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TECHNICAL REPORT

D3.1: Report on solutions to mitigate heat stress of tourism sector workers

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SUMMARY (with overview of identified/screened solutions)

European workers in the tourism sector are seasonally exposed to heat stress levels that undermines individual health (mild hyperthermia and dehydration). This report is dedicated to provide guidelines with screened (effective, feasible and sustainable) solutions and strategies to mitigate or minimize negative effects of excessive heat exposure. Occupational heat stress is very relevant in the tourism industry because many tasks rely on manual work as the prevailing and, sometimes, only feasible method for performing complex tasks. Importantly, occupational heat stress is difficult to mitigate in tourism, as there is a wide range of jobs – with vastly different physiological and environmental specifications – included in this industrial sector.

Based on the data presented in this report, it is advisable that tourism companies, from large multinational corporations to small local businesses, consider/develop an appropriate heat adaptation plan to protect workers' health. This plan may be qualified by a designated person and benefit from consulting advanced warning weather systems to warn in advance when a period of hot weather is expected. Single or combined heat resilience methods appropriate/applicable for the specific work setting should be identified and translated into feasible actions and habits that workers can adopt during hot periods – with timely information at the beginning of the summer and regular follow-up reminders.

Staying hydrated is critical for maintained health in the tourism industry. Unfortunately, workers forget or fail to rehydrate from day-to-day. Thus, almost all tourism workers arrive at work at a dehydrated state. This means they start the day at an elevated risk for hyperthermia and acute kidney injury as well as low probability for performing at their best during their work shift. Tourism workers should drink 500-750 ml (2-3 cups of water) before starting work in the morning. During their work shift, they should drink 500-750 ml of water per hour. When working under heat stress, this strategy demonstrates the best results for maintaining hydration (reducing the risk for kidney disease or acute kidney injury). For this reason, it is important that strategies are put in place for workers to have access to cold/cool water throughout the day, even when working on different floors or remote areas. If such a strategy is followed regularly, day-to-day rehydration would be optimized and 500 ml per hour (2 cups of water) may be adequate for maintaining workers' hydration status to appropriate levels. During periods where workers are sweating profusely, healthy workers should add a larger amount of salt (electrolytes) to their diet. However, workers with heart, blood pressure, or other medical conditions should adopt this advice only when confirmed by their physician. If possible – and, particularly, during breaks – cooling the water by refrigeration will help lower the discomfort and heat stress experienced by the workers.

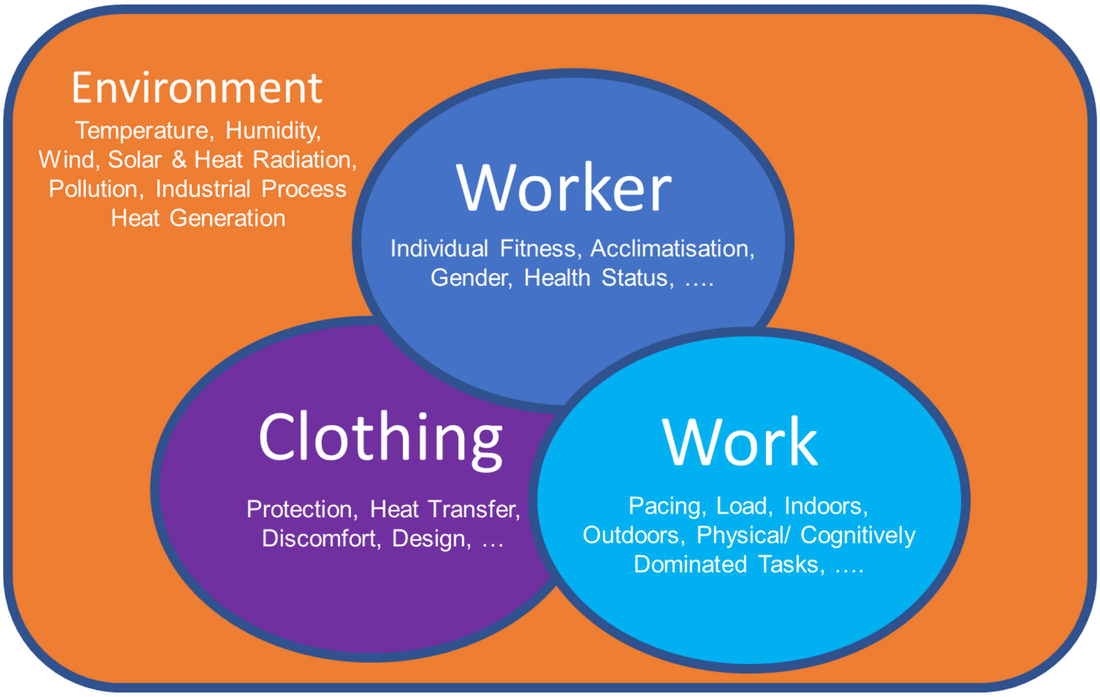
Clothing is important for tourism workers because it can lower the worker's thermal stress. Some tourism workers require special protective clothing (gloves, helmet, boots, etc.), while clothing is also beneficial for protecting the tourism workers from excessive sun exposure. However, clothing can also restrict heat loss as it provides a boundary layer that limits evaporation and convective/dry heat loss. To facilitate heat loss, clothing worn during the work shift should be selected based upon promoting air flow across the skin and improving sweat evaporation (reducing clothing evaporative resistance). This can be accomplished by reducing the total amount of skin covered by clothing by wearing a t-shirt vs long sleeve (if indoors), wearing looser fitting clothing which allows for greater air flow underneath the clothing, and wearing clothing with a wider knitting pattern which allows for more air flow to pass through the clothing. Additionally, lighter colours should be selected on sunny days in outdoor environments to increase the reflection of solar radiation. In situations where long, rigid clothing must be worn (e.g. coveralls), ventilation patches can be incorporated into more protected areas such as under the arms and between the legs to help promote air flow through the garment.

It is crucial to plan the workflow to allow workers time to adapt. Workers will acclimatize to heat during the first days of hot weather, however depending on the initial fitness and previous exposure it will take at least one week before workers get used (physiologically adapted) to the increased heat.

1. INTRODUCTION

1.1 It is quite clear that occupational heat stress can negatively affect workers health and their performance capacity, which subsequently may lower productivity and income for the individual and/or company costs directly related to lost working efficiency or indirectly via illness/sickness. The present report is part of a series of five papers (industry specific reports on each of the key EU sectors [manufacturing, construction, transportation, tourism and agriculture]. Overall the papers focused on defining, screening and optimizing appropriate technical and biophysical solutions to counter the negative impact of high thermal stress imposed by the combination of adverse environmental conditions, industrial heat production, the workers own/internal metabolic heat production, conditions and confounding factors such as protective clothing or other work related factors that may conflict with heat dissipation.

Figure 1. Overview on occupational aspect of human heat balance.



1.2 Human function depends on a balance between internal (metabolic) heat production and heat-exchange with the environment. When a worker is physically active, the metabolic energy release will increase in proportion to the work intensity and hence increase heat production in the body. If not released to the environment, this heat will warm up the worker, increase heat strain, impair both physical and cognitive function and potentially provoke fatal overheating. Therefore, to keep workers safe and avoid decrements in functionality, the produced heat shall be balanced by heat lost from the body (skin) to the environment, which can be by dry heat loss (primarily air convection and radiation) and/or by sweat evaporation. For occupational settings, it is characteristic that in addition to climatic conditions (with air temperature, solar radiation, humidity and wind speed as the factors of importance) the local environment may also be highly influenced by the industrial settings (see Figure 1). The warmer and more humid the environment (micro-climate around the worker), the more difficult it is to lose the heat. In addition, solar radiation or radiation from industrial processes, will further add to the heat load while wind/ventilation can benefit dry heat loss as long as the air temperature is below 35°C. In addition, wind can facilitate evaporation and hence benefit the overall heat balance even at higher environmental temperatures.

1.3 When considering solutions to lower heat stress any practice that may either lower workers internal heat production (e.g. optimizing the work procedures) or facilitate heat dissipation (including lessening of the constraining effects that e.g. clothing may impose) or directly cool the body (e.g. ingestion of cold drinks or ice) can be beneficial. This can range from behavioural and biological interventions/adaptations to technical solutions that may assist heat dissipation (e.g. increasing air flow, cooling vests or air conditioning) or lower the environmental heat load (e.g. reducing solar radiation). In accordance with this overall context, the present report considers the specific solutions screened and identified as both effective and feasible to implement for workers in the tourism sector.

1.4 This report on solutions for the tourism sector focus on the industry specific issues, needs and exposure characteristics of workers from the tourism sector in order to identify ways to mitigate the corresponding heat stress. The focus is in proposing adaptation measures including advanced hydration, shading alternatives, advanced work load planning and smart clothing solutions (i.e. ventilated garments), given the particular exposure of tourism workers to both indoor and outdoor conditions. While assessing the capacity and potential of these adaptation measures to mitigate workers' heat stress, the report also puts special attention on determining the specific requirements of the different solutions, and their compatibility with the intended application environment. The feasibility aspect is particularly important.

2. INDUSTRY SPECIFIC ISSUES FOR TOURISM WORKERS

2.1 Currently, nearly one-third of the world's population is regularly exposed to climate conditions that exceed human thermoregulatory capacity leading to major increases in morbidity and mortality.[1-3] Even if aggressive mitigation measures are adopted, one-half of the world's population will be exposed to such conditions by 2100[1] and a number of studies report that the resulting occupational heat strain (OHS) will directly threaten workers' health, with corollary negative impacts on productivity, poverty, and socio-economic inequality.[4-7]

2.2 The OHS refers to physiological consequences of environmental heat stress and it massively influences the ability to live healthy and productive lives, as nearly one million "work life years" will be lost by 2030 due to occupational heat stroke fatalities, and 70 million "work life years" will be lost due to reduced labour productivity.[8,9] Warning systems for extreme weather events have been recently piloted in some countries, but they are designed for the general population whose needs and exposure to heat are vastly different from those of workers. For instance, they typically advise individuals to stay indoors throughout the day or to remain in "cooling shelters" at public buildings.[10] Such strategies are not compatible with the need to stay productive regardless of the prevailing environmental conditions.

2.3 OHS is a parameter that influences a number of industries worldwide. In the tourism sector, OHS is very relevant because many tasks rely on manual work as the prevailing and, sometimes, only feasible method for performing complex tasks. OHS is difficult to evaluate and mitigate in tourism, as there is a wide range of jobs – with vastly different physiological and environmental specifications – included in this industrial sector. This may be the reason for the lack of previous studies on the impact of OHS in health and productivity outcomes in European tourism workers.

2.4 To address the lack of knowledge regarding the effects of workplace heat on European tourism workers, we conducted an observational evaluation to understand the nature of the problem. Our approach was to evaluate ~325 work hours via time-motion analysis on a second-by-second basis collected from 47 workers while performing different tourism jobs on 10 different days. This study was labelled "Study 1" and is explained in detail in the following sub-sections.

Description of Study 1

2.5 The study involved monitoring tourism workers on 10 separate days (11-21/7/2017) in Crete, Greece. The experimental protocol was approved by the University of Thessaly, School of Exercise Science Ethics Review Board (Protocol No. 1217) in accordance with the Declaration of Helsinki. Written informed consent was obtained from all volunteers prior to their participation in the study before entering the study. They were free to deny participation or withdraw their consent at any point.

2.6 One day prior to the start of data collection, volunteers underwent a familiarization session which included information regarding all data collection procedures. Anthropometric characteristics were also recorded at that time. In total, 47 men and women workers participated in the study:

- 12 waiters/ waitresses
- 10 cooks
- 7 barista staff
- 5 bus drivers

- 2 dish washing staff
- 2 hotel maids
- 2 outdoor manual workers (i.e. gardener, painter)
- 2 snack bar workers
- 5 other workers (i.e. butcher, pool boy, hotel retail store employee, hotel manager, valet parking employee)

2.7 Throughout the 10 study days, all volunteers were assessed from the beginning until the end of the work shift. The measurements performed were non-invasive, time-efficient, practical, and did not disturb the workers during their job.

2.8 During each recording day, each worker was monitored from the beginning until the end of the work shift by a researcher who observed the worker's activities. Also, we recorded skin temperature and environmental data throughout the work shift. No restrictions were placed on water/food consumption or any other kind of work- or non-work-related behavior. To ensure that we did not influence the workers' normal work routine, the temperature sensors used were miniature and wireless. Also, to minimize participant bias (i.e., work activities being affected because the workers were being observed), the true reason for the observations was hidden from the volunteers. Instead, they were informed that the investigators were interested to see the different types of work that they engage in. Of course, once the data collection was completed, all volunteers were informed about the true purpose of the observations and gave their permission to analyze and publish these data.

2.9 We recorded the workers' age and work experience. Anthropometric measurements included height and mass. Body surface area was calculated using the Du Bois formula.[11] We obtained urine samples in the beginning and the end of the work shift to evaluate urine specific gravity, a well-known indicator of hydration status.[12] We also administered different questionnaires to assess the workers' subjective perception of the heat-related issues and symptoms, as well as their level of job satisfaction.

2.10 Temperature at the skin surface was recorded every second at four sites using iButton sensors (type DS1921H, Maxim/Dallas Semiconductor Corp., USA) to calculate the mean skin temperature [T_{sk}; 0.3 (chest + arm) + 0.2 (thigh + leg)].[13] About twenty minutes before the beginning of each work shift, we installed weather stations (Kestrel 5400FW, Nielsen-Kellerman, Pennsylvania, USA) about 40 m away from the different workplaces of the volunteers. Each weather station was used to measure air temperature (°C), humidity (%), wind speed (m/s), and the wet-bulb globe temperature (WBGT) (°C), continuously. The WBGT is a type of apparent temperature used to estimate the combined effect of temperature, humidity, wind speed (wind chill), and visible and infrared radiation (sunlight).

2.11 The real-time observation recordings were used to identify work-related behaviors. Work time spent on irregular work breaks (WTB) was defined as any unprescribed work cessation determined by the workers' own judgment, and not based on specific time intervals or instructions. Lunch time was not considered as WTB because it was prescribed by management.

2.12 Work-related behaviors were determined for each worker individually through time-motion analysis that was conducted on site and in real-time by trained investigators. Experimenter bias was minimized via training the observers to rate by observing the same worker for 1 hour to ensure adequate agreement. For the same reason, the observers worked in close proximity and they were instructed to seek each other's advice in cases where they could not make a firm decision on their own. They were, thus, encouraged to give consensus group ratings of work-related behaviors.

Results

2.13 The reported work experience ranged from 2 months to 30 years, with a mean of 12 years. Workers' age ranged from 18 to 50 years, with a mean of 33.5 years. Waiters were younger (mean age: 29.3 years) compared to the outdoor manual workers (mean age: 31.5 years), the barista staff (mean age: 32.5 years), the cooks (mean age:32.6 years), the other staff (mean age: 34 years), the snack bar staff (mean age: 34.5 years), the bus drivers (mean age: 39.2 years), the hotel maids (mean age: 42 years), and the dish washing staff (mean age: 44.5 years). The mean body mass index (BMI) for the entire group of workers was 25.2, which indicates that, on average, they were overweight. The mean body mass index for the hotel maids (BMI: 21.1), dish washing staff (BMI: 21.3) waiters (BMI: 22.9) barista (BMI: 24.3) outdoor manual workers (BMI: 24.4) indicates that their body composition was normal. The mean body mass index for the snack bar staff (BMI:25), other staff (BMI:25.8), and cooks (BMI:28.4) indicates that they are overweight. Finally, the mean body mass index for the drivers was 30.2, which indicates that they were obese (≥30).

2.14 Detailed temperature and weather conditions for all the study days and the different environments (i.e. kitchen, indoor, outdoor, mixed, bus) is illustrated in Figures 2 and 3. The kitchen environment was the hottest (temperature range: 27.5-35.1°C), while the indoor environment was the coolest (temperature range: 27.3-30.1°C). The WBGT in the kitchens was high, ranging between 23.7°C and 30.6°C. This is noteworthy since, according to the ISO Standard 7243 (1989), an individual cannot sustain working more than 45 minutes every hour when WBGT is between 28.6°C and 29.3°C (Figure 4).

Figure 2. Environmental temperature (°C) for the different environments throughout the work shift. Blue represents the kitchen staff, orange represents the indoor enviroment staff, gray represents the mixed enviroment staff, yellow represents the outdoor enviroment staff, and purple represents the bus enviroment.

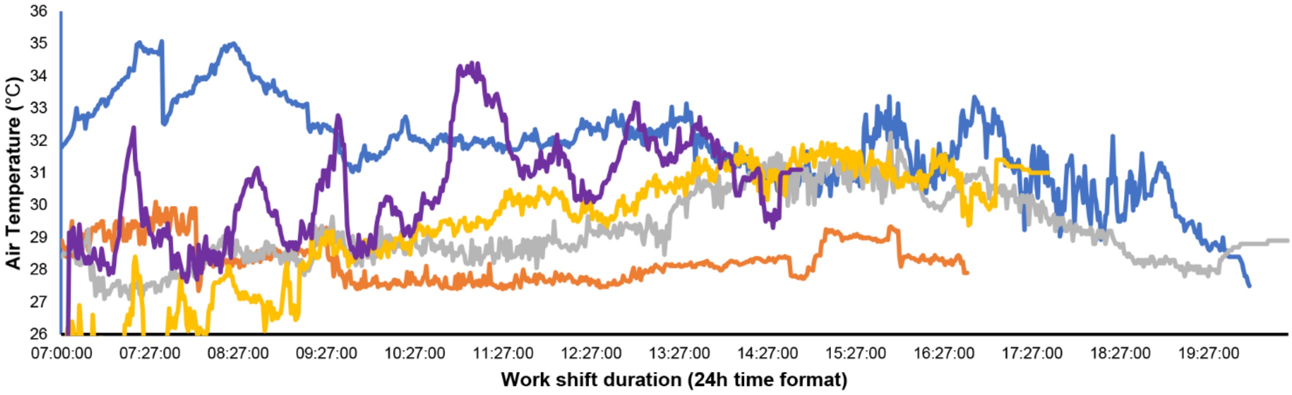


Figure 3. WBGT (°C) for the different environments throughout the work shift. Blue represents the kitchen staff, orange represents the indoor enviroment staff, gray represents the mixed enviroment staff, yellow represents the outdoor enviroment staff, and purple represents the bus enviroment.

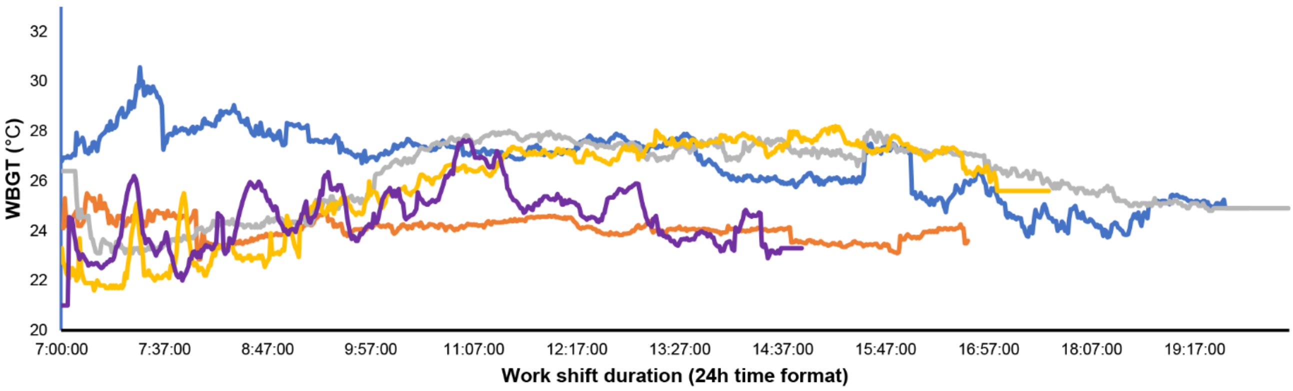


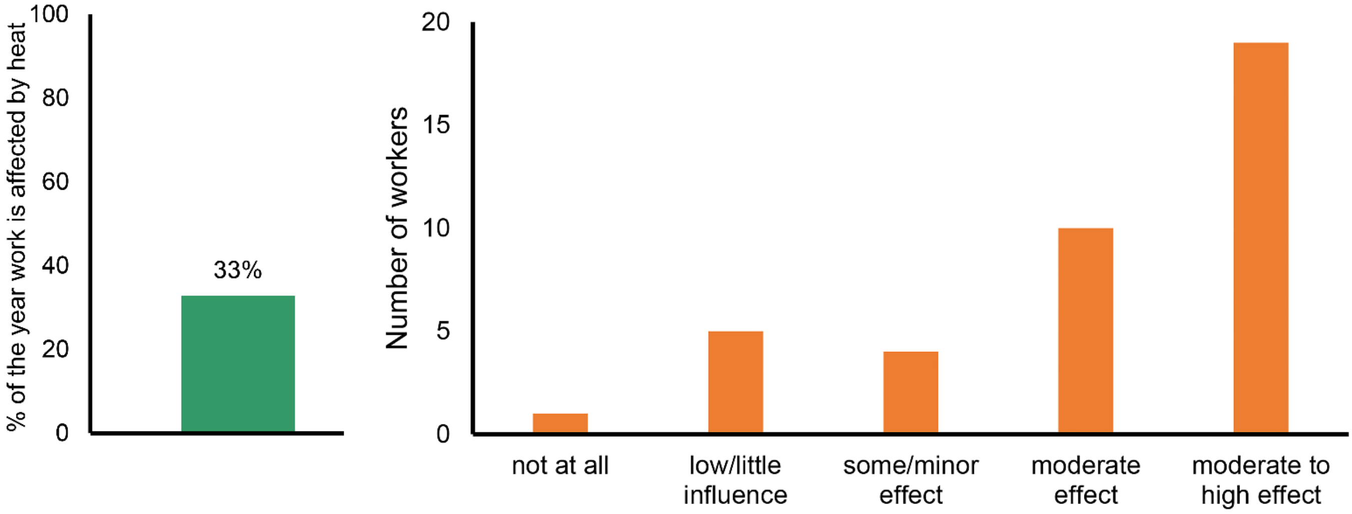
Figure 4. Hourly work capacity for an acclimatized worker carrying out moderate activity (300W) at different WBGT levels.

WBGT °C heat exposure

<28.6	29.3	30.6	31.8	>38
60 min/hr	45 min/hr	30 min/hr	15 min/hr	0 min/hr

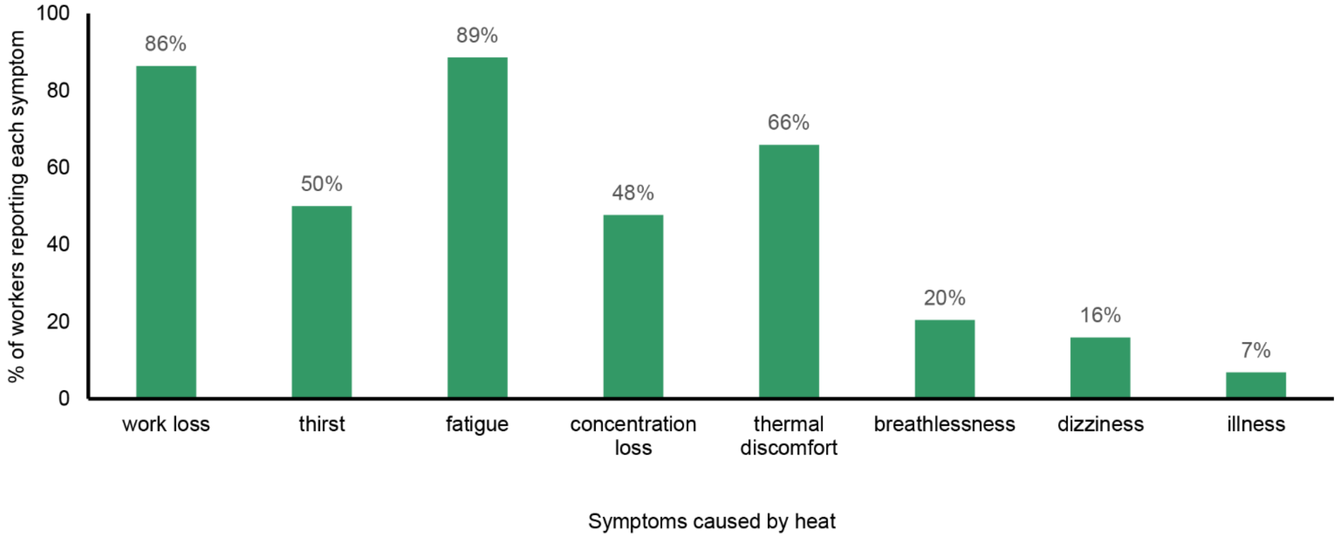
2.15 As reported by the workers, 33% of the work done in a year (i.e. 118 days) is affected by heat (Figure 5). During these hot days, 46% of the workers feel that the intensity of the heat has a moderate to high effect.

Figure 5. Average percentage of yearly work that is affected by the heat (left panel) and intensity of the heat effect during those hot days (right panel), as reported by the workers.



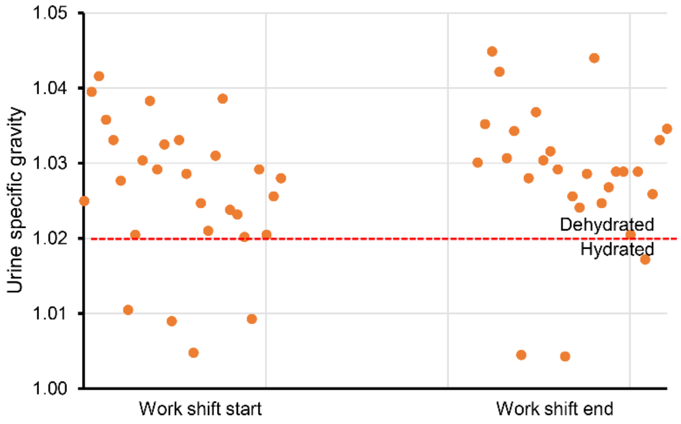
2.16 More than 2/3 of the workers reported working less during a hot day (Figure 6). During such days, 50% reported feeling thirsty, while more than 2/3 were fatigued and uncomfortable, more than 1/2 had low concentration. Also, about 20% of the workers reported feeling breathlessness, 12% of them dizziness, while about 7% reported having been ill due to the heat.

Figure 6. Percentage of workers reporting different symptoms caused by heat in the workplace.



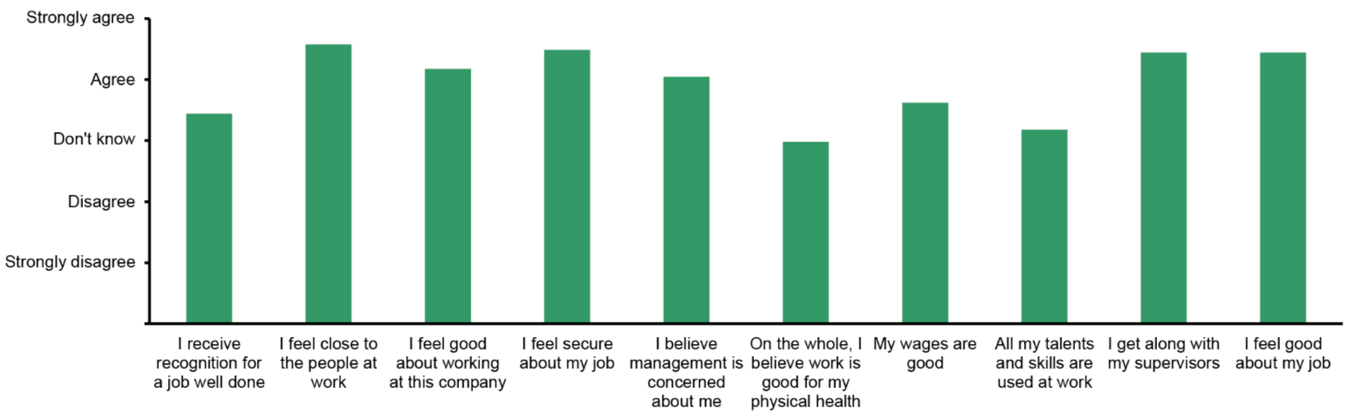
2.17 The urine samples taken to assess the workers' hydration status showed that 86% of them start their work shift in a dehydrated state (Figure 7). At the end of the work shift, 89% of the workers are still dehydrated. These findings are particularly important since dehydration leads to an increase in body temperature because the body reduces its sweat production. Also, dehydration increases the overall perception of fatigue. As a result, dehydrated workers are far more likely not to perform their duties adequately but also to cause/get involved in a work accident. Finally, chronic dehydration (almost daily dehydration for several months) can lead to kidney function disorders.

Figure 7. Urine specific gravity values at the start (left panel) and the end (right panel) of the work shift. The cut off value separating hydrated and dehydrated workers is indicated with a dotted red line.



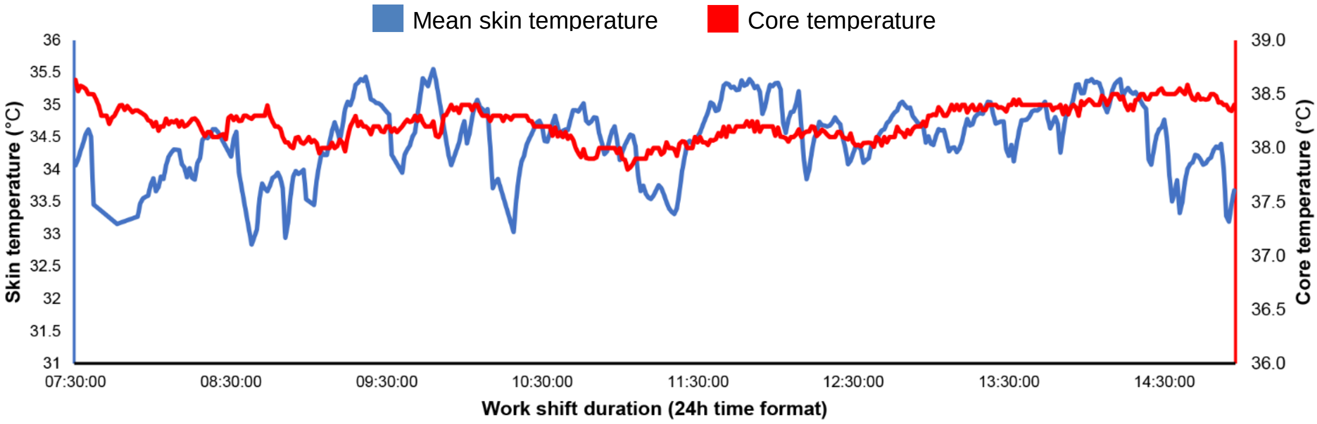
2.18 The majority (61%) of the workers reported receiving recognition for a job well done, while only 23% reporting that this is not the case (Figure 8). Also, most of the workers (95%) reported feeling close to the people at work, and more than the 2/3 (82%) felt good about working in this company and secure about their job (95%). The 70% of the workers felt that the management cares about them, yet 36% felt that this work is not good for their health and only 59% were satisfied with their wage. On the other hand, the 50% of the workers felt that all their talents and skills are used at work and nearly all of them reported getting along with their supervisors (91%) and feeling good about their job (95%).

Figure 8. Workers' perception regarding job satisfaction.



2.19 Individual data for mean skin and core temperatures from a representative cook are illustrated in Figure 9. This worker was found dehydrated at the beginning and at the end of the work shift. During work, his core temperature remained relatively stable (with fluctuations based the amount of work and brakes taken) between 37.9°C and 38.5°C, indicating significant hyperthermia. His skin temperature increased progressively from 32.8°C to 35.6°C during the work shift, indicating a moderate level of hyperthermia.

Figure 9. Mean skin (blue) and core (red) temperature during Day 1 from a representative frame worker.



2.20 During the study, mean skin temperature ranged from 24.6 to 38.2 with an average of 33.6±1.0°C, during the work shift, indicating a moderate level of hyperthermia. Mean core temperature ranged from 36.6°C to 38.7°C with an average of 37.4±0.3°C indicating significant hyperthermia. The average mean skin and core temperatures of the workers in an indoor environment throughout the study are illustrated in Figure 10, while the values of the drivers, of the workers in the kitchen, in an outdoor and mixed environment are illustrated in Figures 11,12,13,14 respectively.

Figure 10. Average of mean skin (blue; left axis) and core (red; right axis) temperatures of all the workers that they were working in an indoor environment.

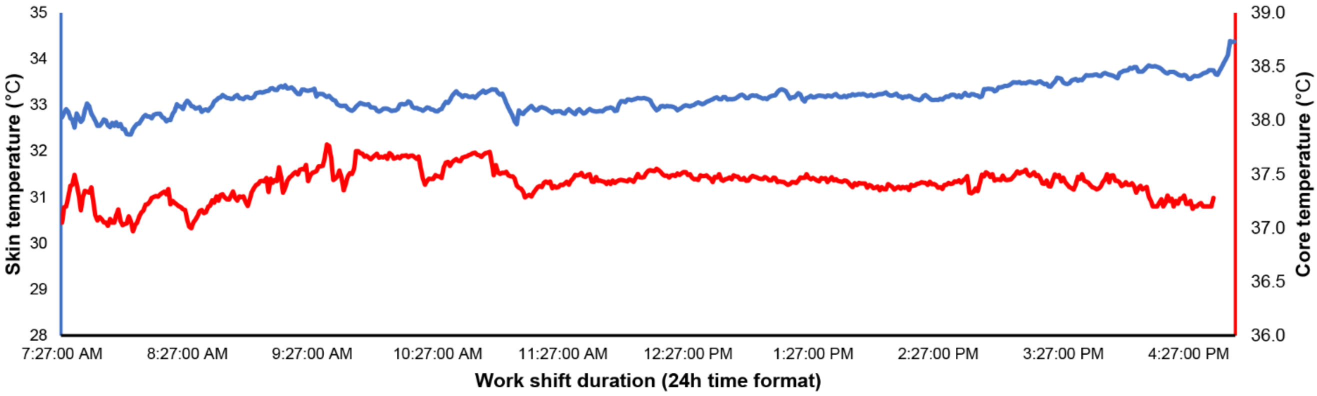


Figure 11. Average of mean skin (blue; left axis) and core (red; right axis) temperatures of all the drivers.

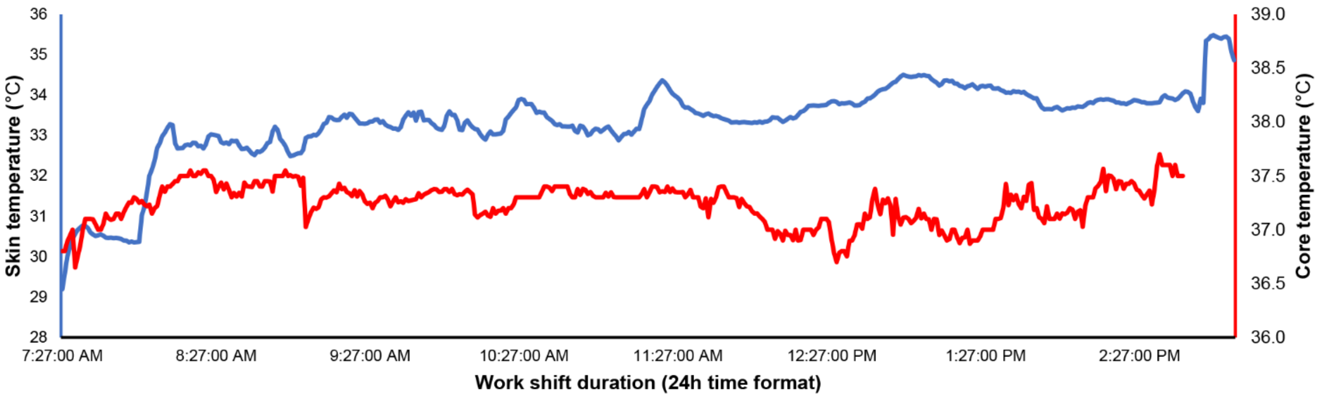


Figure 12. Average of mean skin (blue; left axis) and core (red; right axis) temperatures of all the workers in the kitchen.

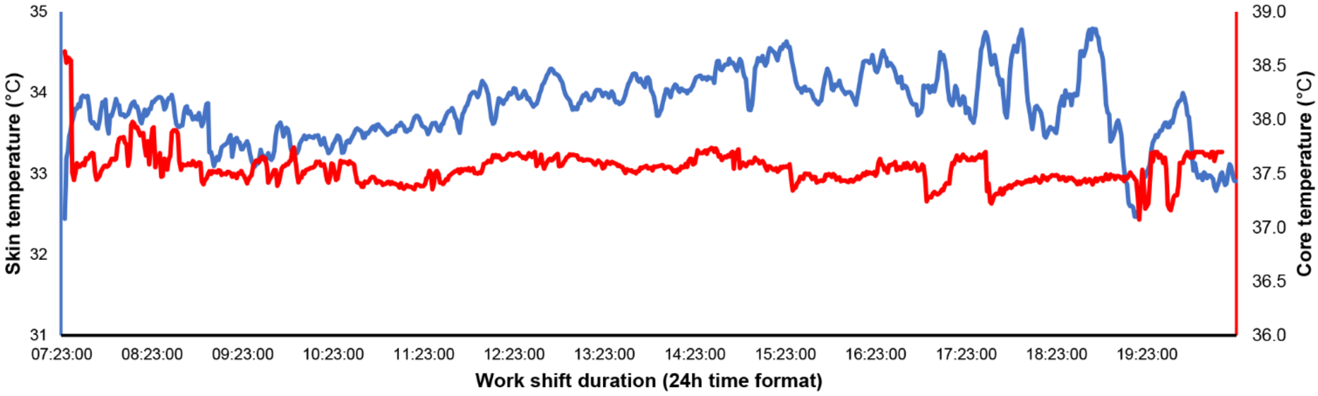


Figure 13. Average of mean skin (blue; left axis) and core (red; right axis) temperatures of all the workers in an outdoor environment.

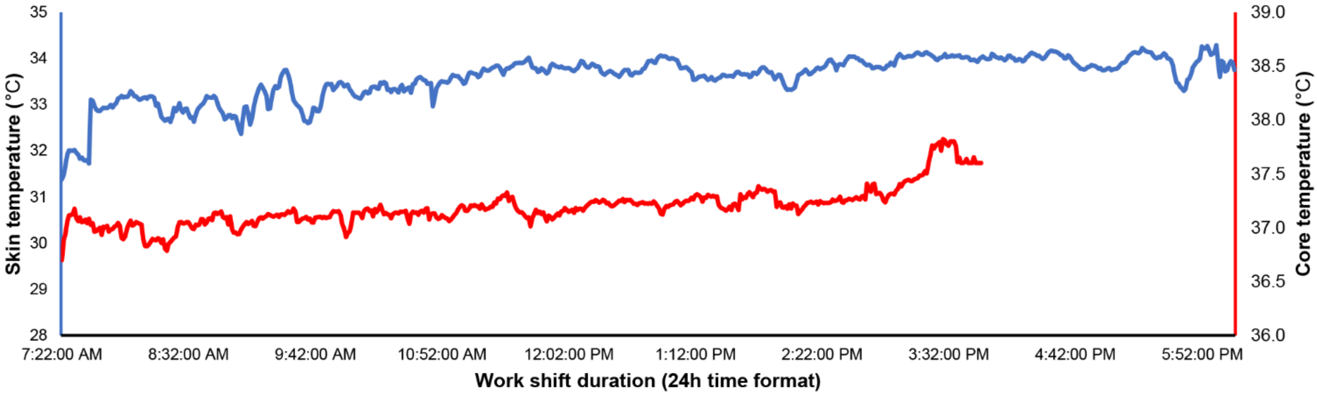
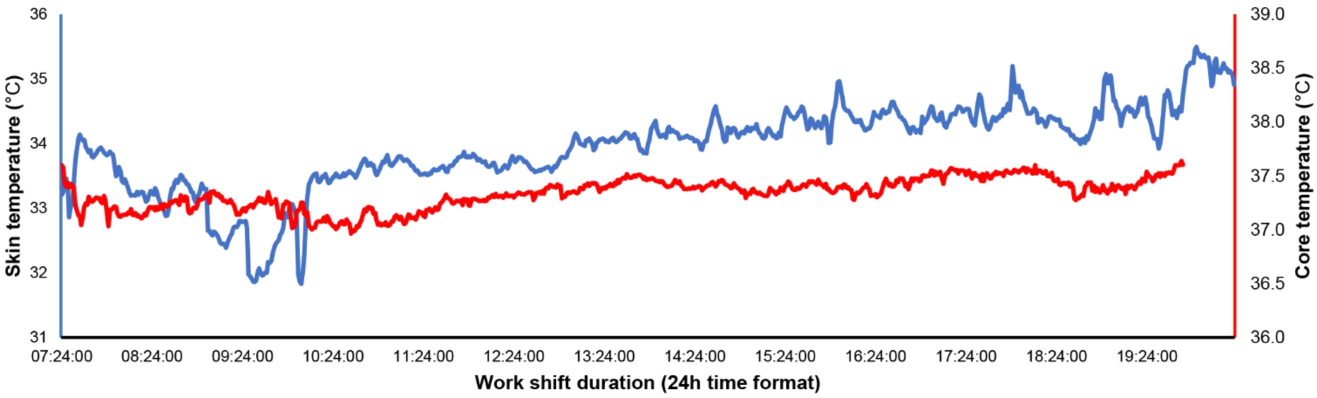


Figure 14. Average of mean skin (blue; left axis) and core (red; right axis) temperatures of all the workers in a mixed environment.

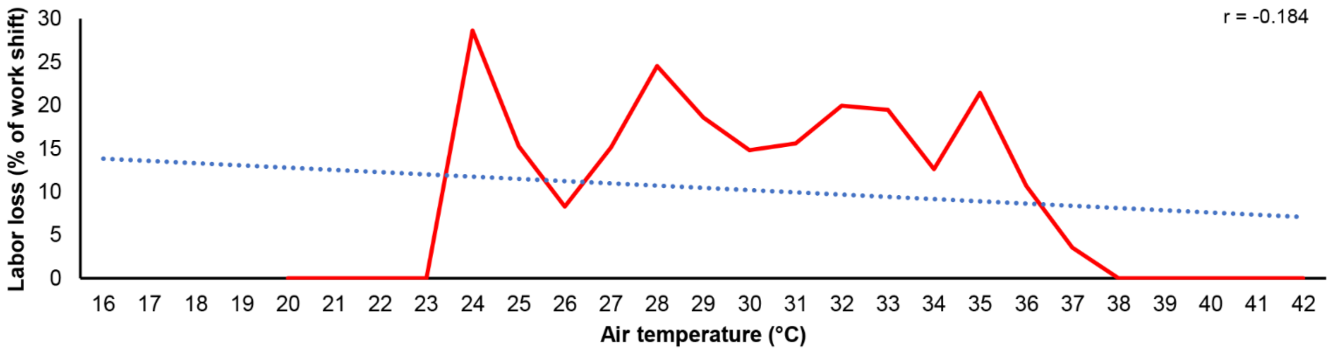


2.21 Work-related behaviours were identified through task analysis conducted by a trained researcher on-site in real-time. Work time spent doing work was defined as the time that a worker spends towards completing a task, not including breaks nor other work-related.

2.22 Work time, and irregular break time from al the workers are illustrated in Figure 15. A total of 325 hours, all the worker's work shifts were evaluated. During this time, the workers:

- worked for 87.4% of the evaluated work shift time
- took irregular breaks for 12.6 % of the evaluated work shift time

Figure 15. Percentage of labor loss (red line; vertical axis), air temperature (horizontal axis) and trend line (blue dot line) of all the workers.



Discussion

2.23 To our knowledge, this is the first study to investigate the effects of workplace heat on European tourism workers. Our study was conducted on 10 different days where we used time-motion analysis of a total of ~325 work hours on a second-by-second basis collected from 47 workers while performing different type of tourism jobs.

2.24 In total, the workplaces were safe places to work and the companies had assessed and addressed a number of risks that may impact the health, safety, and welfare of their employees, customers, and suppliers. Specifically, in the worksites evaluated, it was clear that the companies:

- provided safe work premises,
- assessed workplace layout and provided safe systems of work,
- provided suitable working environments and facilities.

2.25 These are important because creating a safe working environment is critical to the long-term success of a business because it can:

- help the company retain staff,
- maximise employee productivity,
- minimise injury and illness in the workplace,
- reduce the costs of injury and workers' compensation,
- ensure the company meets its legal obligations and employee responsibilities.

2.26 While recognizing the above, this evaluation demonstrated that further improvements are necessary with respect to the thermal stress experienced by the workers as well as the impact on their health and productivity. Specifically, almost 2/3 of the workers reported working less during a hot day, with nearly 50% reporting feeling thirsty, and more than 2/3 were fatigued and uncomfortable and more than 1/2 had low concentration. Also, about 20% of the workers reported feeling breathlessness 12% dizziness, while about 7% reported having been ill due to the heat. Despite these reported symptoms, a total of 86% of the workers started their work shift in a dehydrated state, with 89% of the workers remained dehydrated at the end of the work shift.

2.27 The above results impacted the workers' productivity. In total, across the 10-day study, 12.6%% of the total evaluated work shift time was lost on irregular breaks (i.e., spontaneous work cessation determined by workers' own judgment).

3. IDENTIFIED/SCREENED SOLUTIONS FOR TOURISM WORKERS

3.1 Combining the industry specific issues identified in Study 1 with a systematic review conducted by HEAT-SHIELD partners on the available solutions to mitigate heat stress (see Appendix), we designed Study 2 to test the effects and feasibility of implementing different solutions for tourism workers to adapt to workplace heat. Our approach was to evaluate ~276 work hours via time-motion analysis on a second-by-second basis collected from 11 workers in two different groups [first group: service staff (waiters and barista); second group: dry cleaning staff] while performing different tourism-related jobs and assess the effectiveness of different adaptation measures to alleviate the impact of workplace heat on labour effort. This study was labelled "Study 2" and is presented in the following sub-sections.

Description of Study 2

3.2 In this Study, three adaptation measures were tested in a random order on the first group (service staff) of workers:

1. Planned breaks: during this intervention, the workers were provided with 1:30-min breaks every 30 minutes. During these breaks, the workers were free do as they pleased though an advisory was given to rest and hydrate in the shade.
2. Ice slushy: during this intervention, the workers were provided with a 300 ml mixture of crashed ice and water every hour from the start until the end of the work shift.
3. Combination of breaks and ice slushy: during this intervention, the workers were provided with 1:30-min breaks every one hour and were provided with a mixture of crashed ice and water (2.3gr/kg) every hour from the start until the end of the work shift.

Two adaptation measures were tested at the second group (dry cleaning staff) of workers:

1. Hydration: during this intervention, the workers were provided with a 750 ml of water every hour from 08:00 until the end of the work shift (14:00).
2. Air condition and dehumidifier condition: during this intervention, an air-condition and a dehumidifier were used throughout the work shift to reduce the workplace heat stress.

3.3 The study involved monitoring tourism workers on 11 separate days (10-17/7/2018 and 17-19/9/2018) in Trikala and Volos, Greece. The experimental protocol was approved by the University of Thessaly, School of Exercise Science Ethics Review Board (Protocol No. 1217) in accordance with the Declaration of Helsinki. Written informed consent was obtained from all volunteers prior to their participation in the study before entering the study. They were free to deny participation or withdraw their consent at any point.

3.4 One day prior to the start of data collection, volunteers underwent a familiarization session which included information regarding all data collection procedures. Anthropometric characteristics were also recorded at that time. In total, 11 men and women workers participated in the study:

- 5 dry cleaning staff,
- 4 barista,
- 2 waiters/waitresses.

3.5 Throughout the 11 study days, all volunteers were assessed from the beginning until the end of the work shift. The measurements performed were non-invasive, time-efficient, practical, and did not disturb the workers during their job.

3.6 During each recording day, each worker was monitored from the beginning until the end of the work shift by a researcher who observed the worker's activities. Also, we recorded skin temperature and environmental data throughout the work shift. No restrictions were placed on water/food consumption or any other kind of work- or non-work-related behavior. To ensure that we did not influence the workers' normal work routine, the temperature sensors used were miniature and wireless. Also, to minimize participant bias (i.e., work activities being affected because the workers were being observed), the true reason for the observations was hidden from the volunteers. Instead, they were informed that the investigators were interested to see the different types of work that they engage in. Of course, once the data collection was completed, all volunteers were informed about the true purpose of the observations and gave their permission to analyze and publish these data.

3.7 We recorded the workers' age and work experience. Anthropometric measurements included height and mass. Body surface area was calculated using the Du Bois formula.[11] We obtained urine samples in the beginning and the end of the work shift to evaluate urine specific gravity, a well-known indicator of hydration status.[12]

3.8 Temperature at the skin surface was recorded every second at four sites using iButton sensors (type DS1921H, Maxim/Dallas Semiconductor Corp., USA) to calculate the mean skin temperature [T_{sk}; 0.3 (chest + arm) + 0.2 (thigh + leg)].[13] About twenty minutes before the beginning of each work shift, we installed weather stations (Kestrel 5400FW, Nielsen-Kellerman, Pennsylvania, USA) about 40 m away from the different workplaces of the volunteers. The weather station was used to measure air temperature (°C), humidity (%), wind speed (m/s), and the WBGT (°C), continuously.

3.9 As with Study 1, the real-time observation recordings were used to identify work-related behaviors. Work time spent on irregular work breaks (WTB) was defined as any unprescribed work cessation determined by workers' own judgment, and not based on specific time intervals or instructions. Lunch time was not considered as WTB because it was prescribed by management.

3.10 Work-related behaviors were determined for each worker individually through time-motion analysis that was conducted on site in real-time by trained investigators. Experimenter bias was minimized via training the observers to rate by observing the same worker for 1 hour to ensure adequate agreement. For the same reason, the observers worked in close proximity and they were instructed to seek each other's advice in cases where they could not make a firm decision on their own. They were, thus, encouraged to give consensus group ratings of work-related behaviors.

Results

3.11 First group workers' age ranged from 24 to 48 years (mean age: 30.5±14.2 years), while the second's group age ranged from 32 to 59 years (mean age: 49.2±10.0 years) The mean body mass index for the entire both of workers groups was 24.0±2.9, which indicates that, on average, they were normoweight. The mean body mass index for the first group of workers was 24.3±9.7, which indicates that they were normoweight. The mean body mass index for second group of workers was 23.2±0.3, which indicates that t they were normoweight.

3.12 Detailed temperature and weather conditions for the four test days are shown in Figures 16-17. Overall, the weather conditions and the associated environmental heat stress were similar across the 11 test days.

Figure 16. Environmental temperature (°C; top panel) and WBGT (°C; bottom panel) throughout the work shift during the first group of workers. The purple line represents the Baseline condition, orange line the Planned breaks condition, grey line the Ice slushy condition and the yellow line represents the Combination of breaks and ice slushy condition.

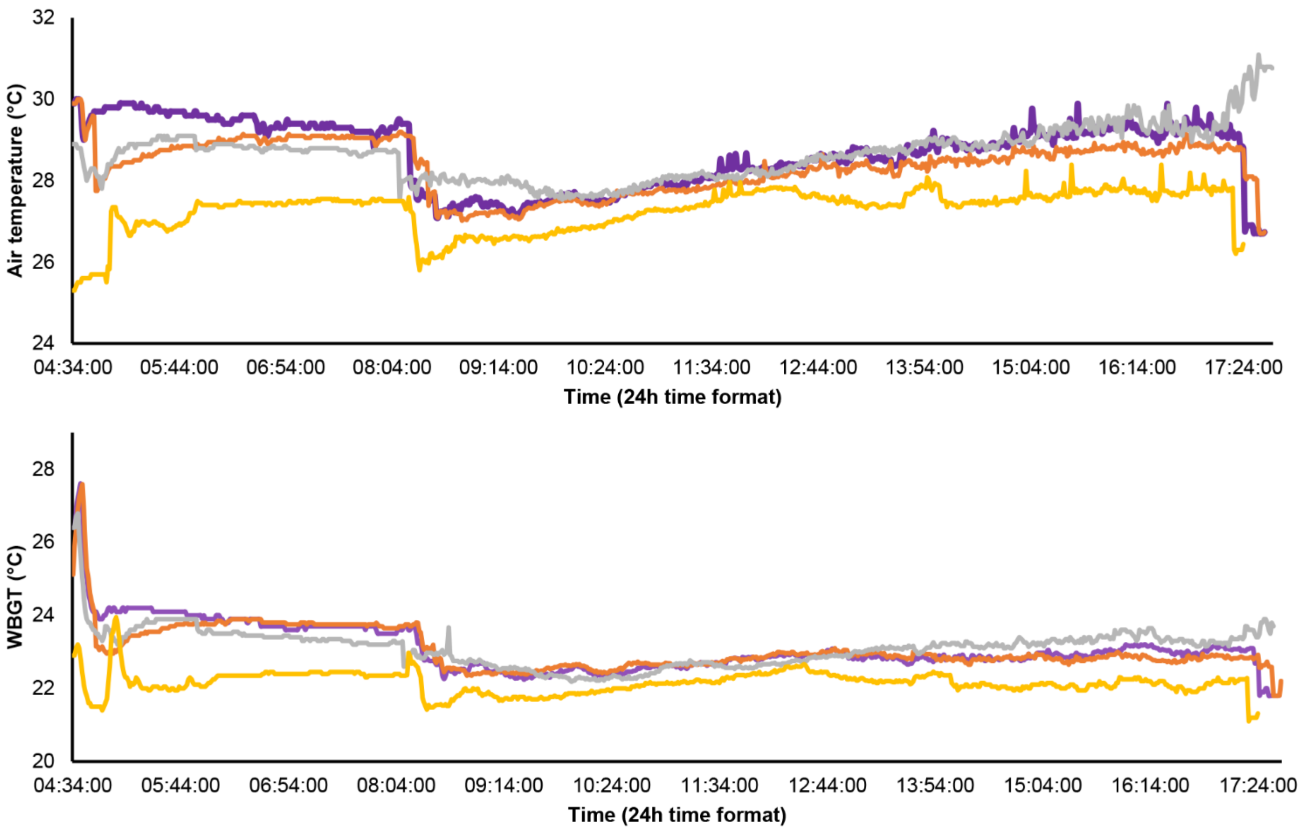
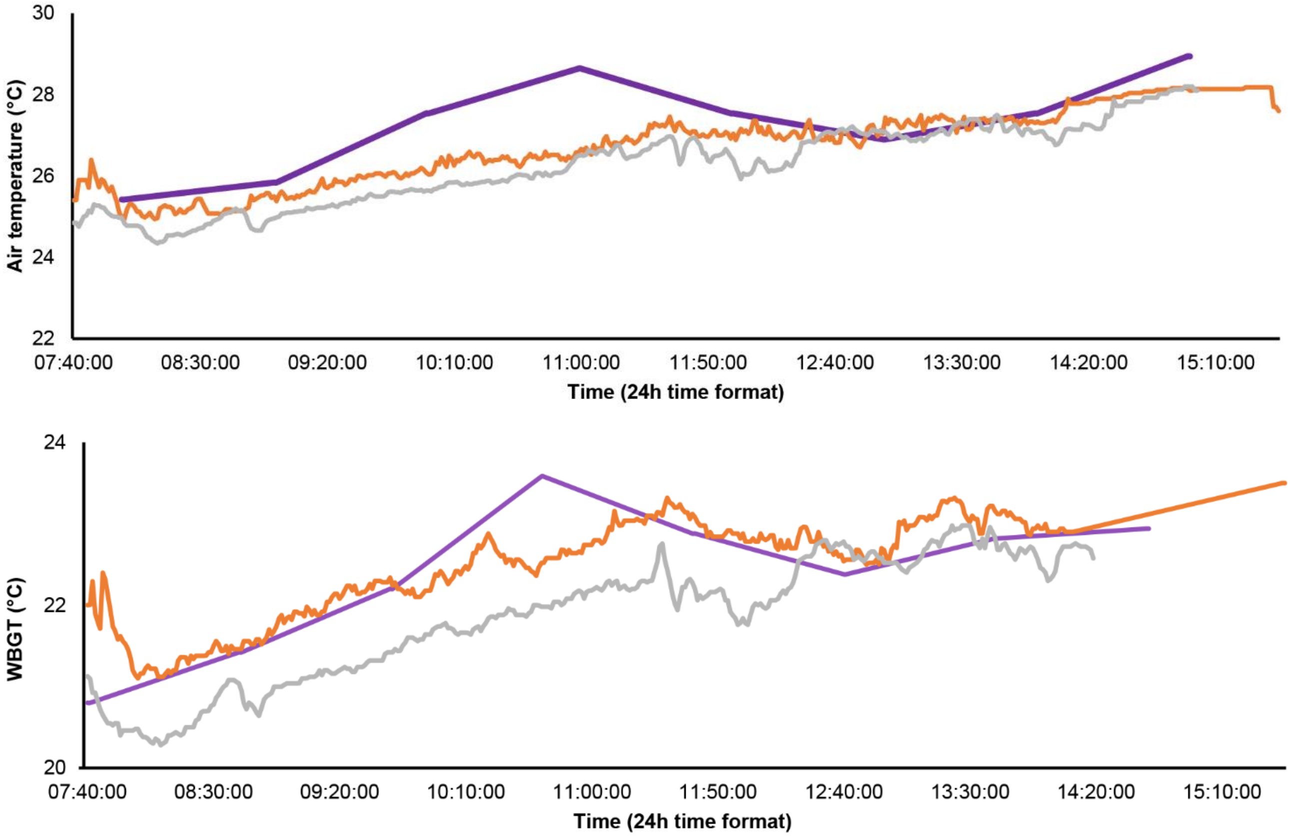


Figure 17. Environmental temperature (°C; top panel) and WBGT (°C; bottom panel) throughout the work shift during the second group of workers. The purple line represents the Baseline condition, orange line the Hydration condition, grey line the Air condition and dehumidifier condition.



3.13 The urine samples taken to assess the first group workers' hydration status showed that all of them start their work shift in a dehydrated state (Figure 18). At the end of the work shift, all workers are still dehydrated. During the normal baseline condition, urine specific gravity was 1.026±0.0007 at the start (100% of workers at risk for dehydration) and 1.024±0.0007 at the end (100% of workers at risk for dehydration) of the work shift. During the planned breaks condition, urine specific gravity was 1.032±0.007 at the start (91% of workers at risk for dehydration) and 1.029±0.005 at the end (100% of workers at risk for dehydration) of the work shift. During the ice slushy condition, urine specific gravity was 1.028±0.004 at the start (100% of workers at risk for dehydration) and 1.029±0.005 at the end (100% of workers at risk for dehydration) of the work shift. Finally, during the combined condition, urine specific gravity was 1.026±0.002 at the start (100% of workers at risk for dehydration) and 1.028±0.002 at the end (100% of workers at risk for dehydration) of the work shift.

3.14 The urine samples of the second group of workers showed different results (Figure 19). During the normal baseline condition, urine specific gravity was 1.0216 ±0.009 at the start (33% of workers at risk for dehydration) and 1.026±0.002 at the end (100% of workers at risk for dehydration) of the work shift. During the Hydration condition, urine specific gravity was 1.017±0.007 at the start (25% of workers at risk for dehydration) and 1.0110±0.01 at the end (25% of workers at risk for dehydration) of the work shift. During the Air condition and dehumidifier condition, urine specific gravity was 1.017±0.007 at the start (25% of workers at risk for dehydration) and 1.011±0.01 at the end (25% of workers at risk for dehydration) of the work shift.

3.15 These findings are particularly important since dehydration leads to an increase in body temperature because the body reduces its sweat production. Also, dehydration increases the overall perception of fatigue. As a result, dehydrated workers are far more likely not to perform their duties adequately. Finally, chronic dehydration (almost daily dehydration for several months) can lead to kidney function disorders.

Figure 18. Urine specific gravity values at the start (orange) and the end (purple) of the work shift for the 1st group of workers. The dotted red line indicates the cut off separating hydrated and dehydrated workers.

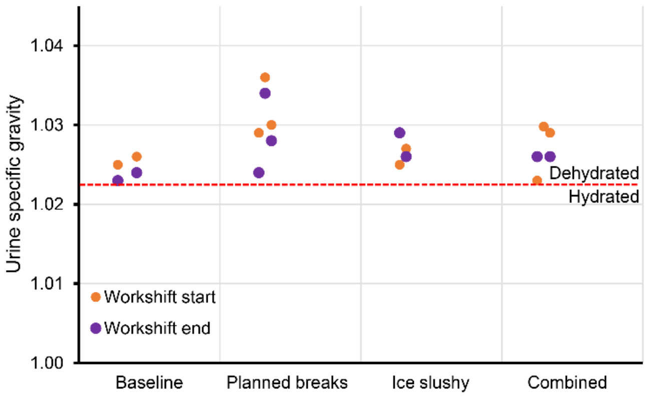
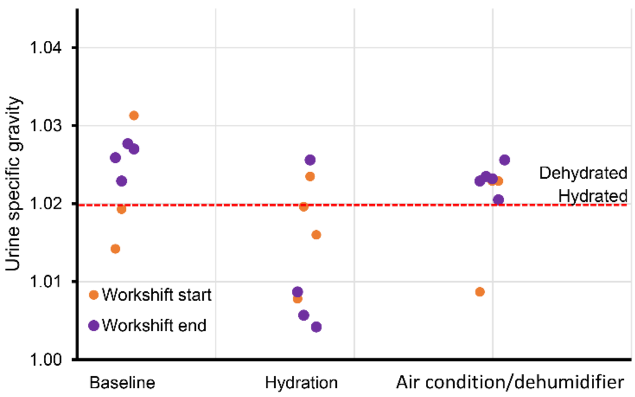


Figure 19. Urine specific gravity values at the start (orange) and the end (purple) of the work shift for the second group of workers. The cut off value separating hydrated and dehydrated workers is indicated with a dotted red line



3.16 During the study, the core temperature of the workers ranged from 36.6°C to 38.0°C with an average of 37.3±0.3°C, indicating minor hyperthermia. For the first group of workers and during the Baseline condition, the core temperature of the workers ranged from 36.6°C to 38.3°C with an average of 37.4±0.3°C. During the Planned breaks condition, the core temperature of the workers ranged from 36.6°C to 38.2°C with an average of 37.3±0.3°C. During the Ice slushy condition, the core temperature of the workers ranged from 36.6°C to 38.4°C with an average of 37.2±0.3°C. During the combined intervention (breaks and Ice slushy) the core temperature of the workers ranged from 36.6°C to 37.9°C with an average of 37.3±0.3°C (Figure 20). For the second group of workers and during the Baseline condition, the core temperature of the workers ranged from 36.6°C to 38.3°C with an average of 37.3±0.3°C. During the Hydration condition, the core temperature of the workers ranged from 36.6°C to 37.7°C with an average of 37.1±0.3°C, while during the air condition and dehumidifier condition core temperature of the workers ranged from 36.6°C to 37.9°C with an average of 37.2±0.3°C (Figure 21).

3.17 The results for labor loss (i.e., percentage of work shift time lost due to irregular work breaks) during the baseline assessment and the three interventions used to test different adaptation measures are illustrated in Figure 22-23. Specifically, we found that the percentage of work shift time lost due to irregular work breaks during the baseline assessment for the first group of workers was 16.7 ±10.4% of the total evaluated work shift time was lost on irregular breaks (i.e., spontaneous work cessation determined by workers' own judgment). This was maintained at 16.6±3.8% when the workers were provided with planned breaks (when adding the time required to take those breaks). When the workers were provided with ice slushies, the labour loss was similar, at 16.6±6%. Finally, the labour loss at the condition "Combination of breaks and ice slushy" remained similar at 16.7±13.4%. In the second group of workers, we found no differences in the labor time lost among the baseline and the two interventions used (Figure 21).

Figure 20. Average core temperatures of the first group workers during each of the different conditions of the study**.**

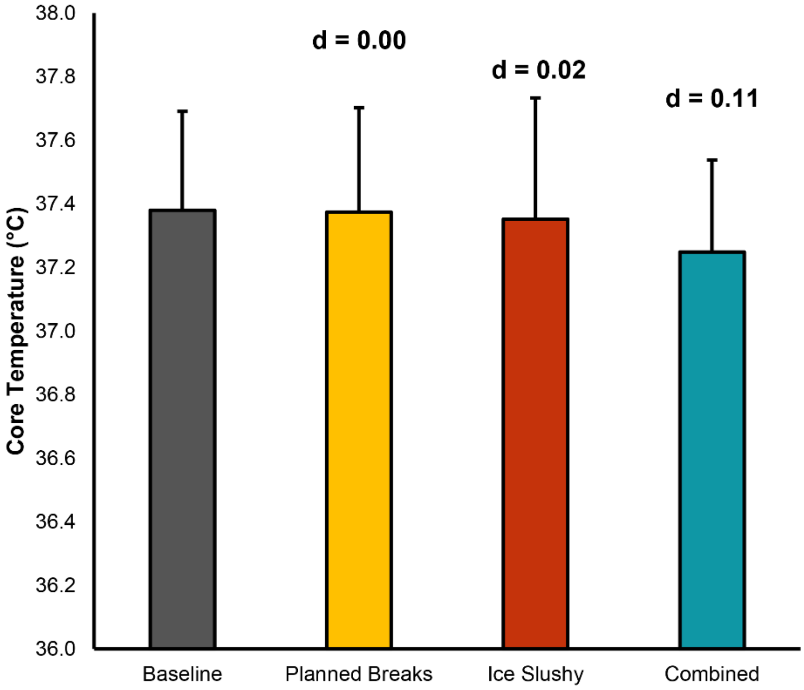


Figure 21. Average core temperatures of the second group of workers during each of the different conditions of the study**.**

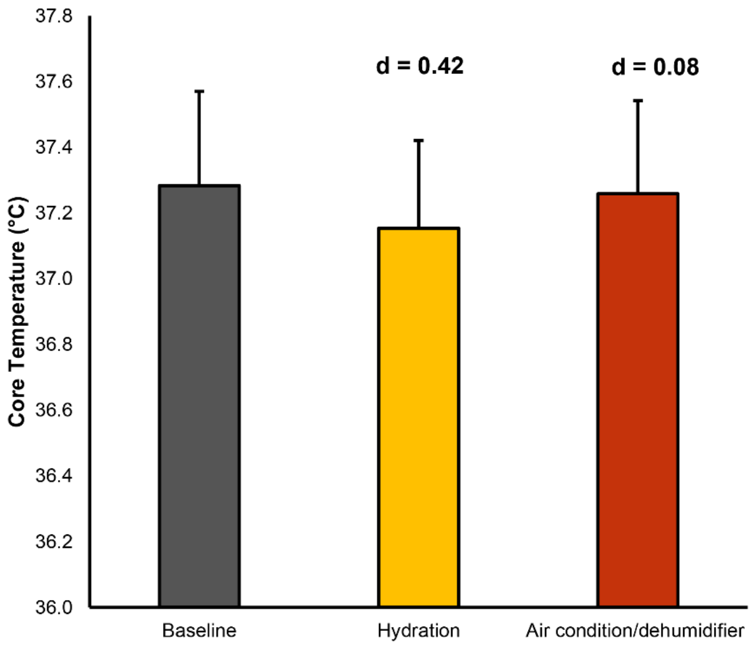


Figure 22. Labour loss (i.e., percentage of work shift time lost due to irregular work breaks) during the baseline assessment and the three interventions used to test different adaptation measures for the first group of workers.

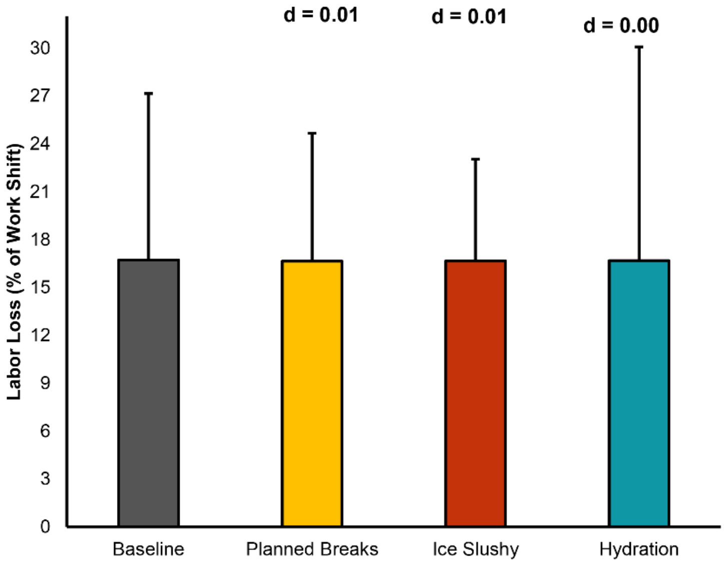
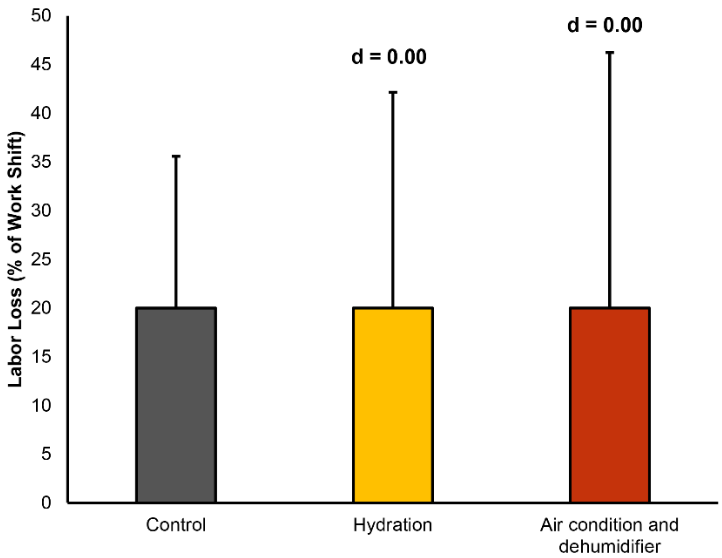


Figure 23. Labour loss (i.e., percentage of work shift time lost due to irregular work breaks) during the baseline assessment and the tow interventions used to test different adaptation measures for the second group of workers.



Discussion

3.18 To our knowledge, this is the first study to investigate the effects of different adaptation measures to mitigate workplace heat on European tourism workers. Our study was conducted on 11 different days where we used time-motion analysis of a total of ~276 work hours via time-motion analysis on a second-by-second basis collected from 11 workers while performing different tourism jobs and assess the effectiveness of different adaptation measures to alleviate the impact of workplace heat on labour effort.

- In total, the workplaces were safe places to work and the companies had assessed and addressed a number of risks that may impact the health, safety, and welfare of their employees, customers, and suppliers. Specifically, in the worksites evaluated, it was clear that the companies:
- provided safe work premises,
- had assessed risks of injury and implemented appropriate measures for controlling them,
- assessed workplace layout and provided safe systems of work,
- provided suitable working environments and facilities.

3.19 These are important because creating a safe working environment is critical to the long-term success of a business because it can:

- help the company retain staff,
- maximise employee productivity,
- minimise injury and illness in the workplace,
- reduce the costs of injury and workers' compensation,
- ensure the company meets its legal obligations and employee responsibilities.

3.20 While recognizing the above, this evaluation demonstrated that further improvements are necessary with respect to the thermal stress experienced by the workers as well as the impact on their health and productivity. During the baseline assessment of the study, for the first group of workers 16.7 ±10.4% of the total evaluated work shift time was lost on irregular breaks (i.e., spontaneous work cessation determined by workers' own judgment). This was maintained at 16.6±3.8% when the workers were provided with planned breaks (when adding the time required to take those breaks). When the workers were provided with ice slushies, the labour loss was similar, at 16.6±6%. Finally, the labour loss at the condition "Combination of breaks and ice slushy" remained similar at 16.7±13.4%. In the second group of workers, we found no differences in the labor time lost among the baseline and the two interventions used. In the second group of workers, we found no differences in the labor time lost among the baseline and the two interventions used.

3.21 Based on the above results, tourism workers should drink 500-750 ml (2-3 cups of water) before starting work in the morning to mitigate arriving to work in a dehydrated state. During their work shift, they should consume 500-750 ml of water per hour. When working under heat stress, this strategy demonstrates the best results for maintaining hydration (reducing the risk for kidney disease or acute kidney injury). For this reason, it is important that strategies are put in place for workers to have access to cold/cool water throughout the day, even when working on different floors or remote areas. If such a strategy is followed regularly, day-to-day rehydration would be optimized and 500 ml per hour (2 cups of water) may be adequate for maintaining workers' hydration status to appropriate levels. During periods where workers are sweating profusely, healthy workers should add a larger amount of salt (electrolytes) to their diet. However, workers with heart, blood pressure, or other medical conditions should adopt this advice only when confirmed by their physician. If possible – and, particularly, during breaks – cooling the water by refrigeration, or better yet, by the addition of shaved/crushed ice will help lower the discomfort and heat stress experienced by the workers and improve work performance. Additionally, spreading water on the skin either during breaks or during work (if there is an abundance of water) can help increase evaporative cooling and help limit the rate of dehydration.

3.22 In view of other interventions evaluated in the systematic review conducted by HEAT-SHIELD partners on the available solutions to mitigate heat stress (see Appendix with summary table), it is important to note that appropriate clothing can lower the tourism worker's thermal stress. In some cases, these workers require special protective clothing (gloves, helmet, boots, etc.), while clothing is also beneficial for protecting tourism workers from excessive sun exposure. However, clothing can also restrict heat loss as it provides a boundary layer that limits evaporation and convective and radiative heat loss. To facilitate heat loss, clothing worn during the work shift should be selected based upon promoting air flow across the skin and improving sweat evaporation (reducing clothing evaporative resistance). This can be accomplished by reducing the total amount of skin covered by clothing by wearing a t-shirt vs long sleeve (if indoors), wearing looser fitting clothing which allows for greater air flow underneath the clothing, and wearing clothing with a wider knitting pattern which allows for more air flow to pass through the clothing. Additionally, lighter colours should be selected on sunny days in outdoor environments to increase the reflection of solar radiation. In situations where long, rigid clothing must be worn (e.g. coveralls), ventilation patches can be incorporated into more protected areas such as under the arms and between the legs to help promote air flow through the garment.

3.23 One final point is that it is crucial to plan the workflow to allow workers time to adapt. Workers will acclimatize to heat during the first days of hot weather, however depending on the initial fitness and previous exposure it will take at least one week before workers get used (physiologically adapted) to the increased heat. This acclimatization process will be hampered/take longer if the workers spend prolonged periods of time in artificially cooled environments when not working.

4. SUMMARY OF RECOMMENDED SOLUTIONS FOR TOURISM WORKERS

4.1 Based on the present evidence, it is advisable that tourism firms, from large multinational corporations to small local contractors, consider/develop an appropriate heat adaptation plan to protect employee (by minimizing health risks) benefits. This plan may be qualified by a designated person and benefit from consulting advanced warning weather systems to warn in advance when a period of hot weather is expected.

4.2 Tourism workers should drink 500-750 ml (2-3 cups of water) before starting work in the morning. During their work shift, they should consume 500-750 ml of water per hour. When working under heat stress, this strategy demonstrates the best results for maintaining hydration (reducing the risk for kidney disease or acute kidney injury). For this reason, it is important that strategies are put in place for workers to have access to cold/cool water throughout the day, even when working on different floors or remote areas. If such a strategy is followed regularly, day-to-day rehydration would be optimized and 500 ml per hour (2 cups of water) may be adequate for maintaining workers' hydration status to appropriate levels. During periods where workers are sweating profusely, healthy workers should add a larger amount of salt (electrolytes) to their diet. However, workers with heart, blood pressure, or other medical conditions should adopt this advice only when confirmed by their physician. If possible – and, particularly, during breaks – cooling the water by refrigeration will help lower the discomfort and heat stress experienced by the workers.

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4.4 It is crucial to plan the workflow to allow workers time to adapt. Workers will acclimatize to heat during the first days of hot weather, however depending on the initial fitness and previous exposure it will take at least one week before workers get used (physiologically adapted) to the increased heat.

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5. APPENDIX

HEAT-SHIELD research under preparation for publication:

Sustainable solutions to mitigate environmental heat stress – occupational and global health perspectives

Morris N.B., Jay O., Flouris A.D., Kjellstrom T., Casanueva A., Gao C., Foster J., Havenith G., Nybo L.

Introduction: Occupational heat stress influences the well-being and productivity of billions of people. As climate change will aggravate these conditions, identifying effective solutions is of critical concern. However, implementation in industrial settings, economic viability and ecological sustainability from a global health perspective are of equally important consideration. We conducted an umbrella-review to identify methods that relieve thermal stress and/or improve performance in the heat and evaluate the "implementation potential" of the procedure.

Methods: A systematic review of systematic reviews was conducted in PUBMED, Web of Science and SPORTdiscus, employing the following eligibility criteria: 1) ambient temperature above 28°C or hypohydrated participants, 2) healthy adults, 3) reported outcomes for physical or cognitive performance, thermal comfort or core temperature, 4) written in English, 5) and published before July 2018.

Results: An overview of the results is provided in Table 1. In total, 45 reviews fulfilled the criteria (36 were exercise-oriented, 6 were occupationally-oriented and 3 included both aspects) including 19 papers with meta-analyses. Lowering environmental heat stress was most effective for maintaining performance in the heat, it was also most expensive and least feasible, correspondingly necessitating more personalised interventions. The most effective interventions in the literature were phase-change and liquid-cooled garments, cold water immersion, heat acclimation, cold fluid ingestion and maintaining hydration status. Albeit effective, cold water immersion and liquid perfused garments are unfeasible under most occupational settings. On the other hand, highly feasible and sustainable methods such as taking periodic breaks, providing shade and using electric fans currently lack experimental and meta-analytical evidence in the literature.

Conclusions: Presently, the literature is overwhelmingly dominated by exercise-oriented studies conducted in laboratory settings and disregard whether the method is feasible to implement in real-life settings (occupational or recreational) or suitable and sustainable for mass application. Future studies are needed which are occupationally-oriented, useable in the field and are scalable.

Summary table: Assessment of different cooling interventions identified from the literature.

Intervention	Strength of evidence	Productivity/ Performance/ Physiological impact	Economic Cost	Feasibility/ Implementation (indoor/outside)	Environmental sustainability
Environmental manipulation					
Air conditioning	📄📄📄	+++	$$$	👎👎👎	🍃
Ventilation	📄📄	- to ++	$	👎	🍃🍃
Shading	📄	0 to ++	$	👍	🍃🍃🍃
External cooling					
Cold water immersion	📄📄📄	+ to ++	$$	👎👎	🍃🍃
Phase change garments	📄📄📄	+ to +++	$$	👎	🍃🍃
Cooling packs	📄📄📄	0 to ++	$$	👎	🍃🍃
Ice towels	📄📄	+++	$$	👎👎	🍃🍃
Skin wetting	📄📄	- to +++	$	👍	🍃🍃🍃
Menthol application	📄📄	0 to +++	$	👍👍	🍃🍃🍃
Vacuum glove	📄📄	0 to +	$$$	👎👎	🍃🍃
Internal cooling					
Ice slurry ingestion	📄📄📄	+ to +++	$	👎	🍃🍃
Mixed method cooling					
External and internal cooling	📄📄📄	++ to +++	$ to $$	👎👎	🍃🍃
Hydration					
Hyperhydration	📄📄📄	++	$	👍	🍃🍃🍃
Maintenance	📄📄📄	++ to +++	$	👍👍	🍃🍃🍃
Rehydration	📄📄📄	++ to +++	$	👍👍	🍃🍃🍃
Clothing					
Liquid & air-cooled	📄📄📄	+++	$$$	👎👎👎	🍃
Compression	📄📄📄	- to +	$$	👍👍👍	🍃🍃
Elevated design	📄📄	++	$$	👍👍👍	🍃🍃
Heat acclimation					
Long term	📄📄📄	+++	$ to $$$	👎👎👎	🍃🍃🍃
Medium	📄📄📄	++ to +++	*$ to $$$*	👎👎	🍃🍃🍃
Short	📄📄📄	+ to ++	*$ to $$$*	👎👎	🍃🍃🍃
Nutrition					
Carbohydrate	📄📄📄	0 to +	$	👍👍	🍃🍃🍃
Amino acids	📄📄	0 to ++	$	👍👍	🍃🍃🍃
Electrolytes	📄	++	$	👍👍	🍃🍃🍃
Pacing strategies					
Breaks	📄	0 to +++	$	👍👍 to 👎👎👎	🍃🍃🍃
Pacing	📄	0 to +++	$	👍👍 to 👎👎👎	🍃🍃🍃
Scheduling	📄	?	$	👍👍 to 👎👎👎	🍃🍃🍃

Summary table of a Heat-Shield-conducted systematic review of systematic reviews on all available interventions that have been employed to improve physical and cognitive performance as well as physiological and perceptual responses to heat stress (see appendix 1). Pages (📄) denote strength of evidence, with 📄📄📄 denoting meta-analyzed data, 📄📄 denoting systematically analyzed data and 📄 denoting first level evidence only. Summative scores (-,0,+) denote effect on performance ranging from detrimental (-), neutral (0) to various levels of effectiveness (+=mildly beneficial, ++=moderately beneficial and +++= very beneficial). Approval signs (👎,👍) denote how feasible the given intervention would be to employ in a standard agricultural environment ranging from nearly impossible to employ (👎👎👎) to essentially no additional effort to employ required (👍👍👍). Finally leaves (🍃) denote environmental sustainability ranging from not sustainable (🍃) to essentially no additional burdon on the environment (🍃🍃🍃).