Running Head: Thermoregulation and team-sport training in hot environments

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A case for the use of 'sun-limiting' garments in sport: Exploring training outcomes and athlete perceptions in a hot environment

Fergus K. O'Connor[1,2], Jonathan D. Bartlett[1,3], Thomas M. Doering[4], Vernon G. Coffey[1]

[1]Bond Institute of Health and Sport, Faculty of Health Sciences and Medicine, Bond University, Queensland, Australia, [2]Human and Environmental Research Unit, School of Human Kinetics, University of Ottawa, Ottawa, Canada, [3]Institute of Sport, Exercise and Active Living (ISEAL), Victoria University, Victoria, Australia, [4]School of Health, Medical and Applied Sciences, Central Queensland University, Rockhampton, Queensland, Australia.

Corresponding Author:

Dr Fergus K O'Connor

Bond Institute of Health and Sport

Faculty of Health Sciences and Medicine

Bond University, Robina, Queensland, Australia

Email: foconnor@uottawa.ca

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Abstract

Purpose: Solar radiation (SR) exposure decreases exercise performance in hot environments. Utilizing garments that cover the upper body could lead to improved training outcomes by limiting SR to the skins surface. The aim of this study was to determine the efficacy of a 'sun-limiting' garment on team-sport training outcomes and perceived thermal stress in a hot environment. **Methods:** Professional Australian Rules footballers (n=16) wore standard training attire (n=9) or standard training attire with the addition of a 'sun-limiting' garment (n=7) during seven standard, pre-season training sessions. External load was collected via GPS, internal load from ratings of perceived exertion (RPE) and thermal stress via thermal comfort (TC) and thermal Strain (TS) questionnaires pre-, during- and post-training. **Results:** Wearing the training garment was associated with decreased post-training TS (-0.94 AU, $p<0.001$) and TC (-0.68 AU, $p<0.001$). The training garment had no effect on Total Distance, High-Speed Running, pre- or mid- training TS and TC or RPE (all $p>0.05$). **Conclusions:** A 'sun-limiting' garment decreased post-training thermal stress without meaningful effect on GPS training outcomes or RPE. Wearing 'sun-limiting' garments may serve to reduce the risk of adverse skin-health outcomes, while potentially mitigating long-term stress in team-sport athletes training in hot environments.

Key words; thermoregulation, team sport, athlete wellbeing, heat

Introduction

Solar radiation (SR) has the capacity to increase skin temperature (T_{sk}) above levels associated with high ambient temperature (T_a) alone.[1] When body temperature is elevated during exercise heat stress, skin blood flow increases to promote effective thermoregulation.[2] The combination of increased skin blood flow for thermoregulatory cooling, concomitant with greater demand for muscle blood flow during exercise in hot environments places the cardiovascular system under heightened strain.[2] Higher T_{sk} as a result of increased SR exposure has been shown to decrease self-selected exercise intensity[3] and fixed-intensity exercise duration[1], and increased SR is associated with reduced exercise performance during professional team-sport training.[4]

SR reaches peak intensity under a clear sky at solar noon and typically reaches values of ~1000 W/m^2 during the summer months on the east coast of Australia.[4] Limiting SR to the skins surface during outdoor exercise in hot environments may mitigate the acute detrimental effects of SR exposure on exercise performance. Specific fabrics or clothing could reduce the impact of SR while concomitantly protecting against skin damage associated with repeated exposure to high levels of SR. Few studies have determined the effect of textiles on thermoregulation during lab-based exercise protocols [5], and even less is known about the effect a specialized garment has on team-sport training when exposed to hot environments characterized by high SR exposure. Therefore, the aims of this study were to; (1) determine whether a garment designed to reduce SR exposure effects total distance (TD) and high-speed running (HSR) during team-sport training in the heat; and (2) assess whether wearing the 'sun-limiting' garment reduced perceptions of thermal stress. We hypothesized that wearing the 'sun-limiting' garment would increase running performance and decrease perceptual markers of thermal stress during training.

Materials and Methods

Participants

Sixteen professional male athletes (mean ± standard deviation (SD)); age: 26.5 (2.5) years, height: 189.8 (8.3) cm, body mass: 89.5 (9.8) kg, maximal aerobic speed 17.6 (0.8) km/h, from one Australian Rules football (ARF) club participated in this study. Nine participants were assigned to the control group (no garment), while seven participants voluntarily wore the training garment. Eighty training observations, across seven training sessions were recorded throughout the experimental period. This resulted in 44 observations within the control group and 36 observations in the garment ‘intervention’ group. Ethical approval was granted by Bond University Human Research Ethics Committee (FO00007).

Informed Consent

Informed consent, and consent to publish was obtained from all participants prior to data collection commencing.

Data Availability

The data that support the findings of this study are openly available in Figshare at https://doi.org/10.6084/m9.figshare.21673793.

Experimental Protocol

Internal and external training loads were captured across a two-week period during a pre-season preparation phase (November-December) in Australia. The control group wore standard training attire (ARF singlet and shorts). The intervention group wore standard training attire with the addition of a ‘sun-limiting’ garment. The garment was a white, torso-less garment made from 92% polyester and 8% elastane. The garment covered the shoulders and arms to limit sun exposure to the upper body (CoolWings, De Soto Sport, San Diego, USA).

External training load

External training loads were captured via global position systems (GPS) for each participant and downloaded in accordance with previous methods.[6] Participants used the same GPS device (S5, Catapult Sports, Melbourne, Australia) for each session to mitigate inter-unit measurement errors.[7] Distance covered per minute ($m \cdot min^{-1}$), percent of total distance completed above 14.9 km/h (% high speed running; %HSR) and total distance completed above 75% maximum velocity (>75%) were selected as external load metrics and used in subsequent statistical analyses.

Internal training load

Thermal comfort (TC) and thermal sensation (TS) [8] were recorded pre-, mid- and immediately post-training. Ratings of perceived exertion (RPE) were obtained 10-30 min following the completion of each training session using Borg’s CR-10 scale.[9]

Environmental Monitoring

The T_a (°C), relative humidity (RH, %) and wind speed (WS, km/h) were measured via a portable weather station (Kestrel 5000, Kestrel Instruments, Pennsylvania, USA). Direct SR (W/m^2) was recorded via a portable pyranometer (MP-100, Apogee Instruments, Utah, USA). Environmental data was recorded at 30 s intervals during each field-based training session and reported as 30 min averages. Training sessions were each completed between 0900 and 1300 h, and solar elevation angles during training ranged between 62° and 83°.

Statistical Analyses

Relationships between internal load, external load, garment group, and the training environment were analysed using mixed-effect linear mixed models (LMM) in *R* (V. 4.1.0). To explore how the utilisation of the training garment may influence internal and external load, LMM were applied to either internal or external load variables incorporating the individual as a random effect and heat stress and garment group variables as fixed effects. Independent t-tests were undertaken to identify differences between groups. The adequacy of the model structures was determined via residual plots and quantified using standard measures of intraclass correlations and coefficients of determination. Variables are reported using standardised regression coefficients (β), allowing assessment of practical significance. The β for each variable were multiplied by the standard deviation of change in dependent variable to obtain the absolute change in the units of measurement.[10]

Results

Wearing the training garment was associated with decreased post-training TS (β= -0.67, -0.94 AU, $p < 0.001$) (Figure 1a) and post-training TC (β= -0.69, -0.68 AU, $p < 0.001$) (Figure 1b). However, the training garment had no effect on any external training load variable ($m \cdot min^{-1}$; β= 0.21, 2.4 $m \cdot min^{-1}$, p = 0.314, %HSR; β= -0.25, -2.1%, p = 0.275, >75%; β= 0.02, 1.9 m, p = 0.954). The training garment also had no effect on pre- or mid-training perceptual variables (preTS; β= -0.03, -0.03 AU, p = 0.887, midTS; β= -0.27, -0.24 AU, p = 0.33, preTC; β= 0.20, 0.1 AU, p = 0.486, midTC; β= -0.37, -0.28 AU, p = 0.255) or post-training RPE (β= 0.03, 0.03 AU, p = 0.896).

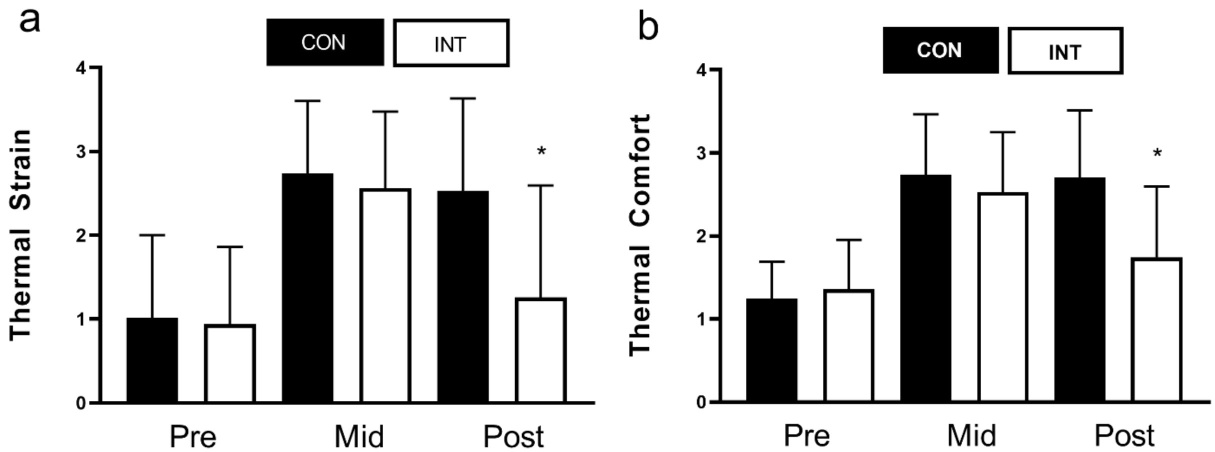

Figure 1 a) Thermal strain response of professional Australian rules footballers pre-, mid- and post-training. **b)** Thermal comfort response of professional Australian rules footballers pre-, mid- and post-training. Data are mean ± standard deviation. * $p < 0.01$. CON; control group who wore 'standard' training attire., INT; intervention group who wore 'standard' training attire with the addition of a 'sun-limiting' garment.

There was no difference in anthropological measures, or training load completed between control and intervention groups (Table 1). Mean environmental conditions during the experimental period were 27.4 ± 1.3°C T_a, 52.4 ± 13.5% RH, 755 ± 239 W/m^2 SR and 3.3 ± 0.5 km·h^{-1} WS.

Table 1. Anthropological and training load comparisons between control and garment intervention groups

Group (n)	Age (y)	Height (cm)	Weight (Kg)	BSA (m^2)	MAS ($km \cdot h^{-1}$)	Distance (m)	HSR (m)
CON (9)	27.1 ± 2.5	191.2 ± 7.8	90.8 ± 9.5	2.2 ± 0.2	17.7 ± 0.9	8663 ± 2787	3156 ± 1540
INT (7)	25.7 ± 2.4	187.9 ± 9.3	87.9 ± 9.9	2.1 ± 0.2	17.5 ± 0.4	9449 ± 2793	3203 ± 1316

CON, control group; INT, intervention group; BSA, body surface area; MAS, maximal aerobic speed; HSR, high-speed running

Discussion

Wearing a commercial garment designed to limit SR to the skin decreased post-training thermal stress in ARF athletes training in hot environments. However, contrary to our hypothesis, the garment had little effect on athlete work rate during training, nor perceptual variables before and/or during training sessions.

Athletes training in geographical locations that are characterized by high SR may experience heightened risk of developing adverse skin health outcomes in areas of the body that are continually exposed to direct SR [16] in conjunction with adverse long-term training outcomes. We have shown no effect (positive or negative) on running performance in athletes residing in *hot* geographical locations characterised by high SR exposure. As such, athletes may consider the utilisation of such training garments with the knowledge that their use is unlikely to induce adverse effects on training outcomes. Moreover, it is possible that wearing the garment could have beneficial effects on chronic stress and/or long-term positive implications for team-sport athletes routinely training in hot environments. Indeed, while hot environmental conditions have been shown to increase [12,13] or have no effect on perceptions of effort and thermal comfort during exercise in the heat [1,14,15] our findings of reduced self-reported thermal stress wearing the garment is a positive outcome. However, a limitation of this work is the lack of 'cross-over' research design. In an optimal research environment, individuals who participated in the study would have completed both control and garment-intervention trial conditions. Unfortunately, this was not possible. While the study objectives were explained in detail to all athletes, there was hesitation to wear the training garment from a large majority of athletes within the professional cohort. This mainly stemmed from uncertainty as to whether the training garment would hinder training performance. In a professional team-sport setting, where optimising individual training outcomes within each training session is of upmost importance, and poor training performance could have ramifications for team selection and ultimately career progression, the research team understand the rationale underpinning the hesitation to wear the garment and are extremely appreciative to the athletes who voluntarily wore the 'sun-limiting' garment. In spite of the lack of cross-over research design, the results presented within this case-study indicate that athletes who wore the garment during training may have experienced less thermal stress, without any detriment to training performance, during each training session and over the duration of the experimental period compared to players who did not wear the garment. Our results appear consistent with Davis and co-workers who reported no effect of garment fibre type on thermoregulation, T_{sk}, RPE or markers of thermal comfort, during moderate, fixed-intensity exercise in hot indoor environments.[11] Similarly, Abdallah and colleagues showed a 'skin-cooling' garment had no positive effect during high-intensity cycling performance undertaken indoors when exposed to thermoneutral environmental conditions.[5] We hypothesised different outcomes to those reported previously due to high levels of SR exposure and intensity and duration associated with outdoor professional ARF training in the Australian summer. Regardless, if skin can be protected from repeated sun exposure during training sessions without compromising the quality of that training, this would generally be considered beneficial to the athletes. Future investigations should look to more closely examine the effect of similar garments on markers of thermal stress, recovery and the long-term implications for team-sport training outcomes and overall athlete health and wellbeing.

Conclusion

The utilisation of specific skin protecting garments that cover the shoulders and arms to reduce solar radiation exposure may be a practical method to promote long-term athlete wellbeing. Our data provide a proof-of-concept to show running performance during pre-season team-sport training in hot environments is not compromised by the utilisation of 'sun-limiting' garments. Further, there is a reduction in post-training thermal stress associated with wearing such garments in hot environments.

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