

**Whitworth-Turner, C, Di Michele, R, Muir, I, Gregson, W and Drust, B**

**A shower before bedtime may improve the sleep onset latency of youth soccer players.**

# AN INVESTIGATION INTO THE APPLICATION OF A THERMOREGULATORY STRATEGY TO IMPROVE SLEEP WITHIN YOUTH SOCCER PLAYERS

CRAIG TURNER 1., ROCCO DI MICHELE 2., IAN MUIR 3., WARREN GREGSON 1., & BARRY DRUST 1.

1. Football Exchange, Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, UK

2. Department of Biomedical and Neuromotor Sciences, University of Bologna, Bologna, Italy

3. Nike Sports Research Laboratory, Nike, Beaverton, Oregon, USA

Corresponding Author:

Craig Turner
Football Exchange
Research Institute for Sport and Exercise Sciences
Liverpool John Moores University
Liverpool, United Kingdom
L3 3AF
Email: C.Turner3@2009.LJMU.ac.uk
Tel: +447947118762

**ABSTRACT**

During the season soccer players are likely exposed to a myriad of factors that may disrupt the process of sleep. Such disturbances may result in shortened sleep quantity, reduced sleep efficiency and impact the overall quality of sleep. Therefore a practical sleep hygiene strategy (10 min showering at ~40 °C, 20 min before time of lights out) was investigated. A group of ten youth soccer players were evaluated under normal sleeping conditions (control) and a shower intervention period, each consisting of three days within a randomized cross over trial design. Sleep information was collected using a wireless bedside sleep monitor. Additionally, measures of skin temperature were evaluated using iButton skin thermistors. The iButtons were used to establish both distal and proximal skin temperatures and the distal to proximal gradient (DPG). The shower intervention elevated distal skin temperature by 1.1 °C (95% CI: 0.1 to 2.1 °C, $p = 0.04$) on average during a 10 minute period prior to lights out in comparison to the control condition. The elevation in distal temperature was also present during the first 30 minutes following lights out: 1.0 °C (95% CI: 0.4 to 1.6 °C, $p < 0.01$) between conditions. The DPG also showed a significant effect between the conditions within the first 30 minutes after lights out 0.7 °C (95% CI: 0.3 to 1.2 °C), $p < 0.01$). On average the sleep onset latency of the youth soccer players was 7 min lower (95% CI: -13 to -2 min, $p < 0.01$) in the shower intervention condition. No other sleep variable was affected as a result of the intervention. These findings demonstrate that a warm shower performed before lights out may offer a practical strategy to promote thermoregulatory changes that advance sleep onset latency in youth soccer players.

Keywords: Sleep Hygiene, Thermoregulation, Team Sports

## INTRODUCTION

Soccer players may experience sleep related disturbances during the competitive season (Nedelec, et al., 2015). These traits are also common within other elite athlete populations (Leeder, et al., 2012). Such disturbances may impact sleep quality and lead to a reduction in total sleep time in comparison to the length of time spent in bed (Leeder, et al., 2012). As a consequence, increasing attention has centred upon improving sleep hygiene through strategies that promote alterations in environmental conditions and individual behaviours, as these may enhance an athletes sleeping pattern (Nedelec, et al., 2015).

The circadian cycle in human thermoregulation is thought to be a contributing factor to the sleep-wake process (Krauchi & Doboer, 2011). Within humans, sleep propensity (the need to sleep) is suggested to rise in relation to the regulated decline in core body temperature (CBT), which is typically observed in the evening, with the inverse relationship being apparent within the morning (i.e. increased CBT relating to increased wakefulness) (Krauchi & Doboer, 2011). Sleep propensity is also suggested to be associated with increased distal skin temperatures (vasodilation) and reduced proximal skin temperatures (Krauchi, 2007'; Krauchi & Doboer, 2011). This distal minus proximal gradient (DPG) (used as an indirect measure of heat loss) has been suggested to be a key predictor in the initiation of sleep onset (Krauchi, 2007). Therefore the circadian derived thermophysiological processes associated to heat loss seem to be important factors that influence the initiation and maintenance of sleep (Krauchi & Doboer, 2011). This may also suggest that strategies that look to manipulate thermoregulatory processes and facilitate heat loss may benefit sleep (Krauchi & Deboer, 2011).

Within the sport of soccer the use of cold-water immersion (CWI) on sleep has been investigated (Robey, et al., 2014), as this may promote changes in the thermoregulatory system (i.e. rapid conductive heat loss and lowered core body temperature) that may

facilitate favourable sleep behaviours (Murphy & Campbell, 1997; Krauchi, 2007; Krauchi & Deboer, 2011). However, there were no observed benefits of CWI compared to days without CWI on markers of sleep quantity and quality (Robey, et al., 2014). However the strategy was performed 20 minutes following evening training exposure and may not reflect the thermoregulatory effect of CWI if the strategy was performed closer to bedtime. However, current evidence investigating the use of such a strategy before sleep is somewhat lacking (Halson, 2014). In addition such procedures may attenuate adaptations to certain forms of training (Frohlich, et al., 2014) thereby limiting potentially important performance improvements.

Research has also examined strategies that attempt to facilitate heat loss, using alternative approaches such as targeted skin warming (Sung & Tochihara, 2000; Raymann, et al., 2005; Raymann, et al., 2007; Fronczek, et al., 2008; Raymann, et al., 2008). It is thought that a rapid sleep onset and facilitation of sleep is linked to an increase in the temperature of distal regions of the skin (Krauchi, 2007). Techniques such as whole body heating or distal skin heating attempt to create small elevations in skin temperature and the promotion of vasodilation of distal regions, which in turn accelerate the process of heat loss (Sung & Tochihara, 2000; Raymann, et al., 2005; Raymann, et al., 2007; Fronczek, et al., 2008; Raymann, et al., 2008; Krauchi & Deboer, 2011). These strategies have been shown to reduce sleep onset latency and the level of disturbance during sleep (Sung & Tochihara, 2000; Raymann, et al., 2005; Raymann, et al., 2007; Fronczek, et al., 2008; Raymann, et al., 2008; Krauchi & Deboer, 2011). Therefore heating strategies of this type may also act as a useful practical strategy to promote sleep related factors within athletic populations.

At present no evidence is currently available in youth soccer players on the effectiveness of strategies that attempt to influence thermoregulatory processes through skin warming in an attempt to promote sleep. Therefore the current study was designed to

manipulate skin temperature through the use of an alternative practical strategy (warm showering), which could be easily incorporated into the athlete's habitual routine. The aim of the strategy was to cause subtle increases to skin temperature before time of lights out in an attempt to reduce the sleep onset latency and level of sleep disturbance shown within youth soccer players.

# METHODS

### PARTICIPANTS

Eleven male youth soccer players participated in the study (Age: 18 ± 1 yrs; Height: 1.78 ± 0.07 m; Weight: 74 ± 10 kg). The soccer players were analysed during their habitual routine within the normal competitive academy soccer season. Each participant was briefed and informed of their requirements during the study prior to any data collection for the investigation. Participant consent was also obtained prior to the start of the investigation. The study was agreed and accepted by the Liverpool John Moores University Institutional Ethics Committee.

### EXPERIMENTAL DESIGN

In a randomised cross over design, participants were required to conduct both three nights of habitual sleep (CON) without showering before bedtime and a three night period that included a 10-min (40°C) shower (SI) twenty minutes before bedtime. Each three-day trial was separated by a one-week period; this allowed the measurements to be taken on training load-matched days during the in-season soccer period. At the time of study, some of the participants were sharing rooms (two players per room) at the elite soccer academies house of residence. Where applicable, the players included in the assessment that shared a room were assigned to different trial groups to avoid the complications of conducting the same trial at the same time. All participants completed both conditions. Each participant was

provided with all of the equipment needed to complete the measurements. This equipment included the Zeo Sleep Manager – Bedside Sleep Management Wireless System (Zeo Inc, Newton: Mass) (WS), a total of six iButton Thermochron One Wire thermistor (Maxim/Dallas Semiconductor Corp, USA), a handheld AVAX DT1 Digital LCD thermometer probe (AVAX TM, UK) and an adapted sleep and temperature diary. The experimenter provided an instruction sheet and training on the placement and use of each measurement device. The practitioner also demonstrated how the sleep and temperature diary was to be completed each day. This was done in an attempt to minimise data collection errors during the study period. A familiarisation period of two days was provided, so the participants could become comfortable with the experimental procedures and minimise any first night effects. All procedures were identical for each night of the respective trials and all devices were worn for a complete night of data collection.

**ENVIRONMENTAL CONDITIONS**

All participants resided in the elite soccer academies house of residence during the time of the study. In an attempt to standardise room temperature, participants were instructed to ensure all windows were closed and no heating devices were active on the trial days. Room temperature was established using a hand held AVAX DT1 thermometer (AVAX, UK). The temperature was recorded both prior to bed and upon awakening to establish the potential temperature range during the nights of data collection (Table 1). All participants slept in their own bed, in the same room, under a 10.5 TOG duvet throughout the assessment period. Participants were also restricted to wearing underwear and the same pair of shorts (<20.5 cm leg length) during the assessment period. This allowed the accurate detection of skin temperature by ensuring any microclimate created by insulating clothing was avoided.

** Table 1 Near Here ***

## EXPERIMENTAL MEASUREMENTS

**Skin Temperature**:

The measurement of skin temperature was performed using iButton Thermochron One Wire thermistors (Van Marken Lichtenbelt, et al., 2006). Each iButton is enclosed within a stainless steel shell; the shell contains a 3V lithium battery, a semiconductor (located at the base of the shell), a 1-wire receiver/transmitter, 2kb of memory, date and time capacity as well as 512 bytes of additional sRAM. The iButton allowed the measurement of temperatures between 15-46 °C at an accuracy of 1 °C with a temperature resolution of 0.125 °C. Temperature was captured at a user defined temperature rate of 60 seconds. Each iButton was configured to start at the same time each evening (8pm) through the in-built missioning process. Participants were instructed when the iButtons were to be attached and where each iButton was to be positioned (See Figure 1). For ease of placement each iButton was numbered to ensure the same site was collected using the same iButton each night. Site locations are visually represented in Figure 1. All iButtons were applied with semiconductor touching the skin using micropourous tape. Four iButtons (two per region) were placed at the distal regions of the body, on the right hand (middle finger tip & dorsal side of the hand) and right foot (big toe tip & dorsal side of the foot). Two iButtons were also placed at more proximal regions of the thigh and abdomen. These sites provided measures to assess the distal to proximal gradient (DPG) of skin temperature (°C) (Krauchi, et al., 2000) associated with each night of data collection. This gradient was calculated by subtracting the average of the distal measures by that of the average of the proximal measures (Krauchi, et al., 2000). When using this approach, proximal skin temperature can be higher than distal skin temperature; therefore a negative gradient may also be likely to be observed (Abe & Kodama, 2015). A

rise in distal temperature to equal that of proximal temperature will signify a DPG value of zero.

The iButton temperature data was downloaded using a 1-Wire iButton port attached through USB to a computer. The data was analysed using OneWireViewer Java Software for Microsoft Windows. The data was then exported into Microsoft Excel were each 60 second sample could be reviewed. Using the information provided within the temperature section of the diary, the 10-minute periods of temperature assessment were identified and clipped. The first 5 minutes of the data collection served as the detection period, allowing the device to accurately calibrate to the correct skin temperature following application (Van Marken Lichtenbelt, et al., 2006). The second period of 5 minutes was used for the skin temperature analysis prior to lights out within the study. After lights out the skin temperature data was averaged over 30 minute within the first 3 hours of sleep. Once the data was stored, the iButtons were then reset, allowing the restart of data collection to commence at 8pm that evening.

*** Figure 1 Near Here ***

**Sleep:**

To establish the objective measurement of sleep and sleep staging, Zeo Sleep Manager – Bedside Sleep Management Wireless System (Zeo Inc, Newton: Mass) (WS) was utilised on a nightly basis. This device has previously been shown to provide a valid assessment of the key metrics inherent in habitual sleep monitoring (Shambroom, et al., 2012; Tonetti, et al., 2013). This data included; total sleep time (TST), sleep onset latency (SOL) and number of awakenings ($N_{WAKE}$), as well as a time spent in wake after sleep onset (WASO).

**EXPERIMENTAL PROCEDURES**

Before commencement of data collection, participants were briefed on the procedures of the study. Each device was also configured prior to data collection to ensure the time and date was calibrated and stored. With each participant being familiar with the data collection procedures. During the measurement period participants were instructed to ensure their chosen shorts did not cover any of the iButtons during the assessment. On the control nights of sleep the iButtons were attached 15 minutes before lights out following a 5 min period permitted for the attachment of equipment. To establish the baseline measures for both distal and proximal skin temperatures the participants were required to sit within their bedroom for a total of 10 minutes before entering bed.

Within the shower condition, data collection started 45 minutes before lights out. Again the participants were given a 5-min period to attach the equipment and were then instructed to assume the seated position in their bedroom for 10 minutes to establish the skin temperature assessment period prior to showering (Pre-Shower). The iButtons were then removed (as the iButtons are not waterproof) to allow the participant to shower freely. A 5-minute period was provided for the removal of each iButton. Within this time the participants

were also instructed to adjust the shower temperature to the desired range of 40 °C. Before commencing the shower, the shower temperature was determined using a handheld waterproof digital thermometer (AVAX, UK). The participants turned on the handheld thermometer and then held the probe directly underneath the showerhead, ensuring their hand was not touching the metal conductor. The shower temperature was then determined (adjusted if necessary) and noted for each night to the nearest 0.1 °C. Participants were then instructed to set a timer using their mobile phone for a duration of 10 minutes. Once the timer was set the participants proceeded to shower for the allocated 10 minutes. Upon completion of the timer the participants were instructed to cease showering immediately. A subsequent period of 5 minutes was then allocated to allow drying and the correct re-application of the iButton thermistors. Once each iButton was re-attached, the participant underwent another 10-min period of temperature data collection to establish the post shower measure. Once the seated skin measure was complete, the participants were also required to record the temperature of the room using the handheld thermometer.

Once all the temperature data collection was complete the participants were instructed to enter bed as soon as possible. This prompted the attachment of the WS headband and the recording of time to bed in the sleep diary. Each participant was instructed to attempt to initiate sleep immediately at lights off. Upon awakening the WS headband was removed and docked so that data was automatically downloaded and stored. The iButton thermistors were also removed at this time. The participants also completed their sleep diary entry for the final awakening. Within that same morning the participants returned all assessment tools to the sports science practitioner for subsequent download and analysis. The data provided by the WS and sleep diary were also entered into Microsoft Excel to create a complete data set for each respective trial night. Once all data was correctly stored, each monitoring device was

then handed back to the participant. The participants then proceeded to follow the same methodologies for each of the subsequent nights of the respective trial period.

**STATISTICAL ANALYSIS**

The data was analysed using the statistical package R - Version 3.2.1 Software (The R Foundation for Statistical Computing, 2014) using the statistical technique of linear mixed modelling. The linear mixed model approach is able to handle repeated measures data, with both fixed and random effects as well as any missing data (Cnaan, et al., 1997)**.** This type of analysis is therefore a viable approach to assess the data within the current study. Within this analysis, the trial condition (SI vs. CON) was treated as the fixed effect, and random intercepts were used for individual players. The main outcomes of the analysis were compared using the coefficient value of the condition. In this case the CON condition was treated as the baseline within the statistical coding. Therefore the difference between the conditions SI vs. CON could be expressed as the coefficient value. Furthermore, in the analysis of skin temperature after lights out, time was also included as a fixed effect, since temperature data were evaluated at selected time points. The interaction between time and condition was therefore also taken into account within the models. Post-hoc contrasts were performed to examine the differences between conditions at any considered time point. This provided a mean to assess the effects of the shower intervention on the skin temperature data (distal, proximal and DPG) within the first hours of sleep. Absolute effect sizes (ES) were calculated by dividing the coefficient value by the between-subject standard deviation of the specific variable. The magnitude thresholds were evaluated as <0.2 trivial; 0.2-0.59 small; 0.6-1.19 moderate; >1.20 large (Hopkins, 2010). Statistical significance was set at $p < 0.05$. Coefficients of the condition were reported with 95% confidence intervals. All the other data are reported as mean ± sd.

# RESULTS

## SKIN TEMPERATURE PRIOR TO LIGHTS OUT

Figure 2 shows a visual representation of this data across the assessment period prior to lights out. Within the comparison of pre-shower skin temperature with that of pre-lights out within the control condition, there were no significant differences observed for distal (-0.3 °C, 95% CI: -1.3 to 0.7 °C, p = 0.55), proximal (0.2 °C, 95% CI: -0.6 to 0.9 °C, p = 0.71) and DPG (-0.4 °C, 95% CI: -1.3 to 0.4, p = 0.30). At pre-lights out, distal skin temperature was elevated by an estimated difference of 1.1 °C (95% CI: 0.1 to 2.1 °C, ES: 0.44, small, p = 0.04) with showering (39.7 °C ± 1.7 °C) compared to the control condition. Additionally showering caused a small, non-significant increase in proximal skin temperature (0.6 °C (95% CI -0.2 to 1.4 °C, ES: 0.36, small, p = 0.13) and DPG (0.6 °C, 95% CI -0.2 to 1.3 °C, ES: 0.30, small, p = 0.15) compared to the control condition.

*** Insert Figure 2 near here***

**SKIN TEMPERATURE AFTER LIGHTS OUT**

A visual representation of the data collected following lights out is shown within Figure 3. Following lights out, there was a continued significant effect of showering on distal skin temperature observed within the first 30 minutes after lights out 1.0 °C (95% CI: 0.4 to 1.5 °C, ES: 0.65, moderate, p = 0.0000042). However, this effect was no longer observed after 60 minutes (+0.0 °C, 95% CI: -0.4 to 0.4 °C, ES: -0.01, trivial, p = 0.94). The DPG also showed a significant effect of showering within the first 30 minutes after lights out (0.7 °C, 95% CI: 0.4 to 1.1 °C, ES: 0.45, small, p = 0.0024). However there were no consequent observed effects of showering on the DPG after 60 minutes of lights out (0.1 °C, 95% CI: -0.3 to 0.5 °C, ES: 0.16, trivial, p = 0.54). Proximal skin temperature showed small, non-significant effects of showering after both 30 minutes (0.2 °C, 95% CI: 0.0 to 0.5 °C, ES: 0.31, small, p = 0.10) and 60 minutes (0.1 °C, 95% CI: -0.4 to 0.1 °C, ES: -0.32, small, p = 0.38) after lights out.

*** Insert Figure 3 near here ***

**OVERVIEW OF SLEEP**

Mean ± sd outputs of the WS for both trial periods are displayed in Table 3. Showering enhanced sleep onset latency by approximately -7 min (95% CI: -13 to -2 min, ES: -0.55, small, p = 0.007) compared to the control condition. In contrast, showering had a moderate non-significant effect on total sleep time (-18 min, 95% CI: -48 to 11 min, ES: -0.63, moderate, p = 0.23) and a small, non-significant effect on the time spent in wake after sleep onset (-1 min, 95% CI: -4 to 2 min, ES: -0.20, small, p = 0.37) in comparison to the control condition. There were no observed effects of showering on the number of awakenings (0, 95% CI: -1 to 2, ES: -0.10, trivial, p = 0.76) in comparison to the control condition.

*** Insert Table 2 near here***

## DISCUSSION

The current study was designed to manipulate skin temperature prior to bedtime within a group of youth soccer players in an attempt to facilitate sleep onset and improve factors relating to sleep quantity and sleep quality. The results of the current study indicated a significant thermoregulatory effect of a 10-minute warm shower intervention, performed 20 minutes before bedtime in comparison to a control condition. A rise in distal skin temperature was observed before lights out and was also apparent during the first 30-min period after lights out. This also reflected in a higher DPG within the first 30-min period after lights out. A significant effect on the sleep onset latency of youth soccer players was also observed in the shower condition. This may suggests that changes in skin temperature before lights out may facilitate sleep onset. No statistical changes were observed for any other variable relating to sleep as a result of the shower condition. This may suggest that warm showering may have acute effects that relate to sleep propensity, though these may not extend throughout the night and influence total sleep architecture. From a practical perspective warm showering may offer a potential strategy to improve the sleep onset of youth soccer players.

Previous research on the relationship between thermoregulation and sleep has indicated that there is a subsequent effect of skin temperature on sleep (Raymann, et al., 2008; Krauchi & Deboer, 2011). For example, a variety of passive heating strategies, which successfully elevate skin temperature, positively influence the properties of sleep in healthy young and old participants (Sung & Tochihara, 2000; Raymann, et al., 2005; Raymann, et al., 2007; Raymann, et al., 2008; Krauchi & Deboer, 2011). Within the current study a shower intervention lasting 10 minutes, performed 20 minutes before bedtime, at a temperature range

of 39.7 °C ± 1.7 °C, showed elevations to the distal skin temperature of the youth soccer players both before and after lights out (up to 30 min). This was reflected by an increase in distal skin temperature of 1.1 °C on average in comparison to baseline measures of temperature under normal sleep routine conditions. Such a rise in distal temperature (hands and feet) is often associated with vasodilation of the periphery and the opening of arteriovenous anastomoses (AVAs), permitting increased levels of heat dissipation from the body and a lowering of core body temperature (Krauchi, 2000). Such thermoregultory changes have also been previously linked to a faster time to achieve sleep onset (Krauchi, 2000). The results of the current study demonstrate a significant effect of the showering condition on the process of sleep onset, which was reduced on average by 7 min when the youth soccer players showered before lights out. This may be due to thermophysiological-induced feedback, which may phase advance circadian derived processes of thermoregulation (e.g. increased distal skin temperature and DPG, heat loss and a decline in core body temperature), which in turn is likely to influence mechanisms of the sleep-wake cycle (i.e. increased sleep propensity and reduced vigilance) (Murphy & Campbell, 1997; Krauchi, 2007; Krauchi & Deboer, 2011, Romeijn, et al., 2012). This data may therefore infer that the heat load induced by the shower intervention may facilitate the process of heat loss (as a result of increased distal skin temperatures and DPG gradient following lights out) and therefore increase sleep propensity. This may suggest that warm showering prior to lights out is a viable strategy to promote this process.

The shower intervention did not statistically influence any of the other variables related to sleep (TST, $N_{WAKE}$, WASO). During sleep humans typically create an insulated microclimate (between 34 – 36 °C) through the use of bed covers/duvets to maintain a high level of skin blood flow whilst reducing the transfer of heat to the environment (Van Someran, 2006). This may offer some explanation as to why the skin temperature

manipulation of the shower did not affect any further properties of sleep, as this may be attributed to the development of this microclimate. Sung & Tochihara (2000), observed that the sleep promoting effects of passive heating (whole body or foot bathing at 40 °C) before bedtime were moderated after ~2 hrs of being in bed. The current data is again in broad agreement with these ideas as the effects of the experimental condition here are seemingly dissipated within 60 minutes of lights out, with both conditions displaying similar temperature values from this time point onwards (Figure 3). This would suggest that heating of this type is only likely to affect the early stages of sleep as opposed to the whole night of sleep (Sung & Tochihara; Raymann, et al., 2008). This may also provide an additional explanation to the observed reduction of sleep onset latency (within the early phase of sleep) and why no further impact was made within the sleep variables collected within the current study.

Though the present study infers that the rise in distal skin temperature induced by the shower intervention reduces the sleep onset latency of youth soccer players, it would seem that this response is also related to a combined relationship with other thermoregulatory mechanisms (Krauchi & Deboer, 2011; Romeijn, et al., 2012). It is likely that the heating of the skin induces thermal afferent feedback to areas of the brain (Romeijn, et al., 2012). A review conducted by Van Someran (2000), shows that specific brain regions that relate the control of sleep and wakefulness are sensitive to the 24 h regulation of temperature. The preoptic area of the anterior hypothalamus (POAH) has been suggested as one such area that plays a key role in both temperature regulation and sleep (Van Someran, 2000). Skin warming and the increase in peripheral skin blood flow has been suggested to increase the firing rate of specific warm sensitive neurons (WSNs), which relay feedback to brain regions such as the POAH and in turn promote a sleep like firing pattern of the brain (Van Someran, 2000; Raymann, et al., 2005). The observed rise in distal skin temperature within the current

study could suggest an increase in peripheral blood flow (Krauchi, 2000), which in turn may promote the maximal firing rate of the WSNs (Van Someran, 2000). If this suggestion were true, then it is likely that an induced firing pattern of sleep-promoting behaviour of the brain would be favoured and thus sleep onset would be promoted under such conditions (Van Someran, 2000; Romeijn, et al., 2012).

The sleep like firing patterns of the brain may also be influenced by the thermal input (i.e. the specific site of skin warming) (Romeijn, et al., 2012). It is likely that during the shower intervention the temperature of the skin of the head would also be increased. Such heating of this area may directly warm the areas of the brain (e.g. POAH) that promote sleep (Romeijn, et al., 2012) or further stimulate neuronal feedback mechanisms that may promote sleep onset. (Van Someran, 2000). However due to the applied nature of the study and the limited amount of equipment, the exact response of the neuroanatomical pathways detailed by Van Someran (2000) in relation to the thermally induced changes of the shower intervention cannot be quantified. Future research may look to optimise techniques of neuroimaging (to outline the thermal influences of the shower intervention in relation to key areas of the brain that control sleep and temperature) and/or thermal imaging (to establish which areas of the body are influenced by thermal induced changes) to further the understanding of how such mechanisms may be influenced by the shower intervention.

It should also be noted that humans typically initiate sleep when they reach the maximal trough in the circadian derived rhythm of core body temperature (Murphy & Campbell, 1997). Though an increase in distal skin temperature caused through the shower intervention may indicate increased heat dissipation and infer a reduction in core body temperature (Krauchi, 2000), the actual response of core body temperature in relation to this particular shower intervention remains unknown. Assessment of core body temperature

should therefore be investigated within future research in an attempt to gain greater understanding of the mechanisms associated with the shower intervention.

The current study was also limited to youth soccer players who were assessed during the in-season period. Therefore future investigations should look to implement a strategy such as warm showering before lights out within soccer players of different ages and competitive levels to provide further evidence to the findings contained within the current study. Additionally these findings may not reflect in-season periods that may cause further disturbance to soccer player's sleep (i.e. away travel and night time fixtures) (Nedelec, et al., 2015). Therefore future research should also look to establish the relevance of this intervention during such periods, to assess if the positive benefits are also transferable to these situations that may occur within elite soccer. The current study is also the first to utilise this type of shower intervention within the applied setting, therefore future research could also manipulate the timing (when the strategy is employed), duration (length of the shower) and temperature of the shower intervention to assess if the effects on sleep are further pronounced as a result of these changes.

## CONCLUSION

The current study is the first to assess the use of a 10-minute warm shower 20 min prior to lights out to manipulate skin temperature in an attempt to promote the process of sleep onset latency and improve sleep quantity and quality in youth soccer players. Through the use of a ~40°C shower intervention, increases in distal temperature and a subsequent reduction in sleep onset were observed in relation to control conditions. However, no subsequent effects were observed on the improvement of sleep quantity and quality. Therefore showering prior to lights out may be a useful strategy to reduce sleep onset times in youth soccer players that display long sleep onset latencies.

## REFERENCES

Abe, N., & Kodama, H. (2015). Distal-proximal skin temperature gradient prior to sleep onset in infants for clinical use. Pediatrics International, 57, 227-233

Cnaan, A., Laird, N. M, & Slasor, P. (1997). Using the general linear mixed model to analyse unbalanced repeated measures and longitudinal data. Stat Med, 16, 2349–2380.

Fröhlich, M., Faude, O., Klein, M., Pieter, A., Emrich, E., & Meyer, T. (2014). Strength training adaptations after cold-water immersion. The Journal of Strength & Conditioning Research, 28(9), 2628-2633.

Fronczek, R., Raymann, R. J. E. M., Romeijn, N., Overeem, S., Fischer, M., van Dijk, J. G., ... & Van Someren, E. J. (2008). Manipulation of core body and skin temperature improves vigilance and maintenance of wakefulness in narcolepsy. SLEEP-NEW YORK THEN WESTCHESTER-, 31(2), 233.

Halson, S. L. (2014). Monitoring training load to understand fatigue in athletes. Sports Medicine, 44(2), 139-147.

Hopkins. W. (2010). Linear Models and Effect Magnitudes for Research, Clinical and Practical Applications. Sportscience 14, 49-58, http://www.sportsci.org.

Kräuchi, K., Cajochen, C., Werth, E., & Wirz-Justice, A. (1999). Physiology: warm feet promote the rapid onset of sleep. Nature, 401(6748), 36-37.

Kräuchi, K., Cajochen, C., Werth, E., & Wirz-Justice, A. (2000). Functional link between distal vasodilation and sleep-onset latency?. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology, 278(3), R741-R748.

Krauchi, K. (2007). The thermophysiological cascade leading to sleep intiation in relation to phase entrainment. Sleep Medicine Reviews, 11, 439-451.

Kräuchi, K., & de Boer, T. (2011). Body temperature, sleep, and hibernation. Principles and Practice of Sleep Medi cine. Eds Kryger MH, Roth T., Dement WC St. Louis: Elsevier, 323-334.

Leeder, J., Glaister, M., Pizzoferro, K., Dawson, J., & Pedlar, C. (2012). Sleep duration and quality in elite athletes measured using wristwatch actigraphy. Journal of Sports Sciences, 30(6), 541- 545.

Murphy, P. J., & Campbell, S. S. (1997). Nighttime drop in body temperature: a physiological trigger for sleep onset?. Sleep, 20(7), 505-511.

Nedelec, M., Halson, S., Delecroix, B., Abaidia, A., Ahmaidi, S., & Dupont, G. (2015). Sleep Hygiene and Recovery Strategies in Elite Soccer Players. Sports Med, 45(11), 1547-1549 doi: 10.1007/s40279-015-0377-9

Raymann, R. J., Swaab, D. F., & Van Someren, E. J. (2005). Cutaneous warming promotes sleep onset. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology, 288(6), R1589-R1597.

Raymann, R. J., Swaab, D. F., & Van Someren, E. J. (2007). Skin temperature and sleep-onset latency: changes with age and insomnia. Physiology & behavior, 90(2), 257-266.

Raymann, R. J., Swaab, D. F., & Van Someren, E. J. (2008). Skin deep: enhanced sleep depth by cutaneous temperature manipulation. Brain, 131(2), 500-513.

Robey, E., Dawson, B., Halson, S., Gregson, W., Goodman, C., & Eastwood, P. (2014). Sleep quantity and quality in elite youth soccer players: A pilot study. European Journal of Sports Science, 14(5), 410-417.

Romijn, N., Raymann, R. J. E. M., Most, E., Te Lindert , B., Van Der Meijden, W. P., Fronczek, R., Gomez-Herrero, G., & Van Someren, E. J. W. (2012). Sleep, vigilance and thermonsensitivity. Pflugers Arch – European Journal of Physiology, 463, 169 – 176.

Shambroom, J. R., Fabregas, S. E., & Johnstone, J. (2012). Validation of an automated wireless system to monitor sleep in healthy adults. European Sleep Research Society, 21, 221-230.

Sung, E. J., & Tochihara, Y. (2000). Effects of bathing and hot footbath on sleep in winter. Journal of physiological anthropology and applied human science, 19(1), 21-27.

Tonetti, L., Fabregas, S.E., Fabbri, M., Occhionero, M., Erbacci, A., Martoni, M., Natale, V. (2013). Comparison of a wireless dry headband technology for sleep monitoring with actigraphy in healthy adults. Biological Rhythm Research, 44, 333-33

Van Marken Lichtenbelt, W. D., Daanen, H. A. M., Wouters, L., Fronczek, R., Raymann, R. J. E. M., Severens, N. M. W., & Van Someren, E. J. W. (2006). Evaluation of wireless determination of skin temperature using iButtons. Physiology & Behaviour, 88, 489 – 497.

Van Someran, E. J. W. (2000). More than a marker: Interaction between the circadian regulation of temperature and sleep, age related changes, and treatment possibilities. Chronobiology International, 17(3), 313 – 354.

Van Someren, E. J. (2006). Mechanisms and functions of coupling between sleep and temperature rhythms. Progress in brain research, 153, 309-324.