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ORIGINAL RESEARCH

Novel Application of Chemical Cold Packs for Treatment of Exercise-Induced Hyperthermia: A Randomized Controlled Trial

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Objective.—Heat-related illness is a common disease with significant morbidity and mortality. Despite no proven efficacy, application of chemical cold packs (CCP) to the skin overlying the large vessels of the neck, groin, and axillae is a traditional recommended cooling modality. The study objective was to compare the cooling rates of CCP applied to these traditional areas vs the glabrous skin surfaces of the cheeks, palms, and soles in exercise-induced hyperthermia.

Methods.—Ten healthy adult male volunteers walked on a treadmill in a heated room (40° ± 0.5°C) while wearing insulated military overgarments until their esophageal temperatures (T_{es}) reached 39.2°C. Each participant had three heat stress trials on separate days: no treatment followed by randomly ordered traditional (neck, groin, and axillae) cooling and glabrous skin cooling.

Results.—With no treatment, T_{es} remained stable after the first 5 minutes of the heat trial (ΔT_{es} = 0.12° ± 0.07°C/10 min). Traditional cooling followed a linear decline (ΔT_{es} = 0.17° ± 0.04°C/10 min; $P < .001$). Glabrous cooling enhanced the treatment effect by a steeper decline (ΔT_{es} = 0.30° ± 0.06°C/10 min; $P < .001$), significantly different from traditional cooling by 2-way analysis of variance ($P < .001$).

Conclusions.—Application of CCP to glabrous skin surfaces was more effective for treating exercise-induced heat stress than the traditional CCP cooling intervention. This novel cooling technique may be beneficial as an adjunctive treatment for heat-related illness in the prehospital environment.

Key words: hyperthermia, heat-related illness, cooling, chemical cold packs, glabrous, exercise

Introduction

Heat-related illness is a common and preventable disease that if left untreated can culminate in potentially fatal heat stroke. Between 1999 and 2009, an average of 658 heat-related deaths occurred annually in the United States, a total of 7233 deaths with nearly all (94%) occurring during May through September.[1] Exertional heat stroke (EHS) is the second leading cause of death in young athletes.[2] The mortality rate for EHS is approximately 10%[3] and, when combined with hypotension, increases to 33%.[4] As heat-related morbidity and mortality is directly attributed to both the magnitude and duration of the hyperthermia,[5,6] cooling needs to be initiated in the prehospital environment and continue throughout transportation to the emergency department.

There are both internal and external mechanisms for accumulating heat. Environmental factors such as thermal radiation, high temperatures, and humidity add to the body's intrinsic heat load and can reduce heat dissipation capacity. Similarly, when the body's metabolic heat production outpaces heat transfer, core temperature rises and heat illness can occur. Heat stroke may occur when internal core temperatures rise above a critical level, leading to a cascade of cellular and systemic responses.[7–9] Cold-water immersion is the most

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effective means for treating heat stroke patients.[10–14] However, in resource-limited settings (eg, ambulances, during natural disasters, or wilderness and military environments) adequate and effective cooling baths are usually not readily available. Because of their low cost, ease of use, and storage, chemical cold packs (CCP) placed on the neck, axillae, and groin have been recommended as a cooling method in prehospital[15] and emergency medicine[16] treatment algorithms. However, no studies have demonstrated this approach has an advantage over passive cooling.[17,18]

Glabrous (nonhairy) skin regions covering the soles of the feet, palms of the hands, and cheeks of the face may be preferable locations for CCP, as they contain densely packed subcutaneous vascular structures (retia venosa) under vasomotor and thermoregulatory control. The primary function of these subcutaneous retia venosa is to facilitate heat loss directly from the body core.[19] By means of their capacity for high blood flow,[20] these arteriovenous anastomoses have been shown to facilitate heat loss more than five times that of nonglabrous skin during exercise.[21] The objective of this study was to compare the cooling rate of a novel application of CCP applied to glabrous skin surfaces vs CCP applied to the neck, axillae, and groin in subjects with exercise-induced hyperthermia during a 30 minute recovery period.

Methods

SUBJECTS

Ten healthy adult male volunteers participated in this prospective, nonblinded, randomized, crossover trial. Recruiting methods consisted of an announcement on local Stanford University and School of Medicine e-mail list servers as well as with a local search and rescue unit. All participants were physically active and passed a health screening survey administered by a study administrator. No individuals were screened and not enrolled in the study. The study was approved by the Stanford University School of Medicine institutional review board (clinicaltrials.gov identifier: NCT01694290).

FACILITIES AND EQUIPMENT

The trials were conducted in a 2.4 × 3.3 × 2.4 m (width, length, and height) temperature-controlled environmental chamber built to specifications. The trial conditions included an ambient temperature of 40° ± 0.5°C, and relative humidity of 20% to 35%. Treadmills (model SC7000; SciFit, Tulsa, OK) housed in the experimental chamber were used for the exercise portion of the trial. Baseline performance capacity tests were administered in a 23°C room.

Esophageal temperatures (T_{es}) and heart rates were monitored throughout the trials. Heart rate monitors and data loggers (model S810; Polar Electro Oy, Kempele, Finland) were used to record and collect heart rate data at 5-second intervals. T_{es} was measured with a commercially available general-purpose thermocouple probe (Mon-a-Therm No. 503-0028; Mallinckrodt Medical Inc, St. Louis, MO). These probes were self-inserted by the subjects through the nose to the base of the probe at a depth of 38 to 39 cm and held in place by a loop of surgical tape (Transpore, 3M Corporation, St. Paul, MN) adhered to the skin adjacent to the nares. The probes were connected to a desktop-based thermocouple transducer and data collection system (GEC Instruments, Gainesville, FL), which recorded temperature data at 1-second intervals. At the end of each trial, temperature and heart rate data was downloaded to a central computer and transferred to a spreadsheet (Excel; Microsoft Corp, Redmond, WA) for subsequent analysis. Chemical cold packs (6″ × 9″, MediChoice product #1480069904; Owens & Minor, Richmond, VA) of the same brand and model used in the local emergency department were donated by the manufacturer.

EXPERIMENTAL PROTOCOL

Data were gathered between August 1, 2012, and November 23, 2012. The protocol required that each subject participate in 4 separate trials: a baseline physical performance assessment followed by three heat stress trials. Baseline assessments of physical performance, including maximal heart rates (HR_{max}), were conducted in a 23°C room. This required participants to walk on a level treadmill at 5.63 km/h for 3 minutes; the slope of the treadmill was then increased by 2% at 3-minute intervals. Slope elevations increased until the participants could no longer proceed, thus yielding HR_{max}. The slope of the treadmill in the subsequent heat stress trials was set at 60% to 65% of the slope attained at the 90% HR_{max}, as based on methods designed by Grahn et al[19,22,23] in previous studies.

Before each heat stress trial, nude weight was measured and each participant was equipped with a heart rate monitor and T_{es} probe. The subjects performed all the trials clad in workout gear (lightweight shorts, shirts, and socks) and insulating outerwear: MOPP (Mission Oriented Protective Posture) military garments that are water impermeable and highly insulating (approximately 1.7 clo [R, –1.7]). Heat stress was induced by having the participants walk at 5.6 km/h (3.5 miles/h) uphill on a treadmill. The slope of the treadmill was adjusted for individual subjects so that heat stress (defined as $T_{es} \geq$ 39.2°C) would be achieved in 30 to 40 minutes. The stop