed one experimental trial wearing a phase change cooling vest (VEST) and one trial without (CONTROL). Specific kinematic and kinetic variables of a CMJ were assessed before and after the warm-ups, with GPS and heart rate data collected during the warm-ups, whilst Tc was recorded throughout the experimental period (see Figure 1). Six athletes volunteered to have their Tc monitored, three in each arm of the crossover design. Food and fluid intake replicated the teams typical match-day practice. The same practitioner obtained each measure outlined below, using standardized language and procedures.

Methodology

Tc: Volunteered athletes ingested an e-Celsius™ telemetric capsule (BodyCap, Caen, France) at 21:00 on the evening prior to the experimental trials, ensuring that a minimum of 8 h (to allow transit into the gastrointestinal tract[17,18]) was observed prior to establishment of baseline values (from 05:00 on each day) for use within subsequent statistical modelling. Tc was sampled at 30 s intervals, with data downloaded at the end of the warm-up via a wireless data receiver (e-Viewer, BodyCap, Caen, France). Capsules underwent an individual 3-point calibration, as described previously.[1,18] The e-Celsius™ system has been shown valid and reliable for running exercise when adopting the above approach[18] whilst excellent validity (ICC 1.00), test-retest reliability (ICC 1.00) and inertia was found in water bath experiments between 36°C and 44°C;[19] and it has been used previously within elite WRSS athletes during match-play.[1]

Specific predefined time periods relative to Tc were employed within analyses (see Figure 1):

- Baseline: 05:00 – 07:00
- Pre-warm-up: 07:00 – 08:10
- Warm-up: 08:10 – 08:40

VEST: The vest (TechNiche Hybrid Cooling Vest Product 4531, TechNiche International, California, USA) can be used to augment evaporative heat loss (e.g. the vest is immersed in water prior to use) and through phase change heat lost whereby the frozen inserts (Cool Pax™ Product 7065V, TechNiche International, California, USA) are melted by body heat. In this study, the vest was used only in a phase change capacity. Athletes wore the vest from 07:00 (commencement of team meeting), during travel to the training pitch and throughout the warm-up (08:10 - 08:40), which was a total duration of 100 minutes, as per Figure 1. Four frozen (freezer temperature: -20°C for at least 48 hours) Cool Pax™ inserts (surface temperature -15.4 ± 2.1°C) were inserted into the vest (itself stored as per Cool Pax™ inserts) at ~06:55. The cooling inserts were not replaced during the 100 minutes of wearing the vest and were not fully melted by the end of use (surface temperature was not taken). The vest was worn under the teams official 2017-18 WRSS warm-up jersey next to the skin, but on top of a players GPS vest.

GPS: External load during the warm-up was measured using 5 Hz GPS devices (SPI HPU, GPSports, Canberra, Australia) that were interpolated to 15 Hz by the manufacturer's software

(Team AMS 2016.6, GPSports, Canberra, Australia). These devices have acceptable accuracy for distance (coefficient of variation [%]; CV: 0.14% – 3.73%) and speed (CV: 4.22% – 9.52%), and reliability for distance (CV: 0.34% - 3.81%) and speed (CV: 3.19% - 6.95%).[20] Each unit was assigned to an individual athlete and worn in their GPS vest, positioning the unit between their scapula blades. Following the warm-up, devices were removed and the data was exported using the manufacturer's software. Metrics exported from the GPS data included; measures of total distance (m), meters per minute (m/min), high speed running (> 5 $m \cdot s^{-1}$), very high speed running (> 6.7 $m \cdot s^{-1}$), acceleration per minute (acc/min; > 2.5 $m \cdot s^{-2}$), decelerations per minute (dec/min; < 2.5 $m \cdot s^{-2}$). Heart rate was collected using a fitted chest strap (Polar T34, Kempele, Finland) worn beneath the athlete's GPS vest. This chest strap recorded heart rate data to the GPS device at 1 Hz. Heart rate data was extracted using the GPS manufacturer software, where average heart rate (HR; $b.min^{-1}$) and maximum HR ($b.min^{-1}$) was included in the present study.

CMJ: CMJ were performed using dual portable force platforms (PASCO Pasport Force Platform PS-2141, PASCO, California, USA) sampling at 1000 Hz. Prior to each set of CMJ (see Figure 1), athletes completed 3 full range lunges each side, 10 'footsies' (small jumps with straight knees and stiff ankle, emphasizing dorsiflexion and plantarflexion) and 3 submaximal CMJ (with wooden dowel) as per the athlete's normal routine before a CMJ. A wooden dowel was provided to athletes, placed across the back and held in a typical back-squat position. Athletes were instructed to limit the dowel movement pre, during and post CMJ execution. After placing one foot on each force platform, athletes stood motionless for 3 seconds to determine body mass. They were then instructed to drop into a squat position and then immediately jump as high as possible with triple extension at the ankle, knee and hip in an explosive concentric action whilst avoiding bending the knees when airborne. Upon landing, they were instructed to stick the landing and hold for 5 seconds. Three CMJs were performed pre- and post-warm-up. The athlete's completed this specific CMJ protocol for monitoring on all training days and whilst away for WRSS tournaments; thus they are well familiarized to this specific CMJ protocol. Data were recorded and extracted using the manufacturers proprietary software (PASCO capstone™, PASCO, California, USA) and commercially available software (Forcedecks 3.1 Software). Utilized metrics exported/calculated from the CMJ data include (with intra-day reliability CV and ICC lower and upper confidence limits provided) peak velocity (m/s; CV: 2.77% - 6.76%; ICC: 0.17 – 0.89), peak power [(W; CV: 4.67% - 11.56; ICC: 0.06 – 0.86) and (W/kg; CV: 4.64 – 11.48; ICC 0.32 – 0.92)], jump height (cm; CV: 6.31 – 15.80; ICC: 0.13 – 0.88), flight time (s; CV: 2.41 – 5.88; ICC: 0.52 – 0.95), eccentric duration (ms; CV: 2.72 – 6.65; ICC: 0.40 – 0.93), eccentric/concentric duration (%; CV: 2.72 – 6.64; ICC: 0.24 – 0.90) and rate of concentric power development [(W/s; CV: 5.77 – 14.38; ICC: 0.23 – 0.77) and (W/s per 100 ms; CV: 8.54 – 21.72; ICC: 0.21 – 0.90)].

Perceptual measures: Thermal sensation (TS) was measured using a 17-point category ratio scale (where 0 = 'unbearably cold' and 8 = 'unbearably hot').[21] Thermal comfort (TC) was measured using a 10-point category ratio scale (where 1 = 'comfortable' and 10 = +1 above 'extremely uncomfortable'). Rating of perceived exertion (RPE) was measured using an 11-point category ratio scale (where 0 = rest and 10 = maximal).[22] These measures were collected as per Figure 1.

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 24 (IBM, SPSS Inc, Chicago, IL, USA) and magnitude-based inferences (MBIs) customizable spreadsheets, using the raw data.[23] Initially, descriptive statistics were generated, and normality checked using quantile-quantile (Q-Q) plots.[24] Descriptive statistics are reported as mean ± standard deviation (SD) and range (minimum – maximum). GraphPad Prism 4 (GraphPad Software, CA, USA) was used to create Figure 2. Individual player Tc was determined and averaged for each pre-defined time period. At each time period, the individual player change (delta; Δ) relative to baseline and other time periods was calculated. Additionally, peak Tc values from the warm-up period were also extracted and compared to other time periods. Linear mixed models (LMM) were used to determine if there were any differences between condition (CONTROL and VEST), and across time (relevant predefined time periods) for Tc, GPS, TS, TC, RPE and CMJ. GPS data was analyzed for between condition (CONTROL and VEST) differences. Fixed and random effects for the LMM were fit for each dependent variable.[25] The most appropriate model was chosen using the smallest Hurvich and Tsai criterion (AICC).[26] The least squares mean test provided pairwise comparisons between the fixed effects. Step down Hommel p value adjustments were used for post hoc analysis in the event of a significant main and/or interaction effect.[27] Normality and homogeneity of variance of the residuals were checked using Q-Q plots, and scatter plots respectively, and deemed plausible in each instance. Cohen's *d* effect sizes (ES), and 90% confidence limits (CLs) were obtained using the MBI spreadsheets, and categorized using standardized thresholds of; < 0.2 trivial, 0.21 – 0.60 small, 0.61 – 1.20 moderate, 1.21 – 2.0 large, and > 2.0 very large[23]. Differences were considered real if there was a >

75% likelihood of the observed effect exceeding the smallest worthwhile effect (0.20)[1], using the following qualitative descriptions; 75 – 95% likely, 95 – 99.5% very likely, and > 99.5% most likely.[23] Data is reported as ES; ±90% CL.

Results (*** Insert Figure 2, Table 1 and Table 2 near here ***)

The between group (CONTROL vs VEST) and across time (pre- and post-warm-up) comparisons of the perceptual and performance data are shown in Table 1. The between group (CONTROL vs VEST) comparisons of the GPS measurements are shown in Table 2.

Tc: Players in VEST had a *most likely* lower ΔTc [mean (SD) VEST 1.3°C (0.1°C); CONTROL 2.0°C (0.2°C)] pre-warm-up vs post-warm-up (effect size; ±90% CL = -1.54; ±0.62) and Tc peak [VEST 37.8°C (0.3°C); CONTROL 38.5°C (0.3°C)] during warm-up (-1.59; ±0.64) compared to CONTROL (see Figure 2). This was seen with a *trivial* difference (-0.18; ±1.2) between VEST and CONTROL during the pre-warm-up period (07:00 – 08:10).

Perceptual measures: There was a *most likely* decrease in ΔTS (-1.59; ±.72) and ΔTC (-1.63; ±0.73) in VEST compared to CONTROL, pre- to post-warm-up. Furthermore, players in VEST had a *most likely* lower post-warm-up RPE compared to CONTROL (-1.01; ±0.46).

Performance and GPS measures: There was a *trivial* effect of VEST on the CMJ performance measures (Table 1). All players demonstrated a *likely* increase in jump height [4.4 cm (3.5 cm)] from pre- to post-warm-up (0.29; ±0.11) irrelevant of condition. There were only trivial differences regarding the effect of VEST on all GPS measures (Table 2).

Discussion

Wearing a phase change cooling vest prior-to and during a match specific Rugby 7s warm-up can elicit favorable alterations in physiological (peak and ΔTc; Figure 2) and perceptual (TS, TC and RPE; Table 1) warm-up responses, without compromising warm-up characteristics (GPS metrics; Table 2) or physical performance (CMJ metrics; Table 1), in acceptance of the experimental hypothesis. Importantly, independent of condition, there was a substantial increase in CMJ height by ~5 cm (0.29; ±0.11) from pre- to post-warm-up, indicating that the warm-ups were effective in augmenting CMJ physical performance. This is likely via increased muscle temperature, and activation of various metabolic and neural pathways (although not specifically measured within this design). The data suggest practitioners could use this intervention with their athletes to limit the rise in Tc during a warm-up.

Through wearing the vest, Tc was ~0.7°C lower on average in VEST compared to CONTROL [VEST 37.8°C (0.3°C); CONTROL 38.5°C (0.3°C)] post-warm-up (Figure 2). This attenuated increase in Tc post-warm-up between conditions could extend time taken to reach a Tc (e.g. ≥39°C[2]; subject to individual variation) that may restrict repeated sprint performance during a match[2], without compromising initial lower body power (Table 1). On a WRSS match-day, the employed warm-up (which was replicated within the present experimental design) can elicit a Tc response of 39°C;[1] a magnitude of change that has been associated with reductions in repeated sprint based performance and capacity.[2] However, wearing the vest during the experimental warm-up ensured Tc did not exceed this proposed performance-impairing threshold (e.g. ≥39°C[2]), yet such a response was seen in one player in CONTROL (Figure 2). Importantly, athletes reported that wearing the vest was not uncomfortable nor did it impede their ability to fully engage with or execute any aspect of the warm-up. Indeed, athletes were willing when directly asked to wear the vest in future WRSS tournament warm-ups without concern.

Wearing the vest between 07:00 and 08:10 did not elicit a favorable body temperature response between conditions (e.g. a pre-cooling effect was not seen) prior to warm-up commencement (8:10). Practically, this data suggests that the vest may not need to be worn for a period prior to the warm-up (in this case 70 min prior to warm-up commencing), if the major goal is to physically reduce body temperature post-warm-up. However, as outlined in Table 1, TS and TC are reduced in VEST compared to CONTROL, immediately before the warm-up at 08:10. Reductions in thermal sensation without accompanying physical body temperature decreases can within some scenarios prove ergogenic to exercise performance in the heat.[10,11,28-30] Therefore, practitioners must consider carefully their rationale for cooling vest use relative to their desired performance outcomes and the complex interaction between peripheral and central thermoregulatory factors.[10,13]

This approach could be trialed across a simulated WRSS match-day to determine any performance changes in response to the observed cooling vest mediated alterations in peripheral and central thermoregulatory factors. These experimental effects are from a single commercially available vest. The phase change material used, the quantity and location of phase change material within a vest, and the vest design (fit, materials used, etc.) itself varies across commercially available garments. Further research that optimizes the combination of these factors with specificity to the unique somatotypes seen within the present and other elite athletes is required, given the variety of body compositions/shapes across the elite sport continuum. Finally, a greater array of externally valid physical and technical performance measures could be employed, to more robustly determine any unwanted effects from wearing the cooling vest during the warm-up.

Practical Applications

The commercially available vest can be comfortably worn within WRSS warm-up contexts to favorably influence perceptual and body temperature responses, without compromising the identified warm-up characteristics or physical performance (lower body power) at the end of the warm-up.

Conclusions

Wearing the vest prior-to and during a warm-up can elicit favorable alterations in physiological and perceptual warm-up responses, without compromising the identified warm-up characteristics or physical performance (lower body power) at the end of the warm-up.

Acknowledgements

The authors thank the players and staff for their willingness, professionalism, engagement and time pre, during and post the executed research project, without which the project would not have been viable. Simon Harries, Mitch Henderson and Jed McGrath (Australian Rugby Union) provided valuable technical, methodological and logistical support pre-, during- and post-project. The authors thank Gavin Travers who provided technical guidance regarding the BodyCap system. Lee Taylor (and co-authors) thanks the Aspire Zone Foundation (AZF; Doha, Qatar) for the funding and support to complete the presented research project and also BodyCap (Caen, France) for the loan of a single e-Viewer for the presented research project. The authors thank various individuals located across the globe (including Europe and Australia) from TechNiche International (California, US) who provided the cooling attire alongside technical and logistical support.

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Figure Captions

Figure 1. Experimental schematic. Tc: Core Temperature (ingestible telemetric pill); GPS: Global Positioning Satellite; TS: Thermal Sensation; TC: Thermal Comfort; RPE: Rate of Perceived Exertion; CMJ: Counter Movement Jump. VEST: Phase Change Cooling Vest.

Figure 2. Core temperature (Tc) responses to warm-up. BLTc: Baseline Core Temperature; WU-P: Peak Tc during warm-up; ΔTc: delta change in Tc from BLTc compared to WU-P. Filled circles individual CONTROL data. Filled squares individual VEST data. Black horizontal line represents the mean. Differences between CONTROL and VEST are denoted as; ^^^ *most likely*. N.B. only three players from each arm of the crossover ingested the telemetric Tc pill.